CABLE SANDS (W.A.) PTY. LTD.

JANGARDUP HEAVY MINERALS MINE ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME

Prepared by
W. G. MARTINICK AND ASSOCIATES PTY LTD

For
CABLE SANDS (W.A.) PTY LTD
JUNE 1989

ENVIRONMENTAL PROTECTION AUTHORITY

PROPOSED MINERAL SANDS MINE — JANGARDUP

ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME

Cable Sands (WA) Pty Ltd proposes to mine heavy mineral sands at Jangardup, in the Shire of Nannup, some 52km south of the town of Nannup.

In accordance with the Environmental Protection Act, an Environmental Review and Management Programme has been prepared by W.G. Martinick and Associates Pty Ltd, describing the project and its environmental implications and management requirements.

The document will be available for Public review for 10 weeks from 1 July 1989 to 9 September 1989.

During this period copies of the report will be available for examination at

- Environmental Protection Authority, Reading Room, Ground Floor, 1 Mount Street, Perth, WA.
- Environmental Centre of WA (Inc), 794 Hay Street, Perth, WA.
- J.S. Battye Library, Alexander Library Building, Perth Cultural Centre, James Street, Perth, WA.
- Councils and Libraries:
  - Nannup
  - Busselton
  - Capel
  - Bunbury

Copies of the document may be purchased for a sum of $10.00 (plus $2.00 postage and packaging) from

W.G. Martinick and Associates Pty Ltd
Unit 4
114 Churchill Avenue
Subiaco, WA 6008.

PUBLIC COMMENTS INVITED

Interested persons or organisations wishing to comment on the documents are invited to make written submissions by 26 August 1989 to:

The Chairman
Environmental Protection Authority
BP House, 1 Mount Street
Perth, WA 6000

Attention: Mr Warren Tacey

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JANGARDUP HEAVY MINERALS MINE
ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME

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

The Environmental Review and Management Programme (ERMP) for the proposed Jangardup Heavy Minerals Mine has been prepared by Cable Sands (WA) Pty Limited in accordance with Western Australian Government procedures. The report will be available for comment for 10 weeks, beginning on 1 July 1989 and finishing on 9 September 1989.

Comments from government agencies and from the public will assist the EPA to prepare an Assessment Report in which it will make a recommendation to Government.

Following receipt of comments from government agencies and the public, the EPA will discuss these comments with Cable Sands, and may ask for further information. The EPA will then prepare an assessment report with recommendations to Government, taking into account issues raised in the public submissions.

WHY WRITE A SUBMISSION?

A submission is a way to provide information, express your opinion and put forward your suggested course of action including any alternative approach. It is useful if you indicate suggestions which could improve the proposal.

All submissions received will be acknowledged.

DEVELOPING A SUBMISSION

You may agree or disagree, or comment on, the general issues discussed in the ERMP or with specific proposals. It helps if you give reasons for your conclusions, supported by relevant data.

You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the ERMP,

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

POINTS TO KEEP IN MIND

By keeping the following points in mind, you will make it easier for your submission to be analysed.

Attempt to list points so that the issues raised are clear. A summary of your submission is helpful. Refer each point to the appropriate section, chapter or recommendation in the ERMP. If you discuss sections of the ERMP, keep them distinct and separate, so there is no confusion as to which section you are considering.

Attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

Please indicate whether your submission can be quoted, in part or in full, by the EPA in its Assessment Report.

REMEMBER TO INCLUDE

Your name, address, date.

THE CLOSING DATE FOR SUBMISSIONS IS 9 SEPTEMBER 1989.
SUBMISSIONS SHOULD BE ADDRESSED TO:

The Chairman
Environmental Protection Authority
1 Mount Street PERTH WA 6000

Attention: Mr Warren Tacey

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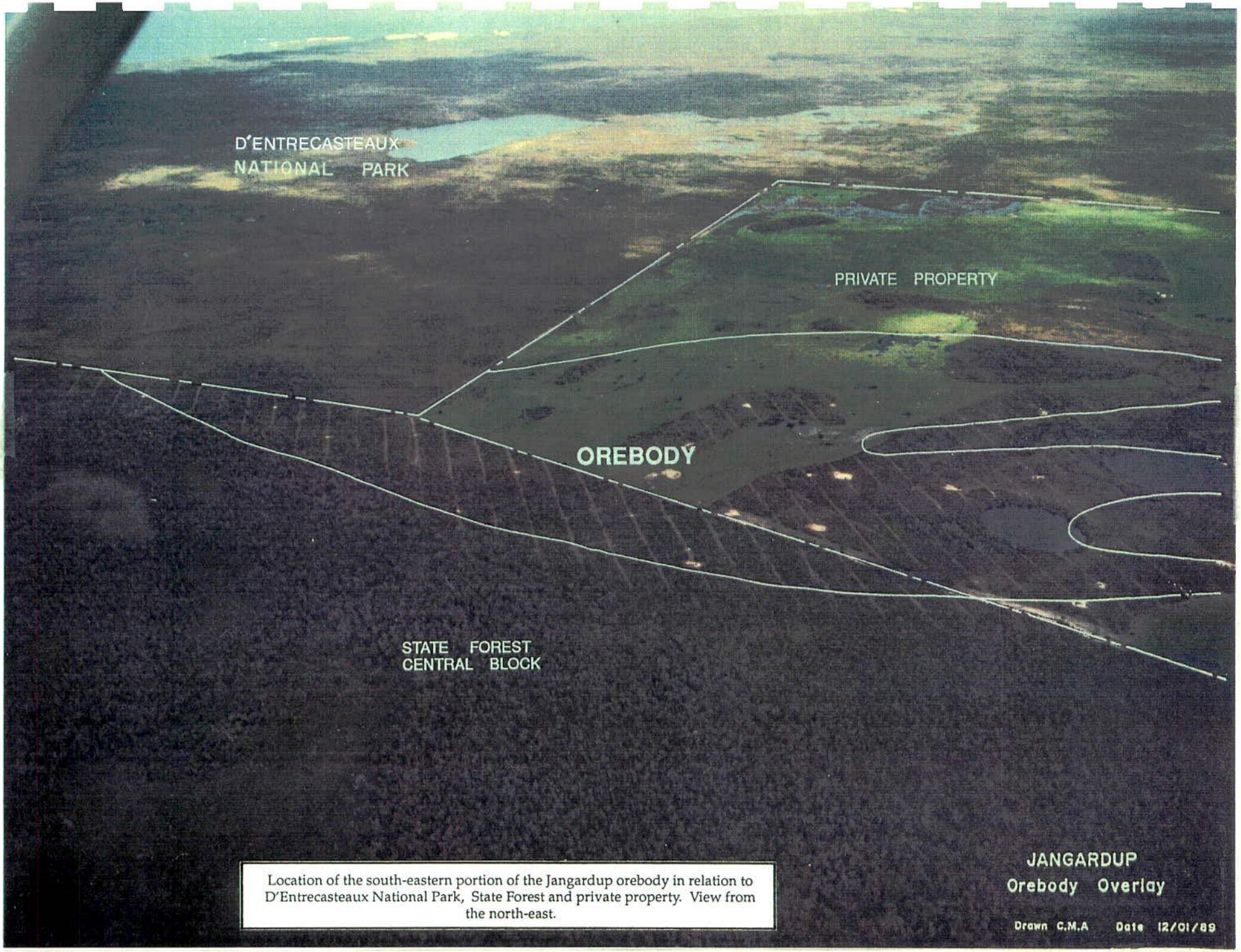
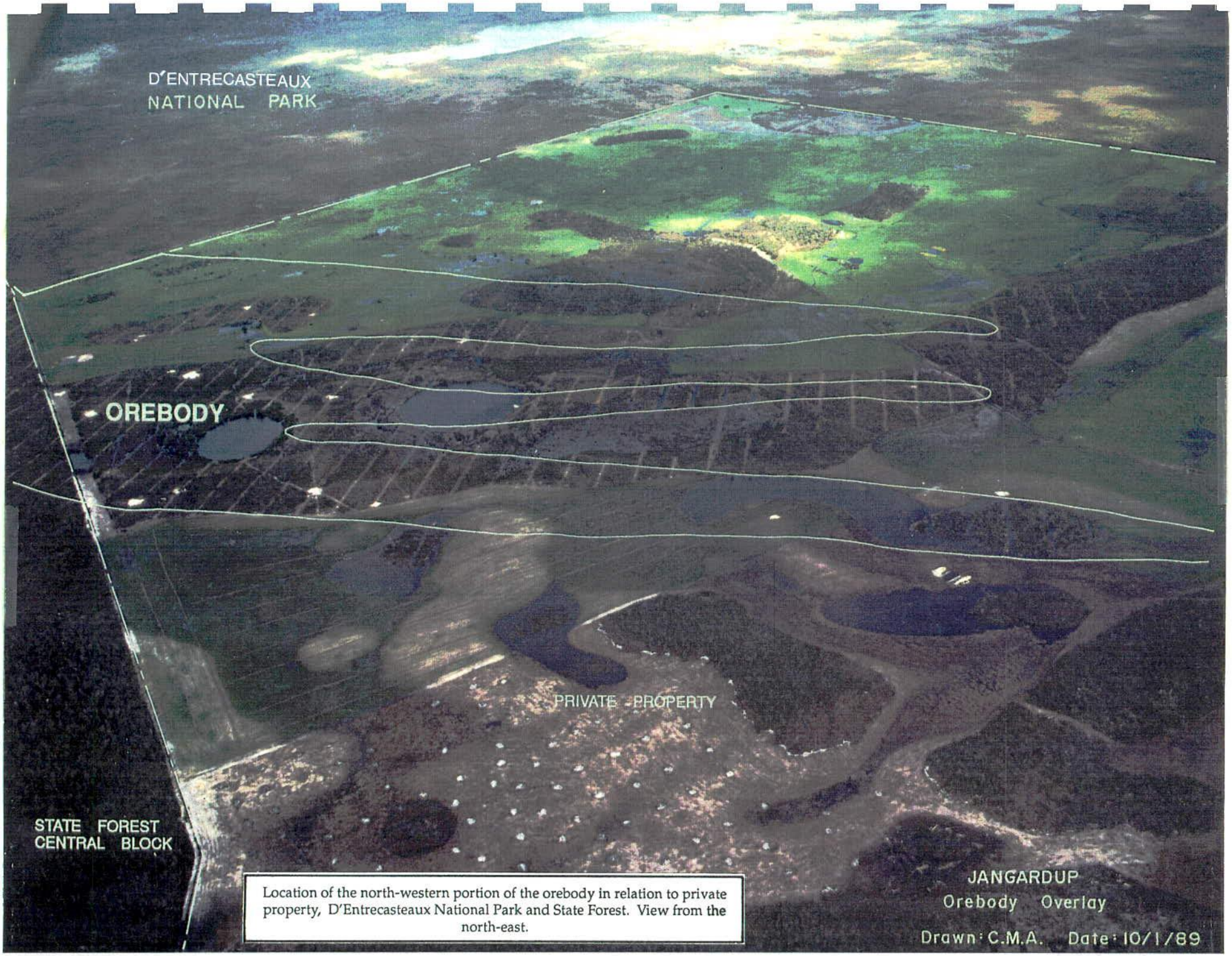


Location of the south-eastern portion of the Jangardup orebody in relation to D'Entrecasteaux National Park, State Forest and private property. View from the north-east.



Location of the north-western portion of the orebody in relation to private property, D'Entrecasteaux National Park and State Forest. View from the north-east.

SUMMARY

The **objectives** of this Environmental Review and Management Programme (ERMP) by Cable Sands (WA) Pty Ltd, known as Cable Sands, are to:

- outline a proposal to mine a deposit of heavy minerals at Jangardup and to transport Heavy Minerals Concentrate from the mine site to Bunbury for processing and export,

- describe and appraise the environment of the proposed operation and its immediate surrounds,

- assess the likely environmental and social impacts and benefits of the proposed project, and

- describe a management programme which will avoid or minimize adverse impacts and maximize benefits.

Cable Sands was the first company to mine heavy minerals in Western Australia where it has been operating in the south-west for 30 years. It is well established and proficient in all phases of the heavy minerals industry, from exploration to exporting. The company is recognised as carrying out its business in a professional and responsible manner and it has a number of awards for its land rehabilitation programmes.

Cable Sands aims to mine the Jangardup deposit efficiently, in an environmentally and socially responsible manner, and to optimise financial benefits to the Company's shareholders, local communities, the State of Western Australia and to Australia. The Company's objectives are to commence mining by mid 1991 in accordance with a long-term corporate schedule of mining and marketing. To achieve these objectives it is imperative that the commencement of mining is not delayed as this would disrupt the continuity of employment and production in Cable Sands' existing secondary separation operations in Bunbury.

The **Jangardup deposit** is located on the Scott River Coastal Plain. By road it is 52km to the south of Nannup, 161km to the south of Bunbury, and 54km to the west of Pemberton. The deposit is approximately 230 hectares' in extent, and of this 200 hectares are on a private property which has been cleared for grazing and the balance is just inside State Forest.

The deposit extends across two Mining Lease Applications and is bounded to the north by private property, to the east by State Forest and to the south and west by the D'Entrecasteaux National Park. There are no dwellings in the area.

The deposit consists of **30 million tonnes of ore** with an average heavy minerals content of 6.8%, of which 76% is ilmenite. The balance consists of secondary ilmenite, zircon, leucoxene,

rutile, monazite and xenotime. There is no separate layer of overburden, the average clay content of the ore is 6%, and large parts of the deposit and the surrounding areas are flooded during winter.

The site has a **mediterranean climate** with hot and dry summers and mild and wet winters. Winds are consistent and strong all year.

Two major **landforms** characterise the Jangardup environment, namely a swampy coastal flat which extends parallel to the coastline and a low ridge with associated uplands. Differences between the landforms are associated with changes in soil types. The flats consist of deep sands and peaty soils while the uplands consist of a mosaic of duplex, gradational, lateritic and deep sandy soils. In most instances these variations in the terrain and soil types are accompanied by changes in the **vegetation.** This applies particularly to the upland areas where the distribution of tall forests and woodlands is closely related to soil types, and it applies to a lesser degree to the lowland areas where changes in vegetation are usually associated with minor changes in drainage rather than with changes in soil types.

All of the native vegetation is widely distributed in the region and conserved extensively in nearby State Forests and the D'Entrecasteaux National Park.

A total of 236 species of native **flora** and six exotic plant species were identified from areas of native vegetation within the adjacent State Forest and from the adjoining area of the D'Entrecasteaux National Park. Most of these species are widely distributed along the south coast of Western Australia. Two of the species are considered by the Department of Conservation and Land Management as possibly being rare. These are Amperea volubilis and Leucopogon alternifolius, and both were recorded in the D'Entrecasteaux National Park. No species of flora which is gazetted as rare was found.

Almost all low-lying areas within the farmland, the State Forest and the adjoining areas of the D'Entrecasteaux National Park are infected by the **dieback** fungus Phytophthora cinnamomi. It is likely that the fungus has been spread mainly by the movement of spores with the flow of surface water in low-lying areas which flood regularly.

Information was gathered on the **fauna** of the study area by trapping, searching and the recording of opportunistic observations. The fauna was found to consist of relatively few species, to be typical for the region and to be widespread.

Two small peat lakes and two ephemeral **water bodies** were sampled for aquatic invertebrates and fish, and for physical and chemical characteristics of the water. All of the water samples were very fresh, acidic and yellow-brown with tannin, and they contained a

contractors, casual workers, and ancillary services such as road maintenance. It is estimated that this will provide full-time employment for a further 27 people.

Mining will be by a combination of front-end loaders, scrapers, bucket wheel excavators and dredges. The ore will be separated in a Primary Separation Plant into **Heavy Minerals Concentrate** and a mixture of sand and some clay. The Heavy Minerals Concentrate will then be trucked to Cable Sands' Secondary Separation Plant in Bunbury for separation into ilmenite, leucoxene, rutile, zircon, monazite and xenotime. These minerals will then be exported through the port of Bunbury.

Prior to mining a particular area, that area will be surrounded by soil embankments to prevent the inflow of surface water. In addition, it may be necessary to lower the watertable of that area by up to 6m to provide a dry environment for a bucket wheel excavator to break the layer of sandstone in the profile of the orebody and to dump it into the dredge path. Such **dewatering** is a worst case scenario and will be avoided in areas where it is considered that dewatering may have an adverse effect on the native vegetation. Such adverse effects are only likely to occur in close proximity to the D'Entrecasteaux National Park and only if dredging takes place during the driest time of the year. In such instances the lowering of the groundwater can be avoided by breaking the sandstone ahead of the dredge path during the wet season. In addition, the dredge path and schedule is designed to avoid dredging near potentially sensitive areas during the dry summer months. Subsequently, the mining of the broken sandstone and the remainder of the deposit will be by **dredging.** A dredge will float in a dredge pond and move across the deposit immediately behind the mining or dredging front. The dredge pond will also move across the entire deposit during the course of mining. The dredge will feed ore into the Primary Separation Plant which will be floating immediately behind the dredge. This separation is achieved by using gravity and water in a series of conventional spirals. This is a well established method which separates the minerals from the sand and clay on the basis of differences in specific gravities. The process requires no chemicals. The Heavy Minerals Concentrate is pumped to a stockpile on high ground where it can be loaded onto trucks for transportation to Bunbury.

The mine will generate an excess of water, except during mid and late summer, due to the wet nature of the land and the lowering of the watertable to allow the excavation of the sandstone. Any deficiency in water will be made up from a deep bore.

The excess water will be pumped to a small pond and recycled as much as possible. Water will also be recycled from the dumped mixture of sand and clay which remains after the heavy minerals have been separated out, and from the stockpile of Heavy Minerals Concentrate. The excess water will be allowed to seep or drain

rich fauna. This fauna is considered to be typical for waterbodies of the coastal plain of the south coast of Western Australia, but it differs from the fauna of water bodies elsewhere in Western Australia.

The deposit consists of a series of strandlines which were formed by marine action on an ancient sandy shore. This shoreline is interrupted by a low ridge which used to be a headland which projected into the sea. All of the materials in and above the deposit are sandy except for a layer of sandstone which has developed at the top of the present day watertable.

The sands form a shallow unconfined **aquifer**, and this overlies the Yarragadee Formation which is a major confined aquifer in the region. The direction of groundwater flow is to the west and south-west where it frequently discharges into swamps and small creeks. The direction of flow of surface water is also in a south-westerly direction, from the State Forest and the private property to the D'Entrecasteaux National Park. The water quality in both aquifers is very good.

A survey of the natural surface **gamma dose rates** revealed no differences between the orebody and natural background rates for the surrounding terrain. This is because the heavy minerals are concentrated at depth rather than at the surface and their radioactive component, monazite, is present only in very low concentrations. All of the rates are less than the allowable limit for public exposure.

There is no substantial **power** supply, no **reticulated water** and only a limited **telephone** service in the region of the deposit. The deposit is accessible from **Vasse Highway**, a two lane bitumen road, via Stewart and Black Point Roads, both of which have gravel surfaces.

The deposit is in an area which has no environmental, cultural or historical features which make it outstanding in a local or in a regional context. No Aboriginal artefacts or camping sites were found on the leases during a survey by an officer of the Western Australian Museum.

The **proposed operations** will make a substantial contribution to the well-being of Australia. The operation will **generate export earnings** of about $196 million and it is estimated that about $32 million will be paid directly to the Federal and State Governments in the form of **taxes and royalties.** The project will provide substantial **employment** and income to the region of Pemberton, Augusta and Nannup, a region which is suffering from a long-term decline in the traditional employment of farming and timber production. An additional 78 people will be employed by Cable Sands, and of these about 50 families will be living on site or in the nearby towns of Nannup and possibly Pemberton. There will also be a need for construction and maintenance

from the ponds into the natural drainage. It will not be discharged as a surface flow into the State Forest or the D'Entrecasteaux National Park.

Restoration of the landforms behind the dredge will be by direct stacking of a slurried mixture of the mined sand and clay from which the heavy minerals have been removed. The surface of the new landforms will then be shaped and contoured using earth-moving machinery, and covered with topsoil which contains all of the pre-mining vegetation. On landforms which will be restored to pastures an additional layer of clay, where available, will be spread over the surface. This clay will be ploughed into the restored landforms, which will then be topsoiled and stabilised with pasture. Such a layer of clay will not be spread on restored landforms in the State Forest which will be stabilised with native vegetation. Trees and shrubs will be planted into the pastures as shelter for stock and for local and regional landscaping purposes. It is anticipated that on completion of mining the restored pastures will contain about three times as many trees as were present prior to mining.

All **topsoil** together with the vegetation which it supports will be stripped prior to mining for re-use during rehabilitation. During the initial two months of operations this mixture of topsoil and vegetation will be stockpiled. Thereafter the stripping of topsoil ahead of the mine path and the respreading of this topsoil on the restored landforms immediately behind the mining operation will be undertaken in a single operation to avoid stockpiling. There will be no loss of topsoil.

The mine is planned to produce 271,000 tonnes of Heavy Minerals Concentrate per year, and at that rate mining will be completed within eight years. The rate of mining is determined by the requirement of the Secondary Separation Plant in Bunbury for a constant input of Heavy Minerals Concentrate. To maintain ilmenite production at the design level **two dredges** will be used for the mining operations. One dredge will commence mining in the north-western strandline of the orebody while a second dredge will be introduced within two years to the south-west strandline of the orebody for a period of three years. The second dredge will then be removed and mining of the central strandline will continue with a single dredge.

The Heavy Minerals Concentrate will be trucked to Bunbury along the Vasse Highway through Nannup and along the Bussell Highway to Bunbury using trucks and trailers with payloads of 38 tonnes. Cable Sands has applied for a permit to use trucks with a payload of 42 tonnes, to decrease the number of truck journeys and consequently provide cost savings.

All buildings and accommodation on site will be transportable, electricity will be generated on site and communications will be via a satellite link.

Normal industrial and domestic rubbish will be buried on site with due regard to vermin control, prevention of littering and hygiene. Petroleum products will be removed from the site for re-cycling.

Most of the workforce will be expected to find their own accommodation locally and Cable Sands has initiated discussions with Homeswest for the construction of an additional twelve houses in Nannup. Accommodation will be provided on site for essential personnel who have to be available at call.

The **major environmental issues** of the mining proposal are identified as:

- rehabilitation of the land to restore the landscape, vegetation, flora and fauna, and to prevent the further spread of the dieback fungus,

- the impact on local communities of increased trucking,

- the impact on local water regimes,

- possible impacts on the adjacent D'Entrecasteaux National Park, and

- the impact on local employment and services.

Minor issues such as assembly work, radiation, noise and dust are also discussed in this ERMP.

No part of the mine site has any unique values in terms of the vegetation, flora, fauna and landscape. The mining will result in the temporary disturbance of approximately 200 hectares of pasture and 30 hectares of State Forest. These landuses will be restored on completion of rehabilitation, and the impacts on the vegetation, flora, fauna, water resources and the local landscape will be very small.

Mining is a short-term landuse and the original landuses will be restored during **rehabilitation** which will be an integral component of the proposed mining. The natural vegetation will not be restored fully because of the presence of the dieback fungus. Species which are highly susceptible to dieback will not be planted on restored landforms during rehabilitation. The small areas which are not already infected by dieback will be used to provide dieback-free topsoil along the edge of the restored area in the State Forest.

Rehabilitation of the farmland will be complete when permanent pasture has been established on restored landforms and trees have been established for stock shelter and for local and regional landscape purposes. Rehabilitation in the State Forest will be considered to have been completed when monitoring demonstrates

that the new landforms have been stabilised with a self perpetuating community of native vegetation.

Cable Sands will monitor the rehabilitation programme to ensure that it is progressing correctly and on schedule. This will include monitoring the impact of dieback.

The **trucking** of the Heavy Minerals Concentrate will increase the traffic through Nannup and on the Vasse and Bussell Highways, but the highway system is designed for these increases. A series of alternative routes and transportation methods were considered and costed in detail, including a rail option. The cost of transportation is a very large component of the total cost of the operation, with every increase of 10 cents in the cost of transporting 1 tonne from Jangardup to Bunbury resulting in an overall cost increase of $200,000 for the life of the project. The final route and transportation method was selected on the basis of costs and the roads being suitable for the volume of traffic. The cost of transportation varies from $10 to $19 per tonne. Trucking along the Vasse and Bussell Highways route was selected because this is the cheapest route where the roads are able to tolerate heavy trucking. The rail option is the most expensive option and is completely unrealistic. The transport analysis included the cost of road damage and the possibility of constructing a bypass around Nannup. A bypass would cost approximately $640,000. This is an unnecessary expense which cannot be justified as roads which are designed for heavy haulage already exist.

The increase in the traffic of trucks through Nannup will be noticeable to residents, but this should be accepted as part of the town's economy just as the trucking associated with logging and farming is accepted.

The mining will have little impact on the local **water regimes.** The mining and treatment operations use no chemicals and the only impact on **water quality** will be from the suspension of clay sediment in the water. The water will be held in settling ponds and behind large embankments so that sediment will settle out or be filtered by the soil before this water is allowed to mix with the natural drainage by seepage through the soil. The water draining from the mine will be a very small addition to the natural drainage and its quality will be similar to that of regional surface and groundwater.

The water added to the mine from the Yarragadee Formation will be of equally good quality and it will not affect the quality of the water of the shallow aquifer. The volume of water which will be taken from the Yarragadee Formation will be extremely small in relation to the regional water resources and it will have no impact on the total resource or on the shallow aquifer.

Dewatering of the mine pit will lower the local watertable over a small area. The drawdown within the dredge pond will be up to 6m and the maximum drawdown at 1km from the dredge pond will be 15cm. This compares with a natural and seasonal variation in the levels of the groundwater of about 1.5m. This drawdown will not affect the vegetation in the D'Entrecasteaux National Park because the mine plan has been designed so that the dredge pond will not be near the D'Entrecasteaux National Park in the late summer period when the D'Entrecasteaux National Park is at its driest. If for some reason it is impossible to avoid dredging this part of the orebody during the dry summer months, then the sandstone in this area will be broken during the winter, ahead of the dredging. By this means the need for dewatering during the summer will be avoided. Water quality and levels will be monitored during the life of the mine.

The mining operations will not have any adverse impact on the adjacent **D'Entrecasteaux National Park.** This is because of the absence of chemicals and the continuous cut and fill operation which allows the natural landforms to be rebuilt immediately behind the dredging front. There will be no final excavation or dumps left after mining.

The mining operations will be marginally visible from Black Point Road, which is a major access track into the D'Entrecasteaux National Park. The mining operations will be seen against the background of cleared pasture and this impact cannot be regarded as important. The area of the D'Entrecasteaux National Park immediately adjacent to the mining operation is remote and rarely visited.

The mining operations will have a beneficial impact on **local employment and services.** Many local residents have already expressed an interest in obtaining employment and in providing services. Cable Sands will fund considerable road works and maintenance through the Shire of Nannup. There will be a need for additional housing in Nannup and Cable Sands has asked Homeswest to construct 12 additional houses.

Various **minor environmental topics** are also discussed in the ERMP.

Noise from the mining operations will not be a nuisance because of the remoteness of the site. The dredging and treatment operations are not noisy and similar operations at other sites are carried out in close proximity to residential areas.

Radiation associated with the Heavy Minerals Concentrate is very low, and the additional radiation exposure to the public during the transportation of the Heavy Minerals Concentrate is minuscule.

At the end of the mining operations all facilities will be removed and the site will be cleaned-up completely. In the long-term there will be no sign that mining even took place.

No sites which are of cultural significance to Aboriginal or other people are known to be affected by the proposed mining operations. Similarly, no known archaeological sites will be affected by the proposed operations. If such sites are discovered in the course of mining, then they will be reported to the Department of Mines and the **Aboriginal Heritage Act** will be observed.

In the ERMP Cable Sands outlines a number of **commitments.** To demonstrate Cable Sands' sincerity to continue to operate in a safe and environmentally and socially responsible manner, the Company suggests that the authorities convert these commitments to conditions for the proposed operations.

The proposed conditions are listed below:

1. Cable Sands agrees to comply with the relevant statutory requirements of both the State of Western Australian and the Commonwealth of Australia.

2. Site preparation prior to mining will be as described in this ERMP.

3. The mining operations, the heavy minerals separation process and the transportation will comply with the descriptions presented in this ERMP.

4. All topsoil will be used for covering restored landforms, and there will be no loss of topsoil.

5. Rehabilitation will be fully integrated with mine production and it will be undertaken continuously, some one to two months behind the dredging front. Rehabilitation will comply with the guidelines presented in this ERMP.

6. Cable Sands will be operating in the area for many years and will maintain the responsibility for rehabilitation until the defined endpoints are achieved. Successful rehabilitation will be determined by the Department of Mines, using the endpoints outlined in this ERMP. The endpoints will be accepted by Cable Sands as a condition.

7. Water usage, electricity generation, access roads, and sewerage and rubbish disposal will be carried out as described in this ERMP and will not be varied greatly without prior consultation with the authorities.

8. All workers will be kept within radiation standards set by the Department of Mines for the heavy minerals mining

industry in compliance with the 1987 Australian Code of Practice on radiation protection in the mining and milling of radioactive ores.

9. Every effort will be made to protect regrowth of plants on the rehabilitated areas from fire and weed encroachment.

10. Part of the rehabilitation process will be to create a range of habitat types.

11. In the event that material of Aboriginal origin is uncovered during the operations, all work will cease within that area and the Western Australian Museum will be called upon to advise.

12. Dust and noise levels will be kept below the standards which are currently set for the mining industry.

13. Groundwater levels and the quality of groundwater around the dredge pond and the production bore will be monitored by Cable Sands. All data will be analysed and should there be any evidence of unacceptable changes, action will be implemented immediately to avoid any harmful changes to the water regimes of the area. The authorities will be notified immediately.

14. Monitoring of the rehabilitation will be undertaken by Cable Sands and reported annually to the Department of Mines, the Department of Conservation and Land Management and the Environmental Protection Authority.

In conclusion, the proposed project will provide substantial economic and employment benefits and will have no long-term environmental impacts. It is a straight forward mining operation with no major complications and there are no reasons why approval for this project should be delayed.

1.0 OBJECTIVES

In October 1987 Cable Sands (WA) Pty Ltd, known as Cable Sands, submitted a Notice of Intent to the Department of Mines to mine a deposit of heavy minerals at Jangardup and to transport Heavy Minerals Concentrate from the mine site to Cable Sands' operations in Bunbury for secondary separation and subsequently for export. The Department of Mines forwarded this notification to the Environmental Protection Authority (EPA) and the latter determined that the general public was to be involved in the assessment of this proposal and that the project was to be evaluated at a level of an Environmental Review and Management Programme (ERMP). The EPA prepared guidelines for the ERMP and these are given in Appendix A. This document is the ERMP and its objectives are to:

- provide a comprehensive outline of the overall proposal, to evaluate alternatives and to provide the authorities and the general public with adequate information on which the proposed project can be assessed independently,

- appraise the ecological values of the project area, both in a local and in a regional context,

- assess the likely impact on the environment,

- formulate an environmental management policy which will ensure that damage to the environment is avoided or minimised, and

- seek formal approval to commence operations.

To fit into the Company's long-term planning and scheduling of production and marketing, it is important that mining commences in mid 1991. For this to be achieved it is important that approval is granted by December 1989 so that 1990 and early 1991 are available for the purchase and manufacture of equipment and for site preparations.

2.0 INTRODUCTION

2.1 Location, land tenure and licences

The Jangardup deposit is located on the Scott Coastal Plain in the south-west of Western Australia (Figure 1). By road it is 52km to the south of Nannup, the nearest settlement, 161km to the south of the port of Bunbury, and 54km to the east of Pemberton.

Most of the deposit lies within a private property which is being developed for grazing. It is covered by Prospecting Licences 70/582 to 70/586 (Figure 2), and these were granted on 1 October 1986. The remainder of the deposit lies within an area of State Forest 58 which is known as the Central Block and is covered by

Prospecting Licences 70/587 to 70/591, which were granted on 18 February 1987. The deposit is adjacent to the D'Entrecasteaux National Park.

Mining Lease Applications ML 70/362 and ML 70/363, have been submitted to cover the deposit. The deposit is bounded by private property to the north, by State Forest to the east and by the D'Entrecasteaux National Park to the south and west. There are no dwellings in the area.

2.2 Scope and timing of the proposal

The discovery by Cable Sands of the Jangardup deposit and other promising mineralisation in the south-west of Western Australia together with a world-wide increase in the demand for products of heavy minerals gives Cable Sands an excellent opportunity to expand its operations.

Market surveys have indicated the immediate existence of a market for an additional 200,000 tonnes per year of ilmenite with a high titanium content. Ilmenite from Jangardup will take advantage of this market while the associated minerals of zircon, leucoxene, monazite and xenotime will be blended with production from Cable Sands' other mines and marketed as common products.

At the proposed rate of mining the operations will be completed within eight years, so that by the end of 1999 it is anticipated that decommissioning of the mining operations will be completed. The rehabilitation of the last areas to be mined is expected to be completed late in the year 2002.

The schedule of mining fits the Company's time frame for the commissioning and decommissioning of mining operations on other orebodies to which the Company has access. The Jangardup deposit will be the basis for expanding the Company's overall mining operations, and undue delays in obtaining approval to commence the mining of this deposit will have severe repercussions on the Company's overall long-term planning and its financial position.

2.3 The proponent

The proponent for this project is Cable Sands (WA) Pty Ltd of North Shore, Bunbury, Western Australia 6230.

Cable Sands is owned equally by Picon Exploration Pty Ltd and Ampol Mining Pty Ltd and these Companies are wholly owned subsidiaries of Pioneer International Ltd and Ampol Ltd. Prior to Cable Sands' incorporation in Western Australia in 1986, the Company operated as Cable Sands Pty Ltd and it commenced operations at Koombana Beach in Bunbury in 1956. This was the first year that heavy minerals were exported from Western Australia. Cable Sands has more than 30 years of experience in the mining and separation of heavy minerals. The Company has

mined in the Shires of Busselton and Capel in the late 1960's and 1970's, and currently mines outside Waroona, along Minninup Beach, near Wonnerup, and will shortly commence another operation near Busselton. The Company operates a Secondary Separation Plant at North Shore in Bunbury and maintains an active exploration programme. Cable Sands is well established and is proficient in all phases of the heavy minerals industry from exploration, mining, secondary separation to marketing, and the Company has established a reputation for carrying out its business in a professional and responsible manner.

Cable Sands' experience in environmental management, especially rehabilitation, is extensive, with the Company having successfully restored all of its mined areas to their long-term landuse and developed new technologies in land rehabilitation. This is widely acknowledged and has resulted in Cable Sands having received a number of awards for its land rehabilitation programmes, the latest being the John Tonkin Tree Award in 1988 from the Greening Australia Campaign for the Company's performance in rehabilitating hind dunes at Minninup and agricultural land in the Shire of Capel.

2.4 Commonwealth and State Legislative requirements, approval processes and compensation agreement

In Western Australia the assessment of the environmental impacts of proposed developments is a formal process which provides the EPA and the public with information about the potential environmental and social effects of such developments.

Proposals for major developments have to be referred to the EPA for determining the level of environmental assessment which will be required. The EPA then develops guidelines for the appropriate environmental report. With respect to the Jangardup deposit the EPA requested the preparation of an ERMP. This is a public document and submissions by interested persons and groups are encouraged to assist the EPA in its assessment of the proposal and in the preparation of recommendations to the Minister for the Environment.

This ERMP will be assessed in terms of the Environmental Protection Act of 1986 which was proclaimed on 20 February 1987. This act formalizes the review process which evolved under the legislation of the Environmental Protection Act of 1971-1980 and provides for the enforcement of management commitments made by the proponent.

The following are the essential steps of an assessment process:

- preparation of ERMP guidelines by the EPA,

- preparation of the ERMP by the proponent,

- acceptance of the document by the EPA as suitable for review,
- public and government review of the document,
- collation of replies by the EPA and their submission to the proponent,
- submission of additional information by the proponent as required by the EPA,
- acceptance of a final document by the EPA,
- review of the document and all comments by the EPA in a public Assessment Report. This report includes recommendations to the Minister for the Environment, and
- a decision by the Minister for the Environment.

There is provision in the Environmental Protection Act for an appeal against the nominated level of assessment and the contents of the EPA's final Assessment Report.

Legislation pertaining to the project and this ERMP includes the:

- Wildlife Conservation Act of 1950-1980,
- Aboriginal Heritage Act of 1972-1980,
- Conservation and Land Management Act of 1984,
- Water Boards Act of 1984,
- Rights in Water and Irrigation Act of 1914-1981,
- State Planning Commission Act of 1985,
- Bush Fires Act of 1954-1981,
- Agriculture and Related Resources Protection Act of 1976-1983,
- Soil and Land Conservation Act of 1945-1982,
- Environmental Protection Act of 1986,
- Country Areas Water Supply Act of 1947-1979,
- Mining Act of 1978-1983, and the
- Code of Practice on radiation protection in the mining and milling of radioactive ores of 1987.

The day to day conduct of a mine is controlled by the Mines Regulation Act of 1946 and it is administered by an inspection system which is operated by the Department of Mines.

Some specific components of the operations, such as road transport, are governed by various statutes.

The private land on which the Jangardup deposit is located is classed as rural and it is located in the Shire of Nannup. The proposed operations have been discussed with that Shire on numerous occasions and discussions were commenced at the early exploration phase. It is Cable Sands' policy to maintain this close relationship with the Shire of Nannup.

After the ERMP has been accepted by the State of Western Australia it will be submitted as an Environmental Impact Statement to the Commonwealth of Australia to obtain an export licence.

Mining in State Forest is governed by conditions which are formulated by the Department of Mines in consultation with the Department of Conservation and Land Management (CALM). The relevant features are that the conditions specify:

- approval to mine,
- rehabilitation requirements,
- reporting requirements,
- any special environmental constraints,
- compliance with particular statutes,
- compensation,
- informing CALM of mine plans, and
- liaison and lines of responsibility.

An agreement which details the conditions for mining on the private property has been negotiated between the landowner and Cable Sands. This agreement is confidential, but the important features are that the proponent:

- has the right to carry out exploration and mining,
- is committed to the restoration of the farmland to productive pastures complete with appropriate infrastructure, including the establishment of trees for the sheltering of stock and for local and regional landscaping purposes, and

- will have an input into pasture management for several years after mining ceases.

Other issues which are addressed in the Compensation Agreement with the owner include water supplies, mining details, owners use of areas not affected by mining or mining infrastructure, protection of livestock, owners indemnity, compliance with all Acts, Statutes and Regulations, replacement and reinstatement of improvements and compensation.

2.5 Description of deposit

Mineralisation at Jangardup was discovered in 1986 and by mid 1987 the existence of a deposit of heavy minerals was confirmed.

The resource consists of 30 million tonnes of ore with an average heavy minerals content of 6.8%. The heavy minerals suite consists of about 76% ilmenite, 6.3% secondary ilmenite, 8.4% zircon, 3.0% leucoxene, 2.5% rutile, 0.7% monazite and 0.3% xenotime. Garnet and kyanite are also present.

The outline of the orebody is given in Figure 2 and a schematic cross-section is given in Figure 3. From this it can be seen that the orebody is irregular in shape and that it is orientated south-east to north-west, with three narrow strandlines in the north-west and pronounced widening in the south-east. The orebody varies in depth from 5m to 22m and it has an average depth of 14m. Mineralisation is generally greatest at the bottom of the deposit and along the northern edge of the northern strandline. Much of the deposit is inundated with water during the winter.

The soils in and below the orebody are sandy with a clay content which ranges from 2% to 10% and averages at 6%. At a depth of up to 6m below the soil surface and immediately above the watertable is a layer of sandstone, with some pockets of sandstone also occurring at greater depths.

3.0 EXISTING ENVIRONMENT

3.1 Regional overview

The landforms of the region can be broadly divided into coastal dunes, followed immediately inland by flats which are often inundated, and further inland by hilly country. The vegetation and soil types reflect this division: scrub and low woodland communities occur on the sandy coastal dunes; low shrub and sedge communities with few trees occur on the flats which are sandy and swampy; and there is a progression from woodlands on sandy rises through low forests on sand, laterite or sandy loams, to tall forests on loams on the inland hilly country.

The coastal dunes and the swamps have in the past been used for grazing, but they have never been developed actively. Some land is held as private property but most grazing was on leases which are still covered with native vegetation. More recently, pastures have been developed on the periphery between the coastal flats and the forests. This land is regarded in the region as valuable summer pasture because of the wet conditions during summer when land elsewhere in the south-west of Western Australia has dried out. The forests have been used for timber production and some have been cleared for agriculture.

As a consequence of this pattern of development, the forested areas are reserved as State Forest and are accessible by roads and numerous tracks. In contrast, the coastal area has little developed access and is one of the largest undeveloped areas in the south-west of Western Australia. Part of this coastal area has been proposed by CALM for inclusion in the D'Entrecasteaux National Park. Access is limited to a few tracks which require a four wheel drive vehicle, and very little vehicle access is possible during wet winter conditions.

The proposed mine will be situated mainly on low lying land, including the interface of the private pastoral land with the elevated State Forest block immediately to the east. This can be seen in the three colour photographs at the beginning of this ERMP. These were taken in August 1988 and further farm land has been cleared since then. There are two small lakes which are partially in the mine path, and they are known to dry out in dry summers.

There has been little other use of the land in the region. Exploration for minerals and oil has taken place, particularly for oil in the 1960's. The area has been explored for heavy minerals previously but this was unsuccessful. Aerial photographs show that previous track clearing for exploration has taken place extensively, although many of these are now overgrown and difficult to locate on the ground.

3.2 Climate

The site has a mediterranean climate of hot, dry summers and mild, wet winters. This is tempered by the near coastal location and summer rainfalls which are high relative to most of the south-west of Western Australia. The climate at Jangardup reflects its geographic position between Cape Leeuwin on the coast and the inland town of Pemberton. Comprehensive and long-term records are available for Pemberton but less complete records are available for the coastal areas.

The annual rainfall for Pemberton is 1205mm and 1067mm of this falls between April and October (Table 1). The rainfall is consistent and heavy in winter and erratic in summer. Rain-free months are rare, even in mid-summer when the mean monthly

rainfall is 25mm, and in the winter the mean monthly rainfall exceeds 200mm. The average monthly rainfall and potential evaporation rates are given for Cape Leeuwin in Table 1. The total potential evaporation per year is approximately equal to the annual rainfall, but potential evaporation exceeds rainfall during the summer. A calculated rainfall intensity diagram for Jangardup shows that at least one day with more than 50mm of rainfall can be expected every year, as can storms which produce 20mm of rain in one hour (Figure 4). These rains are most likely in winter but some heavy summer falls are normal.

Mean temperatures vary from approximately 25°C in summer to 15°C in winter.

At Jangardup the strongest winds are in winter. The winds are generally in association with rain bearing depressions and they are mainly from the west. Afternoon winds can be expected to be from the south-east.

3.3 Geology

The orebody is situated along the Donnelly shoreline of the Scott Coastal Plain, and it is probably a relic of Pleistocene times and associated with high sea levels between ice ages. The deposit is buried and consists of beach and dune sands with no obvious relationship to the geomorphology of the present surface.

The heavy minerals were derived from granites, gneisses and basalts of the hinterland and also from the basement gravelly sands which are thought to be of Cretaceous age. The heavy minerals were transported by rivers and littoral drift, and then deposited in the lee of a headland of Cretaceous Bunbury Basalt which today forms a southerly trending topographic ridge. The basalt is believed to have flowed down valleys which had eroded into the Yarragadee Formation.

Deposits of heavy minerals were formed on beaches which were cut into the gravelly sands. Later, sand banks developed offshore and further deposits were formed on the seaward side of these banks. Thus there are two main regimes of mineralisation, namely, deep ones due to the beach deposits and shallow ones which formed around the sand banks. The gravelly basement sands contain heavy minerals but not at an economic grade.

In the region of the Jangardup deposit, estuarine, strand and aeolian deposits of Tertiary, or possibly Quaternary, age unconformably overlie sandstones and minor shales of the Jurassic Yarragadee Formation.

The sediments are commonly more clayey and coarser grained immediately above the unconformity, where there has been some re-working of the Yarragadee Formation. Away from the deposit, the sediments are generally finer grained, with sand of fine or

fine to medium particle sizes, with clay beds and a higher percentage of clay matrix. The sediments are particularly fine grained on the northern side of the coastal dunes near Lake Quitjup. The clay is carbonaceous, indicating that the clays were laid down in still waters of lagoons, estuaries or lakes.

The Yarragadee Formation consists of beds of weakly consolidated sandstone and minor clay and shale.

3.4 Soils and landforms

The soils of the Jangardup region were never part of any of the regional soil surveys which have been undertaken in Western Australia.

Tille and Lantske (in press) described the soils on the coastal plain immediately to the west of the Jangardup area as siliceous sands, commonly deep and underlain by sandstone, ironstone, clay and laterite. The surfaces are stained by organic matter and there is a bleached A2 horizon in many instances.

The sands differ from many others in the coastal fringe of Western Australia in that they have not been formed on limestone. Churchwood, McArthur, Sewell and Bartle (1988) described the soils to the east of the Jangardup deposit, and they identified the Blackwater group of soils on flat poorly-drained plains. They list podzols as being dominant, and sub-divided these into humic and peaty with often dominant and cemented B horizons. These soils are similar to those seen at Jangardup.

Tille and Lantske described a number of land units within the plains, but Churchwood, McArthur, Sewell and Bartle limited themselves to a single land unit. This is a reflection of the scale of mapping rather than the true complexity of the soils. There has been no regional description of soils similar to those on the basalt ridge at Jangardup.

The uplands which occur above the swampy plain and surround the ridge of basalt have affinities with the Nillup Land System which is described by Tille and Lantske. This system is located on the southern edge of the Blackwood Plateau and lies between this Plateau and the swampy terrain, and extends into the State Forest to the east. Tille and Lantske describe the Nillup Land System as a level to gently undulating plain lying at an elevation of between 20 and 40 metres above the sea level. This system was formed on the lateritised sediments, or Cretaceous beds, of the Perth Basin which extends into this region.

The Nillup Plain consists of flats and poorly drained depressions. Areas of deep white sand are common, and these support Jarrah-Banksia woodland, with Paperbark woodlands in the swampy depressions. In the case of the Jangardup deposit, land with similarities to the Nillup Plain surrounds the ridge of

basalt and extends eastwards until it merges gradually into the swampy plains to the south.

A survey of the soils at Jangardup was undertaken for this ERMP. Black and white aerial photographs at a scale 1:25000 were used to define the broad boundaries of soil types, and this was followed by sampling soils at sites which were selected on the aerial photographs. Holes were drilled into the soil to determine soil texture, colour, and details of soil horizons. Soil profiles were also examined in holes dug to about 120cm and in pits that had been excavated previously for exploration purposes.

The soil types are summarised in Table 2 from descriptions given in Appendix B, and the distribution of the soil types is shown in Figure 5.

The differences between the landforms is accompanied by changes in soil types. The soils of the flats are sands and podzols, but in the uplands of the State Forest there is a complex mosaic of duplex, gradational, lateritic and sandy soils.

The lower drainage plains have bleached and humic podzols and are underlain by sandstone, and in some instances the organic matter is pronounced in the upper horizons of the soil profiles. Low sandy dunes occur on the plains and these dunes are characterised by deep, white or greyish sands.

The uplands have brown, fine sandy loams and grey and brown clay loams over grey/brown clay. There are also substantial areas of grey sandy soils above gravels and laterites.

The distribution of the major soil types is related to the distribution of the major vegetation types, but there are many areas where subtle changes in soil types are not accompanied by changes in the vegetation.

3.5 Vegetation and flora

3.5.1 Vegetation

The vegetation of the Jangardup area was mapped using black and white aerial photographs at a scale of 1:25,000, oblique aerial colour photographs and field inspections. Site descriptions included information on vegetation structure, species present, soils, landforms and terrain. The descriptions were used to divide the vegetation into types and these are summarised in Table 3, from detailed descriptions which are given in Appendix C. The distribution of the vegetation types is given in Figure 6.

The most extensive tall vegetation occurs on the upland areas, which are mainly in the State Forest, and the trees include

Jarrah (Eucalyptus marginata) mixed with Blackbutt (Eucalyptus patens), Marri (Eucalyptus calophylla), Sheoak (Allocasuarina fraseriana) and Bull Banksia (Banksia grandis). Heath and scrub types within the upland areas are restricted to skeletal soils over shallow basalt and colluvial sands in the valleys and depressions.

The lower colluvial slopes and the low dunes support a stunted Jarrah woodland with Candlestick Banksia (Banksia attenuata), Peppermint (Agonis flexuosa) and occasional Holly-leaf Banksia (Banksia ilicifolia).

On the low lying areas and depressions the vegetation is very variable in structure and in species composition. The vegetation ranges from small stands of Melaleuca preissiana trees, through tall thickets which are dominated by species of Agonis, Kunzea and Leptospermum, to low heaths and sedgelands.

The distribution of the vegetation varies with changes in the terrain and soil types, and this relationship is shown in Table 4. Typical cross sections of the distribution of vegetation, were drawn to demonstrate the relationships between the vegetation types and terrain. This is shown in Figures 7 and 8 which are based on transects shown in Figure 6.

The tallest stands of Jarrah occur on sandy lateritic soils (soil type Lt). Jarrah low forest is more open and differs in its species composition from the tall Jarrah forest, and occurs on the freely draining deep white to greyish sands of the foothill slopes (soil type fB) and where sandy lateritic and shallow basaltic soils occur as a mosaic (soil type Bx). Forests of Marri and Blackbutt occur on the heavy duplex soils of the ridge of basalt (soil type B). Where the latter soils are very shallow and over basalt (soil type Bs) they support dense heath which is dominated by Western Prickly Moses (Acacia pulchella) or Melaleuca lateritica.

On the upland areas the distribution of the tall forests and woodlands is closely associated with soil distribution. On the lower areas where minor differences in local terrain determine the extent and the duration of winter flooding, the distribution of vegetation is largely independent of soil types. Communities of Melaleuca preissiana, and scrub and heath communities occur on the humic podzols (soil type lp). Thickets of Agonis juniperina occur on the most peaty soils, while various sedgelands occur on the wettest sites. Podzols (soil type hp) with grey sands overlying yellow to orange sands occur on slightly more elevated locations on the dunes and drainage areas than the humic podzols (soil type lp), and they commonly support scrub communities. Thickets of Kunzea species generally occur on the more humic elements of soil type (hp).

Woodlands of Jarrah-Banksia are usually found on the sandy soils of dunes which are sufficiently elevated within the landscape to avoid water logging at the surface during the winter months (soil type sd).

3.5.2 Flora

Plant species were collected from the Jangardup area between August 1987 and May 1988, and they were identified by reference to plant collections in the Western Australian Herbarium and the literature. Species which could be identified in the field were not collected.

A list of all of the species which were identified is given in Appendix D together with information on the landforms in which they were found.

A total of 236 native species and six non-native species were identified in the State Forest and the D'Entrecasteaux National Park. Pasture and weed species on the farm were not collected.

The families with the highest number of species were Myrtaceae (29 species), Papilionaceae (22 species), Orchidaceae (17 species), Proteaceae (16 species), Cyperaceae (15 species), Epacridaceae (13 species) and Restionaceae (11 species).

Some families show a distinct preference in habitat. The Cyperaceae and Restionaceae were most common on humic podzols, in swamp depressions and lake margins. The Orchidaceae were most common on well drained lateritic and basaltic upland sites and in valleys on the heavier colluvial soils while the Myrtaceae were most common in swamp depressions and in drainage channels.

The non-native species were herbaceous ephemerals and they were generally confined to disturbed sites, such as firebreaks and tracks.

No noxious species were observed, but localised infestations of Apple of Sodom (Solanum sodomaeum) and Arum Lily (Zantedeschia aethiopica) are known to occur further east in the Lake Jasper area.

3.5.3 Dieback due to Phytophthora cinnamomi

Thirty-three samples of roots from dead or dying Banksia attenuata, B. grandis and B. ilicifolia were collected at Jangardup, and Phytophthora cinnamomi was isolated from ten of the samples.

Dieback was subsequently mapped by examining plant damage and their position within the landforms, with areas downslope of known infected areas being mapped as infected. The distribution of infected areas is shown in Figure 6.

Dieback occurs on the farmland, the State Forest and the D'Entrecasteaux National Park. Its presence is related to and dependent on topography, and its distribution does not appear to be related to human activities. It is likely that the majority of the fungus has been spread by spores which are transported by water flowing in low-lying ground which floods every year.

Virtually all of the low-lying areas are infected, and the sandy ridges of Jarrah-Banksia woodland within the flat plains are being invaded by the natural spread of the fungus up the slopes. The more elevated terrain of the State Forest is similarly being invaded from the lower country, but dieback does not appear to be common on the higher areas.

The impact of the fungus is severe in some vegetation types, particularly in the Jarrah-Banksia woodland. In other cases there appears to be little impact, but it is possible that these have already been altered by dieback infection and any changes in species composition are no longer apparent. The low-lying areas contain few plant species which appear to be highly susceptible, but there is evidence that susceptible species were once more extensive or more common. The worst affected plant families are the Proteaceae, Epacridaceae and Papilionaceae.

It is not possible to give an accurate assessment of the extent to which vegetation types are affected by the dieback. This is due to a lack of information on possible previous impacts due to dieback and a lack of information on the inter-relationship of host species, soil and terrain. It is these parameters and their inter-relationships which together determine the impact and the vulnerability of each vegetation type. A summary of the estimated impacts of dieback on each vegetation type and the vulnerability of each vegetation type to dieback is given in Table 5.

3.5.4 Condition and conservation status of the vegetation and the flora

The regional vegetation patterns relate to the two main landform features, namely the Scott Coastal Plain and the southern extension of the Blackwood Plateau. The Scott Coastal Plain consists of swamps and low lying areas which have developed in ancient coastal lagoons and estuaries while the Blackwood Plateau is lateritic and gently undulating.

The Jangardup site centres on an ancient strandline which was formed on the boundary of the Blackwood Plateau, with the vegetation containing representative elements of the swampy plain, the plateau uplands and the intervening colluvial slopes.

Few ecological studies have been undertaken in the region. Smith (1972) mapped the vegetation at 1:250,000 and he included the Jarrah forest of the Blackwood Plateau in his Chapman Vegetation

System, and the swampy vegetation of the Scott Coastal Plain into the Scott River Vegetation System. These systems were both incorporated into the Warren Sub-district of the Darling District of Beard (1981). More recently, some studies of the flora were undertaken (CALM, 1987) for Management Plans for the Shannon National Park and the D'Entrecasteaux National Park.

The vegetation types of the coastal plain at Jangardup are common elements of the Scott River Vegetation System. Extensive areas of similar vegetation occur in the existing and proposed areas of the D'Entrecasteaux National Park which together extend for 140km along the south coast.

Beard and Sprenger (1974) estimate that in the Warren Sub-district there are approximately 400 square km of sedgelands which are dominated by species of the families Cyperaceae and Restionaceae and that Jarrah-Banksia low woodlands on low sandy dunes and colluvial slopes occupy approximately 700 square km.

The proposed mining will affect only a small area of these vegetation types, namely 30 hectares of dunes and swamp vegetation on the periphery of the forest area.

Most of the farmland has been cleared for pasture and the owner is progressively clearing more, and some areas have been chained but not yet cleared. Most of the remnant areas within the pasture are being degraded by cattle grazing and the impact of dieback.

The vegetation of the State Forest is generally healthy with dieback restricted to the edges which are low lying. Numerous dead trees were observed in the autumn of 1988 in the low Jarrah forest on lower colluvial slopes on the edge of the uplands. Field inspections suggest that these deaths were probably attributable to drought. The Central Block has not been cut for timber.

The D'Entrecasteaux National Park has been extensively infected by dieback and this has probably resulted in large changes in the species composition of the vegetation. Much of the area has also been affected by large scale fires. The impact of this is not known but there is no reason to believe that this area has been affected differently from other areas along the south coast.

Fires occur from time to time in the State Forest and the D'Entrecasteaux National Park. The Central Block was last burned in autumn 1983 and it is due for burning in 1989. In 1988 an extensive area in the D'Entrecasteaux National Park was damaged by an uncontrolled fire to the south-east of the proposed mining area. Similarly, fires have occurred in the Jarrah-Banksia woodlands on sandy ridges under private tenure. The low-lying grassland which surrounds the Jangardup deposit is less prone to

burning due to its high watertable which maintains the growth of pasture into mid summer.

The plant species which occur on and adjacent to the Jangardup deposit in the State Forest and in the D'Entrecasteaux National Park are all widely distributed on the Swan Coastal Plain and especially along the south coast between Augusta and Albany. Two species which were recorded adjacent to the Jangardup deposit in the D'Entrecasteaux National Park are on CALM's 1988 list of plants which were considered for declaration as rare flora. These are Amperea volubilis and Leucopogon alternifolius which were both found in the D'Entrecasteaux National Park. Melaleuca basicephala, a poorly collected species but not on the 1988 list, was found in several locations on the farm, the State Forest and the D'Entrecasteaux National Park, and it is common locally. Astartea sp. DB 88233, another poorly collected species, was found in the south western corner of the farm, outside of the area which will be mined. It was previously known only from one collection near the Scott River.

No species which is gazetted as rare flora was found in the Jangardup area.

3.6 Fauna

3.6.1 Terrestrial fauna

Terrestrial vertebrates were studied by trapping for frogs, reptiles and small mammals, searching for frogs, lizards and snakes, and observation of birds and large mammals. Bats were not trapped because it is unlikely that any species would be restricted to the proposed mine site or that it would be affected by the proposed operations.

Trapping was carried out at twenty sites (Figure 9) and these covered the range of habitats in the Jangardup area. A description of the vegetation, soil and terrain of each trap site is summarised in Table 6. Sites 1 to 13 were run for ten days in November 1987 with pit traps and Elliott traps, and sites 14 to 20 were run for ten days in May 1988 with pit traps and cage traps. Searching for animals was carried out concurrently by raking litter, looking in logs and dead vegetation, and raking the abandoned nests of stick ants. Animal calls, tracks, eggs and other signs of animal presence were recorded.

Birds were recorded during visits to the site from August 1987 to May 1988.

The recorded amphibian and reptile species were mainly caught by pit trapping and they are listed in Table 7.

The terrestrial invertebrate fauna was not studied because it is too poorly known to make any useful assessment.

The frog fauna is diverse and prolific and nine species were recorded. This number represents all of the species which on the basis of a literature review are expected to live in the Jangardup area. Three other species are likely to be present in the region, but not on the proposed mine site. These are Litoria moorei which is found near more permanent water, Heleioporus inornatus which is found further north in swamps with acidic water and Geocrinia rosea which is found to the east. All of the species are common and widespread.

The skinks are the only lizard group which are well represented. Nine species were recorded, and all of these are expected to occur in the area. They are all common and widespread. Two other species, Egernia kingii and Egernia pulchra, are also expected to occur. These are widespread but not common. Four other species are probably present regionally, but at Jangardup all would probably be at or beyond the southern edge of their geographic distribution. These are Lerista distinguenda, Lerista elegans, Menetia greyii and Morethia lineoocellata.

The goannas were represented by Varanus rosenbergi. This is common along the south coast and is the only goanna occurring in the area.

A single gecko, the common Marbled Gecko, Phyllodactylus marmoratus, was found. This is the only gecko species which is widespread along the south coast. Other species could be present, but only as occasional individuals outside their main range of geographic distribution.

No legless lizards were found, but several species could occur, with Pygopus lepidopodus known to be the most widespread in the region. All of the species which could be expected in the area are common within the region. No dragon lizards were found. The only species which could be present is the widespread Western Bearded Dragon, Pogona minor, but this species has not been recorded from the southern coastal plain.

Snakes were scarce. Five species were recorded, but only the Crowned Snake (Notechis coronatus) and the burrowing snake (Ramphotyphlops australis) were recorded on more than one or two occasions. The Bardick (Notechis curtus) is undoubtedly present in the area and Notechis minor is also likely to be present. The latter is an uncommon and little known species which is restricted to the coast from Busselton to Albany. The Carpet Snake (Morelia spilota) could be present, but this species is rarely seen along the south coast. Rhinoplocephalus nigriceps may be present, but the study area is probably outside the southern limit of its geographic distribution.

There is a single species of tortoise, the Long-necked Tortoise (Chelodina oblonga), which was seen in one of the two small lakes

and in a swamp in the State Forest. This species is common and widespread and it survives the dry summer buried in mud.

The birds were the most diverse group, with sixty-four species recorded (Table 8). Two species are gazetted as rare or otherwise in need of special protection. These are the Peregrine Falcon (Falco peregrinus) and the Red-eared Firetail (Emblema oculata. The Peregrine Falcon is an uncommon species which occurs all over Australia. Breeding birds occupy large territories and are not threatened by the loss of very small areas of habitat such as the proposed mining area. The Red-eared Firetail is actually common and widespread (Nichols, Watkins and Kabay, 1982) and its preferred habitat is dense vegetation around wet places. This species has declined in population in some areas due to the loss of habitat, but it is secure over large areas of the south-west of Western Australia. Numerous other species of birds are expected to occur on the study area, but it is very unlikely that there are any species in the study area which are of particular interest.

Mammal species which were recorded during the surveys are listed in Table 9. All small mammals were caught by pit trapping except the Bush Rat (Rattus fuscipes) which was caught in Elliott traps and cage traps. All larger mammals were recorded from observations.

The mammal fauna is very limited, and only five native terrestrial species were recorded, including two species of kangaroos. All of these species are common and widespread over large areas, although the Brush Wallaby is scarce along the coastal plain.

Five other species may occur in the area, namely, the Pygmy Possum (Cercartetus concinnus), the Brush-tailed Wambenger (Phascogale tapoatafa), the Quokka (Setonix brachyurus), the Short-nosed Bandicoot (Isoodon obesulus) and the Ring-tailed Possum (Pseudocheirus occidentalis). The Pygmy Possum and the Short-nosed Bandicoot are probably the only mammal species which are common in the region. The other species are uncommon everywhere except in very favourable locations.

The most common species were found in all habitats but a few species appear to be restricted to specific habitats. The lizards Ctenotus catenifer and Egernia luctuosa and the Bush Rat were found in the wetter sites. The findings may be obscured by the low numbers of many species, and the fact that much of the trapping was within a short distance of the interface between the swampy flats and the forest block on higher ground.

The vertebrate fauna was reviewed regionally by Christensen, Annels, Liddlelow and Skinner (1985) and How, Dell and Humphreys (1988) but no detailed surveys have been undertaken previously in the Jangardup area. The results reported in this ERMP for the

Jangardup area are in close agreement with the published reports in terms of species presence as well as the density of animals. The regional frog fauna is varied and individuals are common, but the reptile fauna is limited. There is a dominance of reptiles with live births rather than egg laying, and this is thought to be due to the cool and moist climate which does not favour reptiles. The bird fauna is varied and individuals are common, but no species is known to be restricted to small areas. The mammal fauna is impoverished and the individuals are present at low population densities. Some species have also been reduced or become extinct since European settlement.

The Kookaburra (Dacelo novaeguineae), the House Mouse (Mus musculus), the Fox (Vulpes vulpes) and the Pig (Sus scrofa) were the only exotic species which were observed. It is not known whether dogs in the area are feral dogs or Dingoes. Other species are undoubtedly present, including the Black Rat (Rattus rattus), the Cat (Felis catus) and the Rabbit (Oryctolagus cuniculus).

These species are all typical of the coastal areas of the south-west of Western Australia.

3.6.2 Aquatic fauna

Two small lakes and two seasonal water-bodies (Sites 1 to 4 in Figure 9) were sampled for aquatic invertebrates and fish in December 1988 when the water-bodies were starting to dry up, and water samples were analysed for pH, conductivity and plant nutrients. The aquatic invertebrates were sampled by four replicates of a twenty second sweep with a dip net with a mesh size of 250 microns. The animals were preserved in alcohol and subsequently sorted by washing through 2mm, 0.6mm and 0.18mm sieves in series. Fish were netted using a seine net with a fine mesh.

The physical and chemical characteristics of the sites which were sampled is given in Table 10. The waters of each site were coloured yellow-brown, probably due to tannins, as is typical of many of the undisturbed water-bodies in this region. The waters were very fresh, with a total dissolved solids content of about 250ppm, and they were acidic with pHs of 4 to 6. The chemical analysis of the water samples show that all of the water bodies are low in plant nutrients.

The sites which were sampled in this study contained a rich invertebrate fauna, with 58 species of aquatic invertebrates being recorded from the four sites (Table 11). Site 1 contained the richest fauna with a total of 34 species and Site 3 the poorest with 17 species, but Site 3 appeared to have the greatest number of organisms, especially Copepods. Only five species occurred in all four sites, namely the water-boatman (Sigara mullaka), the back-swimmer (Anisops thienemanni), the midges

Limnophyes pullulus and Pentaneura levidensis, and a calanoid copepod.

Sites 1 and 4 contained species of fish which are endemic to the South-West. The Salamanderfish (Lepidogalaxias salamandroides) and the Black-stripe Minnow (Galaxiella nigrostriata) were present in Site 1 while only the latter species was observed in Site 4. Both species are probably present in all major waterbodies in the area.

In common with many waterbodies in Western Australia the insects with thirty two species, were dominant. There were sixteen species of arachnids and ten species of crustaceans. Crustaceans, particularly planktonic copepods were usually the most numerous.

A relatively high number of species of predatory invertebrates such as the aquatic spiders, the dragonflies and the aquatic beetles were recorded from the waterbodies. This indicates that the quality of the water is good and that no pollution from plant nutrients, heavy metals or other chemicals has occurred.

The assemblages of invertebrate species, including possibly new species of invertebrates, and the endemic fish recorded in this study constitute a fauna which is quite different from those recorded for water-bodies elsewhere in Western Australia. This assemblage probably represents a faunal suite which is unique to the extreme south-west of Western Australia. It is most likely that the fauna described here occurs throughout the waterbodies of the extreme south-western coastal plain, but as no studies of other water-bodies in this area appear to exist little further comment can be made.

3.7 Groundwater

The surface sands form a minor unconfined aquifer, which is referred to as the shallow aquifer, and this over-lies directly the major confined aquifer in the Yarragadee Formation. Rockwater Pty Ltd investigated the hydrology of the Jangardup area, and they report that the groundwater flows to the west and south-west and discharges into swamps and small creeks. Figures 10 and 11 show the watertable contours and the direction of water flow in 1988 during low water levels in April and high water levels in August.

Two bores and 11 piezometers were constructed on the deposit and its immediate vicinity in addition to 22 regional piezometers which were constructed previously. One production bore (J1) was installed to a depth of 184m to supply water from the Yarragadee Formation, and another test bore (CS3P) was completed to a depth of 17.6m to determine the hydraulic characteristics of the superficial sands.

The piezometers were installed to permit the sampling of the shallow aquifer, for monitoring water levels during the pumping tests prior to mining, and subsequently during mining. Variations in hydraulic conductivity were determined in the piezometers by falling-head tests.

At most sites there are two piezometers, one is deep into the superficial sands and the other is just below the watertable. This allows the measurement of variations with depth in head and water quality.

The storativity of the Yarragadee Formation was not determined, but it is estimated to be in the range of 0.01% to 0.1%, which is typical of a confined aquifer. The static water level in the test bore, J1, is 10.3m below the ground level and at an Australian Height Datum of 39.15m.

At Jangardup, the Yarragadee Formation is generally in partial hydraulic connection with the overlying Tertiary sediments, as both aquifers occur in sand or sandstone. The similar chemical properties of water from the Yarragadee Formation and the shallow aquifer also demonstrates the close relationship between these two aquifers. The vertical movement of groundwater between these aquifers is restricted by the layer of sandstone, interbedded clay and shale, vertical variations in grain size, and clay which is dispersed in the soil.

The casing in the bore, J1, was grouted with cement to a depth of 150m. This was done to minimise the possibility of the pumping of water affecting groundwater levels in the Tertiary sediments. Any changes in shallow groundwater levels resulting from pumping of the bore are expected to be very small.

The head in Bore J1, which is situated near the ridge of basalt, is 6m below the head in the overlying shallow aquifer, indicating the potential for recharge by the downward movement of groundwater. An artesian bore which was previously drilled by Broken Hill Proprietary Company Ltd in the western part of the private property indicates that further west there is the potential for groundwater to discharge upwards from the Yarragadee Formation into the shallow aquifer.

Test pumping of the shallow aquifer showed the transmissivity to be initially high, about 250-300 square m/day, but with extended pumping the presence of aquifer boundaries reduces the effective transmissivity to around 200 square m/day. Dividing the transmissivity by the thickness of the aquifer gives an average hydraulic conductivity of 13m/day. The storativity of the shallow aquifer is calculated to be in the range of 0.2% to 0.5%, and this suggests that the aquifer is semi-contained and that any vertical movement of groundwater is restricted by the sandstone. This layer has much lower permeability than the uncemented sands.

The watertable of the shallow aquifer is commonly above ground level during the winter months, and this causes ponding and flooding. The study showed that the water contours follow the contours of the ridge of basalt, with a southerly direction of flow to the east of the ridge, and a westerly or south-westerly flow to the west of the ridge. The water levels in early August 1988 were 0.4m to 2.1m, and on average 1.5m higher than at the end of summer. In low-lying areas the water levels were above ground level, with the groundwater discharging into the low lying areas. An aerial inspection on 30 August 1988 indicated that water levels had risen further and resulted in large areas of ponded water. The aquifer has insufficient storage above the watertable to contain all the potential recharge from rainfall infiltration.

In summer, groundwater levels of the shallow aquifer above the sandstone (CS2, CS3B, and CS4B in Figure 12) are between 0.7m and 2m above heads in the sand below (Figure 13). This confirms that the sandstone forms a semi-confining layer. Heads in the eastern area near the basalt ridge are about 6m above heads in the underlying Yarragadee Formation.

The small lakes form groundwater sinks during the summer, with losses due to evapotranspiration causing a local depression in the watertable (Figure 12).

The lower heads deeper in the shallow aquifer indicate that, at least in February 1989, the Jangardup deposit is in an area of groundwater recharge. The vertical hydraulic gradients are probably reversed in the winter months. There is also a discharge of water during the summer by evapotranspiration from the top of the shallow aquifer where the watertable is close to the ground surface, and by evaporation from the lakes.

The high flow in the shallow aquifer indicates that a large percentage of the rainfall on the periphery of the ridge of basalt infiltrates to the groundwater.

The salinity of water samples from the piezometers and the larger of the small lakes was estimated from measurements of Electrical Conductivity and from a relationship between the Total Dissolved Solids and the Electrical Conductivity as established by the Geological Survey of Western Australia, a division of the Department of Mines.

At all measurement sites the water is fresh and suitable for domestic consumption. The average salinity of water of the shallow aquifer is statistically indistinguishable from the salinity of water obtained from the Yarragadee Formation (Table 12). The salinity of water in the larger lake is higher than most of the groundwater samples, but this is expected for the month of February when the potential evaporation rate is at its highest for the year.

The waters are of the sodium chloride type which is common throughout the south-west of Western Australia. Water from above the sandstone has a low pH, probably due to the organic acids which are common in swampy land, while lake water and groundwater from the Yarragadee Formation are also acidic but less so than the water from the shallow aquifer.

3.8 Radiation

Low levels of radiation are usually associated with deposits of heavy minerals due to their monazite component. In the Jangardup deposit the monazite comprises less than 0.07% of the in situ ore, which when concentrated is less than 0.7% of the Heavy Minerals Concentrate.

A survey of natural surface gamma dose rates was carried out with measurements being recorded 1m above ground level over the orebody. The results show that the rates are low, with the 300 measurements varying from 0.10 to 0.22 microGray per hour and most readings are 0.15 microGray per hour or less (Figure 14, 15 and 16). There are no obvious differences between rates on and off the orebody. Surface gamma radiation dose rates are at low level natural radiation rates, they are not caused by human activities, and they are well within the allowable limit for public exposure of 0.6 microGray per hour.

3.9 Dust and noise

Dust levels are very low and sand movements are very limited even in strong winds.

Noise levels are insignificant and no different from similar situations elsewhere.

3.10 Archaeology and anthropology

Several districts in the South-West, especially the coastal areas, are noted for their abundant and well documented archaeological evidence and ethnohistoric literature. In contrast there is a lack of archaeological data for most of the inland areas. The ethnographic records for the entire south-west region are generally poor and there are few surviving persons who have detailed and first hand knowledge of traditional Aboriginal life. Traditional Aboriginal life can be reconstructed from analysing archaeological discoveries and other physical data, and from reviewing records from informants. There is a unique art site (Clarke, 1983) near the Scott River, some 50km to the west of the Jangardup area. This consists of a series of engraved animal tracks in a 5m long horizontal exposure of limestone and there may be other such engraving sites on the coastal plain.

The Jangardup area was surveyed for archaeological material by Mr. C.E. Dortch of the Western Australian Museum. No Aboriginal

sites are recorded for the Jangardup area and its immediate surrounds. Archaeological investigations on the coastal sand plain between Northcliffe and Point D'Entrecasteaux, some 50km to the south-east of Jangardup and in landscapes similar to Jangardup, have been described by Dortch and Gardner (1976). These studies suggest that the sites which could be expected in the Jangardup area would be scatters of flaked stone artifacts and that they are likely to be buried in the upper one or two metres of sandy soil. Scatters of artifacts are often extensive and along with materials such as ochreous pigment, mollusc shells and bones, give some insight of the function of these sites. Such sites appear to have been open-air camps, where groups of hunter-gatherers were employed in food preparation and the manufacture of stone tools and wooden implements. Similar sites may exist in the Jangardup area, and they exist around Lake Jasper. The evidence from Northcliffe suggests that the most important sites would be situated on the well-drained dune ridges, adjacent to wetlands.

In excess of thirty open-air camp sites have been identified in the Northcliffe area in road cuttings and other deep exposures in sand dunes and hillocks. All stone artifacts were buried by 20 to 100cm of sand. The great scarcity of flaked stone artifacts in the sands of the Jangardup area suggests that the same pattern of deeply buried artifacts may exist, though it is unlikely that any sites of importance are present.

There is no doubt that the Jangardup area was occupied by hunter-gatherers, although the pattern and type of sites there would not be unique, and could be expected to be repeated throughout the coastal sandplain. The basalt formation just east of the proposed mine site could have been used as a stone quarry and factory prior to it being covered by sands. No other types of sites are predicted for the area.

If archaeological sites are present in the Jangardup area then they are probably Holocene open-air camps. These are identified by scatters of stone tools and waste flakes which are buried in sandy hillocks or dunes. Such sites are unlikely to be unique, and they may not be of great importance.

The mining operation offers an unusual opportunity for archaeological investigation of the sand plain, particularly since there are few deep exposures of the soils in the dunes and hillocks between Lake Jasper and the Blackwood estuary to the west. Mr Dortch recommended that Cable Sands permits archaeological investigators to view excavations in the Jangardup lease during various stages of the mining operation. The Company agrees to provide such assistance.

In the event that material of Aboriginal origin is exposed during mining, work in that area will cease immediately and the

Department of Mines and the Western Australian Museum will be informed.

3.11 Landuse and European settlement

Agricultural development in the area began in the late nineteenth century when cattle were driven to the coast from farms further north and grazed on the natural grasses of the coastal hills and sand dunes. The practice then was to burn the native vegetation regularly to promote the growth of palatable ground feed which emerged in the burnt scrub and low woodland thickets. The area was noted for its infertile soils and difficulties in establishing permanent pastures, and it was recognised that stock could only be grazed there for limited periods to avoid the development of nutritional deficiencies.

Following the identification and the correction of soil and animal nutritional deficiencies, including the macro-deficiencies of phosphorus and the minor element deficiencies of copper, cobalt, molybdenum and zinc in the 1930's, permanent occupation of the coastal plains became a reality. At the same time more productive pasture plants such as subterranean and strawberry clovers, perennial and annual rye grasses became available for introduction into the pastures of the swampy flats. These discoveries led to a great increase in the economic value of these areas for grazing, and nowadays they are highly valued for their productivity, especially during summer.

Horticulture and forestry is limited in the region by water-logging and consequently it has never prospered.

At Jangardup the coastal plain has been cleared and developed into pastures which are based on subterranean clover and used for cattle production. The low sand dunes have little or no agricultural potential and they have been retained for stock shelter purposes.

A small area of the mineral deposit is in State Forest 58 which is part of a very large area of State Forest in the region. These forests have traditionally been retained for timber production, but more recently they have been given increasing values for recreation, water conservation, nature conservation and landscape preservation. No specific purpose other than timber production is attached to this area of State Forest 58 (CALM, 1987).

Most of the area which is to be mined is private property and has no public recreational use. By contrast, the landuse of the D'Entrecasteaux National Park focuses on recreation in a natural environment. No comprehensive survey of the recreational use of the D'Entrecasteaux National Park has been undertaken but recreation is recognised as being greatest where vehicle access is easiest and where alternative recreational opportunities

within the region are most constrained. Most recreation in the D'Entrecasteaux National Park is during summer and autumn and revolves around fishing, swimming, bushwalking and camping along the coast. During this period many four wheel drive vehicles traverse along Black Point Road to the coast. The area of the D'Entrecasteaux National Park which is immediately adjacent to the Jangardup deposit has no four wheel drive tracks which are open to the public and it is little used by the public.

Traditionally camping and day use are the preferred activities of people visiting the State Forest. The section of the State Forest adjacent to the proposed mining is not noted for its outstanding forests or other tourist attractions. There is also no evidence that the area which is to be mined in this forest is used for recreation other than by very occasional visitors.

3.12 Population and employment

The population of the Shire of Nannup is about 1200, and of these about 500 live in the town of Nannup, which is the only large settlement within this Shire, and the balance of the population is living on rural properties. The nearby town of Pemberton has a population of about 800, and it is part of the Shire of Manjimup which has a population of about 9000.

The Shires of Manjimup and Nannup have similar demographic patterns and, from the 1986 census (Table 13), it can be seen that the biggest single employer is agriculture and forestry. These are traditional industries in the region but they are declining in terms of employment. It is generally accepted that employment in tourism and recreation in the region is increasing, but these industries are not clearly distinguished in the census results. Mining is a very small industry in the region, with the census in the two Shires recording only seven individuals who are employed by the mining industry. It is not clear whether these persons are employed locally in mining, or whether they were only present in the Shires at the time of the census.

In the 1986 census, 53 people, or 10.3% of the work-force, were unemployed in the Shire of Nannup and 318 people, or 7.6% of the work-force, were unemployed in the Shire of Manjimup.

3.13 Infrastructure

Only very limited services are available near the mine site. There is no adequate power supply, no reticulated water supply, no sewerage and only a limited telephone service. The nearby towns of Nannup and Pemberton provide normal domestic shopping and recreational facilities but only limited services for the maintenance of heavy machinery. The nearest major service centre is Manjimup which attends to the logging industry.

The property on which the mine is located is accessible from Vasse Highway via Stewart and Black Point Roads. The highway is a two lane bitumen road whilst the two other roads have gravel surfaces.

4.0 PROPOSED OPERATIONS

4.1 Rate of mining, dredging and dredge path

The proposal is to mine the deposit over an eight year period and it will be mined by dredging. This method was selected because it is by far the cheapest option for extracting the ore and because the low clay content of the ore and the availability of water lend itself readily to such an operation.

The rate of mining is determined by sales contracts and the capacity of the Secondary Treatment Plant in Bunbury which will treat the Heavy Minerals Concentrate from Jangardup. This plant has an annual capacity of 271,000 tonnes of Heavy Minerals Concentrate.

The heavy minerals content of the deposit varies greatly and consequently the volume of ore that needs to be mined to meet the capacity of the Secondary Separation Plant will also vary greatly. To facilitate the production of a constant supply of Heavy Minerals Concentrate to the Secondary Separation Plant, the Jangardup deposit will be mined with two dredges, each with an hourly capacity of 700 tonnes. Dredge-1 will be used to mine the higher grade north-western strandline of the deposit at a variable rate of 350-700 tonnes per hour, while Dredge-2 will mine the lower grade south-western strandline at a constant rate of 700 tonnes per hour. Both dredges will be assembled on site, with the assembly of Dredge-1 being commenced immediately on obtaining approval to mine while the assembly of Dredge-2 will commence some two years later.

The deposit has been divided into rectangular blocks, each with a mining front of about 100m, and with sufficient ore for three months of dredging. The proposed mine layout is given in Figure 17.

Dredge-1 will commence on private property at the north-western tip of the north-western strandline and move in a south-easterly direction (Figure 18). After traversing twelve production blocks it will reach the State Forest within the third year of operations, in which it will operate for some two years before dredging the central strandline by moving in a north-westerly direction. Dredge-2 will mine the south-western strandline which is entirely on private property. It will commence dredging at the north-western end of the deposit and move in a south-easterly direction. This will require a period of some three years. Thereafter Dredge-2 will be removed from Jangardup and the operations will continue with Dredge-1 for a further three years.

4.2 Description of the mining and separation operations

Prior to dredging any given area, scrapers will remove the topsoil from this area to a depth of 15-20cm. At any given time each dredge/pond will occupy about 3 hectares. The initial three hectares on which dredging will commence, will be stripped of their topsoil and this will be stored for future rehabilitation purposes. In all other instances topsoil will be stripped up to 200m ahead of the dredge path and respread immediately behind the dredge path on restored landforms. There will thus be no further storage of topsoil. The dredged area immediately behind the dredge path will be restored to approximately its pre-mining landforms by filling it with the remaining mixture of sand and clay after the heavy minerals component has been removed from the ore. Landform restoration, complete with topsoiling, will be an integral component of mine production, and it will follow some 50-100m behind the dredging operations.

The return of the mixture of sand and clay to immediately behind the dredge pond will ensure that the profile of the restored landforms will have relatively good water holding characteristics compared to situations where the clay and the sand fractions are disposed of separately. Care will be taken to ensure that the separation of the clay and sand fractions within this mixture is minimised at the disposal site. This will be achieved by regularly moving the stacker over the entire width of the mine pit.

To commence the dredging programme it is necessary to excavate a dredge pond for Dredge-1 where dredging of the north-western strandline will commence, and to excavate a similar dredge pond some two years later for Dredge-2 where dredging of the south-western strandline will commence. The initial dredge ponds will be partially excavated with conventional earthmoving machinery until the dredges are in a position to continue to dig their own ponds. At that time there will be no excavations available into which the sand and clay obtained from the ore of these initial dredge ponds can be dumped. Consequently, this remaining sand and clay will be stockpiled as a mixture on the central strandline adjacent to the last mining block to be dredged by Dredge-1 in that strandline. This is where the dredging of the entire orebody will be completed. The final excavation will then be filled with material previously excavated at the beginning of dredging the north-western and the south-western strandlines. The areas on which dredging commenced and ended have identical landuses and their topsoils are for all practical purposes identical. Consequently, the transferring of topsoil from its pre-mining to its post mining location presents no rehabilitation problems, and the storage of the relatively small volume of topsoil is not considered to be detrimental because the restored landforms in these parts of the deposit will be returned to pastures. Such storage would be detrimental if native vegetation was to be established on these areas as the

viability of seed in the topsoil would have declined greatly with storage time.

Topsoil will be managed carefully and no topsoil will be wasted. Within the State Forest the topsoil from different vegetation communities will be kept separate and a strict management policy will be followed to avoid the mixing topsoils from different vegetation communities. In the State Forest the topsoil will be stripped in two operations. The top 5cm of topsoil will be removed together with all of the vegetation excepting large trees, which will be removed by bulldozers, and a further 10-15cm of topsoil will be removed in a follow-up operation. This deeper topsoil will then be respread so that the initially stripped topsoil will end up as the top layer of respread topsoil. This will ensure that the seed contained in the topsoil will be retained near the surface of the topsoil rather than being buried within the topsoil.

The method of mining is shown in Figure 19. The mining operation requires no blasting but it is necessary to break-up the layer of sandstone so that this can subsequently be dredged together with the remainder of the orebody. A conventional bucket wheel excavator will be used to break this sandstone into particles with diameters of less than 125mm and to place it into the dredge path.

The sandstone is 2-6m below ground level, and to break the sandstone it will be necessary to dewater the deposit to the base of the sandstone. This will require the surface aquifer to be drawn down by up to 6m. This water will be pumped into a number of settling ponds to settle the clay within the water. This water is free of added chemicals and it will be permitted to return to the groundwater by seepage from the storage pond.

The dry pre-treatment of the sandstone will be carried out in a separate excavation from the dredge pond. The depth of the sandstone is variable and this procedure will give greater flexibility in allowing the water level to rise again once the pre-treatment is carried out.

Settled clay from the settling ponds will, from time to time, be removed. This clay will be stockpiled, and when it is sufficiently dry it will be spread as a thin veneer over part of the restored landforms of future pastures. This clay will then be ploughed into the surface of the new landforms which are then ready for covering with topsoil. This spreading of additional clay into the surface profile of restored pasture landforms will enhance the moisture retention capacity of the upper profile and increase their productivity by extending growth further into the summer months. Insufficient clay will be available due to the low clay content of the orebody to treat all pasture areas in this manner. This technique will be managed strictly.

No clay from the settling ponds will be incorporated into areas on which native vegetation will be re-established as this vegetation is more deeply rooted than pastures and generally less dependent on such a clay layer for the uptake of water.

To prevent surface water from flowing into the mine pit during the wet winter period, the entire dredging area will be surrounded by earth embankments. These embankments will be constructed each summer, together with a pumping system for the control of water levels.

The broken sandstone and the remainder of the ore will be mined with a dredge, and pumped to a surge bin and then to a Primary Separation Plant. This entire operational plant will be mounted on pontoons and it will be floating in tandem in the dredge pond. The mixture of remaining sand and clay from which the heavy minerals have been removed in the Primary Separation Plant will be pumped via a stacker to immediately behind the dredge pond to restore the landforms. The dredge and the dredge pond will mine forwards with the stacker continuously restoring the land behind it to landforms which resemble those prior to mining.

In the surge bin all materials which are greater than 5mm in diameter, such as rocks, roots and stumps, are removed by screening and dumped to the base of the restored landforms where they are buried by material discharged from the stacker. All material of less than 5mm in diameter will be pumped to a constant density tank and then to the Primary Separation Plant. Here water jets promote the disintegration and separation of clay and oversize material from the heavy minerals and the sand. This plant is a conventional wet gravity concentrator in which the heavy minerals, which are all finer than 0.3mm in diameter, are separated from the sand and clay in the presence of water on the basis of differences in specific gravities. No chemicals are used in this process, and no chemicals are added to any of the operational components of this project. The general arrangement of this plant is given in Figure 20 and a flowsheet is given in Figure 21. The plant will recover 95% of the heavy minerals which will consist of a mixture of ilmenite, leucoxene, rutile, zircon, monazite and other minor constituents such as quartz.

Water is recovered from the remaining mixture of sand and clay from which the heavy minerals have been removed and from the separated Heavy Minerals Concentrate. The concentrate is pumped to a stockpile. At the time of discharge the Heavy Minerals Concentrate has a water content of about 50%, but this is reduced to 4.5% before it is trucked to Bunbury, with all of the recovered water being recycled into the operational water circuit.

The clay fraction of the ore will be removed in the overflow from the constant density tank, and remixed with clean sand from which the heavy minerals have been removed and discharged by the

stacker at the rear of the dredge pond as land fill. Water will be recovered from this and returned to the dredge pond while excess water will be pumped to the settling pond. The overflow from this settling pond will be collected in a recycle pond and allowed to drain into the groundwater. In dry conditions all of the water will be recycled to the dredge pond to make up for losses due to evaporation and seepage. This will be supplemented on a needs basis by water from a deep bore.

The dredge will have a bucket wheel cutter to permit the mining at depth of pockets of sandstone. The dredge will pivot on two adjustable pillars and it will be moved by pulling on a series of cables which will be anchored on land. This is a well proven method and will allow the dredge to move in all directions or to remain stationary as required.

For most of the winter there will be an excess of water from the operations due to dewatering. There are areas where the sandstone layer is at a shallow depth or absent, and in these instance it will not be necessary to lower the groundwater. If mining in these areas coincides with the dry period from November to April, then water losses from the operations may exceed the natural inflow to the dredge pond, and it will be necessary to pump bore water into the dredge pond.

The stacking of the mixture of remaining sand and clay following the separation of the heavy minerals will be controlled strictly to ensure that the final shape of the restored landforms are achieved as planned by the use of the stacker without an excessive need for earth-moving machinery. Some reshaping with earth-moving machinery will be required, but this will be minimized.

The need for mobile machinery is limited because most of the material handling operations are undertaken by the dredges. The mobile machinery which will be used from time to time on site will include scrapers, a bucket wheel excavator, bulldozers, front-end loaders, back-hoe, a mobile crane, four wheel drive vehicles and a watertruck for dust suppression and road maintenance.

4.3 Rehabilitation of landforms

The rehabilitation of mined land at Jangardup consists of landform restoration and its stabilisation with vegetation. This rehabilitation is recognised as the most important environmental component of the project and the requirements of rehabilitation will be fully integrated with other operational procedures of mine production. The objectives of rehabilitation are to:

- save all topsoil,

- restore all mined areas to landforms which are compatible with the surrounding terrain,

- integrate drainage from the restored landforms with regional drainage systems,

- cover the restored landforms with the original topsoil,

- establish permanent pastures on the private property,

- establish groves of trees and individual trees on the pastures for shelter for stock and for local and regional landscaping purposes,

- stabilize the restored landforms in the State Forest with native vegetation and re-establish the aesthetic and conservation values attached to the State Forest, and

- establish plant species which are not readily susceptible to dieback and which will be compatible with the vegetation of the surrounding landscape.

The mining will remove about 7% by weight, or about 4% by volume, of the material which will be available for landform restoration. Initially there will be a swell factor of up to 10% which will more than compensate for this loss, but as settling of the new landforms proceeds with time, there will be a small shortfall. This will be considered during landform restoration by deepening the reformed lakes and marginally lowering the sand dunes, so that the rehabilitated land will be similar to the surrounding landscape.

Landform restoration will be undertaken on a continuous basis with vegetation being established during the winter months. The post mining landforms will closely resemble pre-mining landforms, except that the lakes will be deepened to provide an all year round supply of stockwater. This will be done at the request of the landowners.

Landforms which are restored for pasture establishment will be fertilised initially in April to May with 400kg per hectare of superphosphate complete with trace elements and 400kg per hectare of a NPK fertilizer. The need for potassium will be assessed on the basis of soil analysis and inspection of pasture growth. These landforms will then be seeded in April-May with a mixture of clovers and pasture grasses with the final selection of species being undertaken in consultation with the landowner and the Department of Agriculture.

In the subsequent three years the pastures will be fertilised with 200kg per hectare of superphosphate. This rate of application will be re-assessed regularly, and if it is considered appropriate to use slow release mixtures of

superphosphate and rockphosphate, then these will be used to minimise the leaching of plant nutrients into the groundwater.

Pastures will be grazed lightly in the first three years of rehabilitation and weeds will be controlled on a needs basis. The object will be to establish permanent pastures which will be based on clovers, and only subterranean clover varieties with a low oestrogen content will be sown.

On the restored farmland it is planned to establish about three times as many trees as were present prior to mining, and only tree species which are compatible with species already growing in the area will be selected. Trees will be protected from livestock by fencing until they are sufficiently mature.

Seedlings of suitable tree species will be selected and established under contract in a commercial nursery. There will be no on-site nursery, although there will be a temporary facility for the handling of tree seedlings as they arrive on site.

Trees will be planted as seedlings in the first year of the rehabilitation programme. Some seedlings for planting on foothill slopes will be raised in tubes of 0.5m length and slightly less than 50mm in diameter, and they will be planted out immediately after the roots become visible at the bottom of the tube. At that time the foliage of the seedlings are not expected to be more than about 10cm in height. The tubes are placed into augured holes of 50mm diameter and 0.5m depth, and their immediate surroundings are kept free of pasture species.

Experience with this method has shown that seedlings develop rapidly and their survival rate is very good. Planting of seedlings into restored pasture areas will be done each year in May and June during wet weather.

The planting of all trees will be undertaken according to a carefully designed landscaping programme, with due consideration being given to the need for shelter for stock.

In the State Forest the principal vegetation types which will be affected by the mining include Jarrah Low Forest, Jarrah-Banksia Low Woodland, Blackbutt Open Low Woodland and to a lesser extent swamp thickets, scrub, heath and sedgeland.

The establishment of vegetation on reformed foothill slopes will be based on replanting and seeding species which are currently present in Marri-Blackbutt Forest and Jarrah Low Forest.

In the lowland areas more emphasis will be given to common and dominant representatives of the existing vegetation by the direct relocation of topsoil, supplementary seeding and hand planting of seedlings. This will restore vegetation which in height,

structure and cover will be similar to that of the pre-mining vegetation in the area.

Vegetation in the State Forest will initially be re-established by hand planting of select overstorey and groundcover plant species to provide for a rapid establishment of vegetation which will stabilise the restored landforms. This will be supplemented by hand seeding. All seed will be collected locally to preserve the local gene pool, and similarly only plants will be planted which have been raised from locally collected seed and cuttings. A diversity of species will become established with time, and experience suggests that it will originate mainly from seed stored in the topsoil.

In the State Forest, depending on rainfall, planting and seeding will commence in May of each year and continue to about mid August, and it is anticipated that the bulk of the planting and seeding will be completed by the beginning of July.

Each planted seedling will be fertilized with a 60g tablet of an NPK fertilizer, complete with trace elements, which will be placed at the time of planting some 10cm to the side of the seedling and to a depth of about 5cm. In addition, the entire area will be fertilized with a once only application of 400kg of superphosphate per hectare. No nitrogenous fertilizers will be used to avoid stimulating the growth of grasses and weeds.

Weeds will be eradicated regularly by spot spraying and by mechanical means, and a policy of fire prevention will be carefully maintained.

The establishing vegetation will be inspected regularly to assess the progress of establishment and to determine the need for additional planting, seeding and weed control.

A number of endpoints have been defined for the rehabilitation of mined land in the State Forest. Rehabilitation in the State Forest will be considered to have been completed when monitoring demonstrates that all of these endpoints have been attained. These endpoints are as follows:

- perennial plants have survived two seasons and there are no reasons to believe that they will not continue to grow,

- in each vegetation type the above perennial plants are present at densities which resemble pre-mining densities. This will be measured in terms of numbers of plants per 20 square m,

- future overstorey plants have survived two seasons at densities which are at least twice the pre-mining densities of mature overstorey plants in similar vegetation types to

allow for natural thinning. This will be measured in terms of the number of plants per 100 square m,

- understorey plants have established adequate ground protection to prevent erosion. This will consist of annual and perennial plants, and the densities will be measured in terms of the number of species which are present in 10 square m and in terms of the percentage of groundcover within the same 10 square m,

- the future overstorey of each vegetation type has the desired diversity of common species, and

- monitoring indicates that stable landforms have been established and that the establishing vegetation is becoming self perpetuating.

The vegetation in the State Forest is expected to be well established after three to five years. This establishment will be monitored during the spring and autumn of each year to provide a sound record of rehabilitation progress and to complement observations recorded throughout the year. The results will be presented to the Department of Mines in annual reports.

Cable Sands will retain responsibility for rehabilitation within the State Forest at Jangardup until the defined endpoints for the establishment of native vegetation on the restored landforms have been reached to the satisfaction of the Department of Mines and CALM.

Mining is scheduled to be completed by mid 1999, and by that time the rehabilitation of the State Forest is expected be in its fourth year while the total rehabilitation of pasture is expected to be completed late in the year 2002.

4.4 Transportation of Heavy Minerals Concentrate from Jangardup to Bunbury

4.4.1 Transport requirements

There is a need to transport 271,000 tonnes of Heavy Minerals Concentrate per year from Jangardup to Cable Sands' Secondary Separation Plant in Bunbury. The alternative is to construct a new Secondary Separation Plant at Jangardup or nearby and to export the final products via a new port along the south or south-west coast. This option was considered but it was dismissed on the basis of being too expensive because of the duplication of existing infrastructure and the short mine life of less than eight years. Similarly, operating a Secondary Separation Plant at Jangardup and transporting the final products to Bunbury for export was dismissed on the basis of costs. This latter option would decrease by only 4% the need for transportation to Bunbury.

There are a number of road and road/rail options, and these were considered in relation to costs, environmental and social impacts and the requirements of all bodies controlling transportation or having a major interest in transportation. This included the Shires of Nannup, Busselton-Margaret River and Capel, the City of Bunbury, the Department of Main Roads and Westrail.

The existence of mineral sands on the Scott River Plain to the west of Jangardup was announced recently by the Broken Hill Proprietary Company Ltd (BHP). Discussions were initiated with BHP to investigate the potential for Cable Sands and BHP to share infrastructure associated with transportation. At this stage it is too early to consider any joint development and sharing of transportation infrastructure since the BHP project is still at an exploration stage and it is awaiting a detailed feasibility study. The outcome of these investigations are uncertain, and any dependence by Cable Sands on BHP's feasibility studies will delay the Jangardup project by at least three years. Furthermore, BHP may not decide to transport products to Bunbury because the option of exporting via a new port may be an attractive option in view of BHP not owning any existing infrastructure in Bunbury for the separation of Heavy Minerals Concentrate or for export of the products.

Transport costs are the greatest single cost of the Jangardup project and they have been assessed in detail. Following a detailed analysis of the options and their costs, Cable Sands decided on a method of transportation and on a transport route on the basis of:

- availability of an extensive road and highway system that will meet Cable Sands' specifications,

- minimal environmental and social impact. The use of existing roads and highways minimises the environmental damage which is associated with the construction of new roads,

- maintenance costs must remain reasonable, and

- other costs, this includes the initial capital outlay and the subsequent remedial maintenance costs.

The proposed transport method, transport route and costs are discussed here together with the options which were considered and eliminated.

4.4.2 Proposed transportation method and route

The Heavy Minerals Concentrate will be trucked from the mine site to Bunbury in eight-wheeled trucks, each with a dog trailer on dual axles and capable of carrying a load of 38 tonnes. Trucking will be 13 hours per day, only on weekdays and for 52

weeks per year. On average, a total of 28 loads will be transported per day for the life of the operation. This may be decreased to 25 loads per day if permission is obtained to carry payloads of 42 tonnes using dog trailers with triaxles. This option is also cheaper and is being pursued by Cable Sands who currently are only permitted to use the trucks with payloads of 38 tonnes.

The transport route is (Figure 22):

- 5km from the mine site to Black Point Road. This road will be constructed and maintained by Cable Sands for the life of the operation. The road will be constructed from crushed sandstone and gravel, and it will be on private property and on an existing road reserve.

- 8km along Black Point Road to Stewart Road.

- 7km along Stewart Road to the Vasse Highway.

- 35km along Vasse Highway to Nannup.

- 56km along Vasse Highway from Nannup to Bussell Highway.

- 50km along Bussell Highway to Bunbury.

Black Point and Stewart Roads have gravel surfaces. These will be upgraded and maintained by the Shire of Nannup in conjunction with Cable Sands' to a standard which will meet the trucking requirement.

Cable Sands will commit the initial capital to upgrade the relevant portions of Black Point and Stewart Roads. In addition, the Company could spend up to $150,000 per annum on a maintenance contract with the Shire of Nannup.

Cable Sands will review these methods and routes if circumstances change substantially, such as may be the case if BHP should develop its proposed mine. For the immediate future the method and route described here remain firmly as Cable Sands' selected option.

4.4.3 Transport options which were considered

4.4.3.1 Access to the Jangardup deposit

Access to the mine site could have been from the east via Jangardup Road. This is a longer route than via Black Point Road to the west and it would have required the construction of a new road through or around the State Forest. This option was dismissed on the basis of environmental impact.

4.4.3.2 Rail option

There are a number of road and road/rail options for carrying the concentrate from Black Point Road to North Shore in Bunbury. These are shown in Table 14 and in Figure 23. Alternative road and rail routes were considered by Cable Sands relative to a haulage requirement using trucks with a payload of 38 tonnes.

The nearest rail loading terminal is Jardee, which is 5km to the south of Manjimup. The terminal is 70km from the proposed mine via Coronation, Davidson and Graphite Roads and the South Western Highway to Jardee. A more direct 65km route is via Seven Day Road.

A major cost in all road and rail options is the requirement for double handling at Jardee, because there is no rail-only option. Cable Sands has evaluated the cost per tonne of railing the concentrate from Jardee after trucking via Coronation and Graphite Roads, or alternatively trucking via a road which would need to be constructed across Crown Land. The cost of transporting the Heavy Minerals Concentrate via these two routes is estimated to be respectively, $17.18 and $19.33 per tonne. These costs are well in excess of those for road transport and consequently this option was eliminated on the basis of costs. A further consideration in the elimination of this option was that it was not sufficiently flexible to meet the requirements for the Jangardup project and likely future expansions by Cable Sands.

4.4.3.3 Method of trucking

A number of options with respect to the capacity of trucks were considered. These included conventional semi-trailers with payloads of 23 tonnes, eight-wheeled trucks with a dog trailer on dual axles or on triaxles. To meet the transport requirement a conventional semi trailer with a 23 tonnes payload would need to carry 46 loads on a 24 hours per day, weekdays only, and 52 weeks per year basis. By comparison, an eight-wheeled truck with a dual axle dog trailer and a payload of 38 tonnes will on average transport the same volume in 28 loads in 13 hours per day. The use of a triaxle dog trailer with a payload of 42 tonnes will reduce this to 25 loads per day, and decrease the transportation costs by $0.51 from $10.35 to $9.84 per tonne.

The Main Roads Department assessed Cable Sands' overall transport requirements and options and preferred the combination which allows a 42 tonnes load to be evenly distributed through a triaxle on the first trailer behind the prime mover. These units, being bottom dumpers, cannot tip wet heavy minerals, but a similar tipping combination with a triaxle tip trailer fixed to an eight wheeled truck can be used. This combination meets all of the regulatory requirements of the Main Roads Department. It has an overall combination mass of 64 tonnes, a payload of 42 tonnes, and a triaxle trailer of 17.5m in length.

The preferred method of transporting Heavy Minerals Concentrate to Bunbury is by means of the combination of an eight-wheeled truck with a triaxle trailer. Cable Sands will apply for a permit to use the 42 tonne payloads and if this permit is not obtained, then Cable Sands will use the option of 38 tonnes payloads which is currently used by Cable Sands in the south-west of Western Australia.

4.4.3.4 Road transport routes

The costs for the different routes are based on payloads of 38 tonnes.

The two least expensive road options estimate trucking to be $10.35 per tonne using major public roads via the Vasse and Bussell Highways, and $10.12 per tonne using the most direct roads via the Vasse Highway, Hithergreen Road to Ludlow and the Bussell Highway to Bunbury. This latter option is not feasible because the Hithergreen Road link is not of a sufficiently high standard to withstand an average of 56 truck journeys per day for five days a week and 52 weeks per year without major damage. Consequently, the first option at $10.35 per tonne is the cheapest. The other road options are all more expensive and in excess of $12 per tonne. It should be noted that every increase of 10 cents per tonne in transportation adds a cost of $200,000 over the life of the project. These other road options are by Sue's Road then Acton Park Road or Sabina Road, or along the Vasse and Bussell Highways and returning empty via Sue's Road. All of the options via Sue's Road were rejected by Cable Sands on the basis of being too expensive due to the high costs required for the initial upgrading and especially the high annual maintenance costs of operating on gravel roads.

The operating cost of $10.35 per tonne for Cable Sands' selected option is based on 1988/89 dollars, and has been derived from the following components in dollars per tonne: capital $2.67, labour $2.24, fuel $1.70, tyres $1.71, maintenance $0.43, registration and insurance $0.25, permit $0.20, administration $0.12, loading $0.25 and nominal profit $0.25. The remainder of the costs are capital requirements for the upgrading of roads and, where applicable, road remedial maintenance costs.

4.4.3.5 Shire of Nannup and the town of Nannup

Following the discovery of the Jangardup deposit, Cable Sands met the Council of the Shire of Nannup and advised them of the Company's conceptual plans regarding the development at Jangardup.

Following a subsequent meeting with the Council in January 1988, Cable Sands advised the Council, in February 1988, of its preferred route for the trucking of the Heavy Minerals Concentrate so that formal approaches could be made to the State

Government for additional expenditure which would permit the bypassing of Nannup.

The Council's preferred route was to bypass Nannup.

In April 1988, following an Annual General Meeting of Electors in the Shire of Nannup, a decision was made to discuss Cable Sands' proposed trucking route at a public meeting which was subsequently held on 31 May 1988. Representatives from Cable Sands addressed the meeting and answered questions.

It is Cable Sands' perception that sections of the population of Nannup are concerned that the proposed mining operations will affect Nannup's quiet lifestyle, have an adverse impact on the tourist industry and its potential, and endanger the safety of school children. The Company also believes that most residents are not opposed to the project, but that they would prefer, if possible, that Cable Sands bypasses Nannup either by using Sue's Road or by using a bypass around the town.

Cable Sands has considered using Sue's Road. This would need major upgrading to a seal equivalent, with entire sections being recrowned and many drains being installed along Stewart, Sue's, and Sabina Roads. A 60km stretch of gravel roads from the junction of Black Point and Stewart Roads to the Vasse Highway would cost $3.3 million to upgrade and to seal. If this gravel component is not sealed Cable Sands estimates that it will cost $155,000 per annum for road maintenance to keep the road open and to prevent undue wear and tear to trucks. If the Acton Park Road alternative is taken, there would be an additional requirement of $25,000 for remedial road maintenance to the Shire of Busselton. This increases the trucking costs to greater than $12.00 per tonne. If Stewart, Sue's and Sabina Roads are sealed, Cable Sands is still not prepared to use this route as it is 20km longer than the Vasse-Bussell Highway route through Nannup and it would add at least $300,000 per year onto Cable Sands' operating costs or $2.4 million over the life of the project.

There are three alternative routes to bypass the town centre of Nannup, namely:

- **Deans Road bypass**

  This route bypasses the town of Nannup totally. It leaves the Vasse Highway at Middle Street, crosses the Blackwood River at an old timber bridge which was once used by trams, and returns to the Vasse Highway via Deans and Barabup Roads. The estimated cost for this bypass is $640,000 of which $450,000 will be required for a new bridge and $190,000 will be required for the upgrading and construction of new roads. This bypass will increase the trucking distance by 3km.

- **Railway easement bypass**

  This bypasses only the town centre via a ring road which includes Terry Street, 300m of the old Westrail easement and Brockman Street. The estimated cost is $170,000, which includes $10,000 for the construction of the Terry Street entry, $30,000 for a drain in Terry Street, $120,000 for a sealed road along the existing railway easement, and $10,000 for the construction of a cul de sac for Brockman and Jepson Streets.

- **Railway easement bypass and railway bridge**

  This also bypasses only the town centre. It is via Terry Street, the Westrail easement and Brockman Road, but continues along the old rail line and crosses the Blackwood River on the disused railway bridge and on to Vasse Highway. The estimated cost is $480,000 including $170,000 for the bypass of the Terry Street-Railway easement, $300,000 for upgrading the bridge and $10,000 to construct the entry to Vasse Highway.

Of the three options to avoid the centre of Nannup, the Deans Road bypass is the most effective in that it bypasses the town completely. The cost of $640,000 adds an extra $0.33 per tonne to the trucking of Heavy Minerals Concentrate over the life of the project. The extra trucking distance adds another $0.18 per tonne which is $350,000 over the life of the project. The capital expenditure cannot be justified given the small population of Nannup, the less than eight year life of the mine, and the existence of other major road users such as log trucks, the trucking of timber for the silicon smelter at Kemerton and other heavy haulage users.

The other options are cheaper but less effective, with one option dividing the town and the other relying on an old wooden railbridge of uncertain strength.

Cable Sands prefers to use the main street in Nannup with suitable speed constraints rather than the bypasses, but the Company would use any bypass in the event that one is constructed.

4.5 Gravel requirements for road construction and maintenance

Maintenance of the sections of Black Point and Stewart Roads used by Cable Sands will be funded by Cable Sands in conjunction with the Shire of Nannup with work being carried out by that Shire. The gravel for this work will come from existing sources under the control of the Shire.

Some gravel will also be required by Cable Sands for internal roads within the mine. Gravel for this work will come from new pits which will be opened in State Forest and will be held as mining leases by Cable Sands. If necessary, this gravel could be used to supplement the requirements of the Shire of Nannup.

4.6 Infrastructure and services

4.6.1 Introduction

The area proposed for mining is remote and the landuse is primarily rural with no houses. Limited facilities are available and Cable Sands will have to provide the necessary infrastructure and services.

4.6.2 Water supply

A single deep bore into the Yarragadee aquifer will provide water for the mining operations and for domestic purposes. The bore is 184m deep and 200mm in diameter. An application for a permit for such a bore was submitted to the Water Authority of Western Australia who subsequently advised Cable Sands that a permit was not required for the area.

4.6.3 Electricity

The project area is too remote to be connected readily into the State Energy Commission's grid and the existing local grid is insufficient to supply the power needed by the mine. The upgrading of the electricity grid to the mine is expensive and will have a long delay in construction. Consequently, power will be provided on site from diesel generators, generating at 415 Volts, 3 phase and 50 Hertz. The generators will be housed in a generator room with a separate switch room and the power will be reticulated throughout the site as necessary. All electrical work will be undertaken by appropriately qualified and licensed personnel.

Cable Sands would prefer to use power from the SEC grid, and should such power become available it will be used by the Company.

4.6.4 Communications

Telecommunications will be established via a satellite system.

4.6.5 Waste disposal

All organic waste will be buried in the mine pit. All steel, timber and other structural waste will be removed from the mine site and taken to an approved disposal site. No oil, petrol or diesel wastes will be disposed of on site. All waste oil will be placed in drums and sold for recycling. Other wastes from the

workshop, such as fuel and oil filters, will be stored in drums and taken to a suitable place for disposal. No chemicals are used in the operations and consequently there are no disposal problems. Fuel tanks will be surrounded by embankments according to standard specifications for the purpose of preventing any spread of fuel in the case of spillages.

4.6.6 Fire prevention

A policy of fire prevention during mining and rehabilitation operations will be carefully maintained.

4.6.7 On-site facilities and assembly

The following facilities will be assembled on site:

- site office,
- store for spare parts and materials,
- meal area and ablution block for employees,
- generators and power distribution facilities,
- small laboratory for production control,
- satellite dish for telephone,
- workshop for mechanical repairs,
- workshop for general repairs and maintenance,
- electrical service building,
- fuel and oil storage,
- six houses for staff who need to be called out for urgent maintenance and therefore cannot live away from the mine site, and
- six transportable units for short-term visitors or temporary workers, with self-contained facilities.

The office, workshops, store, crib room, change room, vehicle and equipment sheds, will be mounted on skids and travel close to one of the dredges, probably Dredge-1.

The large equipment used for mining will be built elsewhere in modular form and transported to the site for final assembly.

The other facilities will be either transportable units or designed to be erected on site but able to be dismantled and removed on completion of mining.

The assembly work-force will be housed in a temporary camp which was previously used for exploration. This camp consists of caravans, a water bore, portable generators, transportable units for messing, ablution facilities and sheds.

Internal roads will be built progressively on a needs basis.

4.7 Work-force

The project will require a work-force on site of 50 full time employees, all in new jobs. Six of these employees will be required for senior supervision and to attend to urgent repairs. These will be housed on site. All other employees will be expected to find their own accommodation.

Many of the employees are expected to be recruited from the Shires of Nannup and Manjimup, and are likely to have housing in the region. Additional housing will be required and Cable Sands has requested Homeswest to build 12 houses for married people in Nannup. Cable Sands also has a need for six single caravans at Nannup.

Employees will be expected to make their own arrangements for accommodation and transportation to site.

There will also be a need for 27 directly employed contractors such as cartage contractors, contract service personnel and short-term workers for specific purposes.

The dredges and the Primary Separation Plant will operate three shifts a day, seven days a week, with some of the employees working only on the day shift.

4.8 Public access to the site

It will be necessary to restrict access to the mine site for public safety by fencing and appropriate sign posting.

4.9 Decommissioning

At the end of the operations, all facilities except for the access road and the bore will be removed from the site. There will be developed pasture on the private property complete with shelter belts, fences and water points. There will be native vegetation on the restored State Forest. Rehabilitation will not be completed until these objectives have been met.

Once the vegetation has become fully developed there will be no obvious signs that mining has taken place.

5.0 ENVIRONMENTAL AND SOCIAL IMPACTS AND MANAGEMENT

5.1 Mining and separation operations

The operations involve well established processes. The dredging method is being used by Cable Sands at its operations in Minninup while the separation processes have been used in all of Cable Sands operations. These operations have no potential for any chemical pollution as no chemicals are used in any of the operational steps.

Mining is a short-term landuse, with the long-term landuses of the area being returned on completion of mining.

Environmental management will be an important component of the overall management policy for this project, and together with appropriate engineering design, environmental management will ensure that the operation is undertaken in an environmentally sound and cost efficient manner. The important environmental components of the overall management policy are rehabilitation, water resources, transportation, employment and the local economy, the biological and social values of State Forest 58, and impacts on the D'Entrecasteaux National Park.

The environmental consulting Company, W G Martinick and Associates Pty Ltd, will be engaged to overview the rehabilitation programme and other environmental issues. This Company has been retained by Cable Sands since 1981 as environmental consultants and together with Cable Sands has developed considerable expertise in land rehabilitation during and following the mining of heavy minerals on farmland as well as areas with native vegetation.

5.2 Rehabilitation

Rehabilitation is identified as the major environmental issue and as such it will receive high priority in the management of the overall operations.

The sound rehabilitation of mined areas will ensure that the disturbances of the mined landforms and their current landuses are temporary, by restoring the mined areas approximately to their pre-mining landforms and by stabilising these landforms with vegetation which will resemble the pre-mining vegetation.

Rehabilitation is regarded as an integral component of mine production and as such it will be fully integrated with production procedures. Rehabilitation and its integration with production is described in section 4.3.

In the event that for whatever reasons the operations are closed down temporarily by Cable Sands before completion of mining, all

bare surfaces will be stabilised with vegetation and the overall rehabilitation programme will continue.

5.3 Hydrology

5.3.1 Introduction

An investigation by Rockwater Pty Ltd to determine the impact of mining on groundwater included an assessment of the following aspects:

- pumping from the Yarragadee Formation,
- lowering water levels of the shallow aquifer by up to 6 metres, and
- comment on the disposal of excess water.

5.3.2 Test pumping of the Yarragadee Formation

A test bore, Bore J1, was pumped at a constant rate of 1,000 cubic m/day for 24 hours on 8 February 1989. The water level was lowered by 13.2m in the first minute of pumping, and after five minutes it was lowered by 28m. The rate of drawdown then declined as seepage from other sections of the Yarragadee Formation almost equaled the rate of pumping. From 50 minutes onwards the drawdown continued to range from 33.2m to 35.1m, for the remainder of the test. There were some fluctuations but these were attributable to minor variations in the pumping rate or due to seepage.

The capacity of the bore is uncertain, as it is difficult to extrapolate the results of a pumping test where a large portion of the yield is derived from inter-aquifer seepage. The bore is probably very capable of long-term pumping at a rate of 2,300 cubic m/day or more, subject to the water level being monitored at the higher rates of pumping. Such pumping will have no long-term impact on the total water resource of the region because of the vastness of this resource and the relatively small volume of water which will be extracted.

The heads of the shallow aquifer in the eastern area near the ridge of basalt are about 6m above the heads in the underlying Yarragadee Formation. Consequently, there will be little or no upward flow of water from the Yarragadee Formation into the dredge pond when the water level in the dredge pond is drawn down by up to 6 metres.

5.3.3 Simulation of dewatering

The planned lowering of the watertable during mining was simulated by setting the heads over an area of 200m x 100m to 6m below the static water level, and calculating inflows to, and

drawdowns around, the excavation at various times. Two cases were simulated:

- an undisturbed state of recharge minus evapotranspiration losses for calibration of the model, and

- a situation that assumed a rainfall recharge of at least 15% over the area where there were drawdowns of greater than 0.1m. This is considered to be the most realistic case, as drawdowns around the dredge pond and the sandstone excavations will induce additional recharge in areas where recharge was previously rejected.

The actual inflows may be less than those calculated if the dredge pond is partially sealed by clays on the walls and the floor of the pond. Practical experience with similar dredging operations, as at Minninup, suggests that this will be the case.

Average inflow rates to the dredge pond as calculated by the model are:

CALCULATED INFLOWS TO DREDGE POND

TIME PERIOD	INFLOW (CUBIC m/DAY) CASE (1) RECHARGE	CASE (2) RECHARGE
0 - 40 days	2870	2930
40 - 95 days	2330	2460
95 - 180 days	2090	2280

These results indicate that inflow rates are likely to be between 2,000 and 3,000 cubic m/day, and that the rates are relatively insensitive to the adopted values of recharge. Inflow rates after 180 days should be similar to those calculated for 95 - 180 days, because hydraulic gradients will be maintained by the movement of the dredge pond. This inflow will not come from the Yarragadee Formation.

Heads calculated by the model indicate that after six months of dewatering, the drawdowns towards the D'Entrecasteaux National Park, will be as shown below. It is expected that additional recharge will be induced around the dredge ponds, and that this will decrease drawdowns, and Case (2) in the table below is the more relevant. These results suggest that the drawdowns around

the pond will be less than normal seasonal variations at distances of about 1km from the dredge pond (Figure 24)

CALCULATED DRAWDOWNS AROUND DREDGE POND

DISTANCE FROM POND (m)	CALCULATED DRAWDOWN AFTER 180 DAYS (m)			
	CASE 1		CASE 2	
	TO SOUTH	TO WEST	TO SOUTH	TO WEST
100	ND*	3.8	ND	3.6
200	2.5	ND	2.1	ND
600	1.1	1.1	0.6	0.7
1,700	0.2	0.2	0.01	0.02

* = not determined

The drawdown is comparable to the annual fluctuation in the watertable, except very close to the dredge pond where the drawdown will be up to 6m. When the dredge pond is in the south-east part of the orebody, close to the D'Entrecasteaux National Park, the area of discernible watertable drawdown will extend into the Park. The calculated drawdown in the adjoining D'Entrecasteaux National Park is, in fact, an over-estimate because the ground and water contours drop to the south-west. It is unlikely that such a drawdown will affect the vegetation in the D'Entrecasteaux National Park, but the mine path has been designed so that the dredging near to the D'Entrecasteaux National Park will not take place in the dry season of January to April unless the water level can be raised and the dredge is still able to operate with this depth. During other times of the year the rainfall will be sufficient to ensure plant survival during any drawdown.

The dry treatment of the sandstone in the area adjacent to the D'Entrecasteaux National Park will also be carried out during the wetter months, and the excavation will be flooded again if it is not mined before summer.

5.3.4 Chemical properties of the shallow and deep aquifers

It is planned to pump water from the Yarragadee Formation (Bore J1) to maintain the water level in the dredge pond at times when

water losses exceed inflows to the pond. The ion concentrations in water from the Yarragadee Formation are very similar to those in water from the shallow aquifer, and the pH of the water is also the same as for the deeper part of the shallow aquifer. Pumping water from the Yarragadee Formation into the dredge pond will, therefore, have no effect on the quality of the shallow groundwater.

The water of the operational circuit will be of a quality which is similar to that of water being abstracted from the Yarragadee Formation. Hence the seepage of water from the operational circuit to the groundwater regime will not affect the quality of this groundwater.

5.3.5 Disposal of excess water

The larger of the two seasonal lakes on and adjacent to the Jangardup deposit could be used for water storage and disposal. The hydrology of the lake was investigated to determine its capacity for additional storage or disposal of water.

In an average year, water could be stored or disposed of in the lake during the summer months, however the capacity for storage or disposal is only about 7,200 cubic m/yr, and summer is not the period when the need for maximum disposal is necessary. The pond is, therefore, not suitable for the storage of excess water for the summer, but will be used for the settlement of suspended clay prior to discharge from the site.

The most practicable means of disposing of the excess water during winter is to allow it to drain away naturally and to mix with the existing surface drainage, after the removal of suspended clay particles by settling in the settling ponds. The natural run off from the farmland due to the excess of rainfall over evaporation is estimated to be as high as 174,000 cubic m/day in July. The addition of 2,000 cubic m/day of seepage of good quality water from the mining operation is a relatively small contribution and it will have no adverse impact.

In some areas where the sandstone is at shallow depth or absent, it will not be necessary to lower groundwater levels. This is particularly so if mining of these areas coincides with dry periods. Water losses will probably exceed inflows to the dredge pond and make-up water will need to be pumped from the bore in the Yarragadee Formation.

5.3.6 Proposed monitoring programme

A monitoring programme will be established to measure changes in:

- groundwater levels,
- quality of groundwater, and

- quality of surface water.

This information will be collated into an annual report which will be made available to the Authorities on request. This report will identify any trends of likely changes in water levels or quality, compare these trends with expected changes, draw attention specifically to the possible development of unacceptable changes, and recommend any actions to avoid harmful changes to the hydrology of the area.

Details of this programme are as follows:

- Water levels will continue to be measured at monthly intervals in all of the piezometers, the shallow bore (CS3) and the bore into the Yarragadee Formation (J1). Piezometers that are within the orebody, will be replaced by piezometers in adjoining areas as the original piezometers are overtaken by mining. The overlap period between the old and new piezometers will be as long as possible to enable reasonable correlation between the behavior of groundwater in the replacement and old piezometers.

- Water samples will continue to be obtained at monthly intervals from all of the piezometers, the shallow bore (CS3) and the bore into the Yarragadee Formation (J1) and analysed for salinity. Salinity will be determined as total dissolved solids and this will be calculated from the electrical conductivity. These measurements will begin as soon as possible to determine the magnitude of seasonal variations and any existing trends which result from activities other than mining. After the range of normal variations and the effects of mining have been monitored for two years, it may be possible to reduce the frequency of these measurements to once every three months.

- The electrical conductivity will be measured at monthly intervals in water samples obtained from a number of small tributaries of an unnamed stream which discharges into flats to the north of Lake Quitjup in the D'Entrecasteaux National Park. These diffuse drainage lines have very low gradients, they are not permanent, and their courses are poorly defined.

- The suspended clay content will be measured monthly in the above drainage lines. All field staff will be instructed to report immediately any evidence of clay deposition or erosion in the area.

- All of the major ions will be measured once a year in samples of water obtained from all of the above sample sites. This frequency will be increased if any substantial variations of electrical conductivity are observed in the monthly monitoring programme.

This monitoring programme will be reviewed if there is any substantial change in the quality of surface or groundwater, or if the water levels are drawn down by substantially more than expected.

5.4 Landscape, vegetation, flora and fauna

All of the landforms which will be affected are common and widespread in the region and they do not support unique vegetation, flora or fauna. The mining proposal will thus not result in the destruction of landforms, vegetation, flora or fauna which is rare or of outstanding scenic, botanical or zoological importance.

There will be a temporary loss of production from the pastures, but the property owner will be compensated for this. In the State Forest all vegetation and fauna will be removed from 30ha, but this will be re-established after successful rehabilitation. The adjoining D'Entrecasteaux National Park will not be affected by the operations.

The restoration will result in a new soil profile in the pasture areas which in areas where additional clay will be incorporated in the surface of the profile will be superior to the pre-mining profile. This is because the new soil in these areas will have a more favourable moisture retention potential in its upper horizons. This will extend the growth season into the summer and provide additional grazing during this critical period.

There are no unusual or unique conservation values attached to the area that will be mined. Nevertheless, the need to restore landforms which will resemble those prior to mining, and their stabilisation with pastures on the private land and with native vegetation in the State Forest is identified as a major aim of environmental management. On completion of rehabilitation it is expected that most of the displaced fauna will recolonise in the restored and vegetated landforms of the State Forest.

5.5 Radiation management

The radiation levels on the surface of the rehabilitated areas will be similar to, or slightly less than, those measured before mining because the topsoil will be replaced and the monazite will have been removed.

The radiation rates associated with the Heavy Minerals Concentrate are low and they will present no operational or environmental problems. The handling of these materials is controlled under the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1987). Cable Sands will observe this Code and will also undertake all of the necessary monitoring and precautions as directed by the authorities.

5.6 Noise and dust

The operations are remote and there are no residents within several kilometers of the proposed operations. Consequently the noise from the operations will not be a public problem.

There will be some noise from the plant and earth-moving machinery, but the work-force which is exposed to this noise will be protected from operational noise levels by the wearing of appropriate protective equipment and by operating enclosed machinery.

The noisiest components of the stationary machinery will be the diesel generators. These will be contained within the power house and they are sufficiently removed from the operations not present a noise problem to the workforce.

Dust will not be a problem as the operations are in a high rainfall area and mining will be by dredging which does not present any dust problems. Dust may be expected during the summer when scrapers are stripping topsoil. This will be confined to a small area and it will not be a problem. The establishment of vegetation on restored landforms will control any potential dust problems from these areas.

5.7 Transporting Heavy Minerals Concentrate to Bunbury

A traffic survey in September 1987 by the Main Roads Department showed the daily movement of vehicles both ways along Vasse Highway to be 472 vehicles on the northern side of the town, and 680 vehicles on the southern side.

The results from the September survey are probably typical of the normal domestic and commercial traffic for Nannup, but are outside of the main tourist season and therefore less than the true annual average.

The values for total traffic must be adjusted upwards to include tourism if they are to be used to estimate the annual traffic volume. In this ERMP no such increase has been included in estimating the impact of trucking on the traffic along Vasse Highway through Nannup to the Bussell Highway. Consequently, the impacts prescribed in this ERMP are greater than will actually occur.

Further, it is important to note that the heavy haulage as observed in September 1987 was mainly associated with timber haulage. This heavy haulage traffic will be further increased substantially by an additional haulage contract for transporting wood from Nannup Mill via Vasse Highway to the silicon smelter in Kemerton.

The town of Nannup is accustomed to heavy haulage and this is to be expected as Nannup is an important centre for the timber and agricultural industries of the region. The scheduling of trucks for the Jangardup project was designed on the basis of costs, minimising the impact on traffic in the town of Nannup and maximising local employment opportunities.

There will be an average of 28 truck journeys from the mine to Bunbury per weekday and a similar number of return journeys, giving an average total of 56 truck journeys per weekday. The trucks are expected to cover the 161km road distance from the mine site to Bunbury at an average speed of 60km/hour, resulting in a 2 hour 40 minute journey. This will be done over a 13 hours day, and usually for five days per week.

Seven trucks will be used exclusively for transporting Heavy Minerals Concentrate from Jangardup to Bunbury and they will each transport two loads per day. These seven trucks will be split into fleets of four and three and they will start each day fully loaded from Jangardup at 6.00am or commence empty from Bunbury between 5.00am to 6.00am. There will be a requirement for a further fourteen truck journeys per weekday. This is likely to be undertaken by a fleet of fourteen trucks which will carry only one load each per weekday from Jangardup to Bunbury, with the balance of the day or night being used to transport Heavy Minerals Concentrate to Bunbury from Cable Sands' other four mine sites. Part of this fleet of trucks is likely to be based in Nannup to maximise job opportunities in the Shire of Nannup. Some of these Nannup based trucks will then be required to make two journeys between Jangardup and Bunbury.

This breaking up of the fleet will minimise convoy formation and will result in all trucks operating through Nannup only between 6.00am and 6.00pm of each weekday.

On average 28 trucks will leave the mine between 6.00am and 6.00pm of each day at average intervals of 22 minutes. This spacing of 22 minutes will be maintained approximately because of the three different truck schedules which will be operating.

The distance from Nannup along Vasse Highway to the Bussell Highway is 56km. Theoretically, at any given time there will be a maximum of three trucks from the mine site on this section of the highway and they will be travelling at intervals of about 20km. A motorist travelling along this road at the same time would need to average 110km per hour to overtake two of these vehicles. This is a worst case situation, as in most instances there will only be two trucks at any given time on this section of the highway and motorists will pass only one before the second truck has reached Bussell Highway without slowing up the motorist who passed the first truck. It is also unlikely that a motorist would be able to maintain a speed of 110km per hour along the highway.

Similarly, any of the 300 motorists who travel daily from the Bussell Highway along Vasse Highway to Nannup, will see five trucks coming the other way. This assumes that the motorist travels at an average speed of 110km per hour. If the motorist travels at an average speed of 60km per hour then he or she will meet four oncoming trucks.

If it is assumed that 80% of the vehicles travelling along Vasse Highway, travel between 6am and 6pm then there are 288 vehicles, or 24 vehicles per hour, travelling north along the Vasse Highway. Travelling at 110km per hour a motorist will see approximately 32 oncoming vehicles. The other way and at 60km per hour a motorist will see 40 vehicles. Cable Sands trucks will increase these visual contacts from 32 vehicles to 36 at a travelling speed of 60km per hour or from 40 to 45 vehicles if the motorist is travelling to Nannup at 110km per hour.

The percentage increase for both instances is 12% and this is not considered to be a major increase in the density of traffic for existing road users.

From the above it is concluded that the trucking from the mine site to Bunbury will have a minimal affect on the traffic flow along Vasse Highway. The traffic along Bussell Highway is substantially greater than along Vasse Highway and the increased traffic due to the trucking from Jangardup will be marginal.

There are a number of sections along the Vasse Highway from Nannup to the Bussell Highway where the traffic flow will be affected because of the lack of safe passing opportunities. This could be overcome by constructing additional passing lanes in select locations along Vasse Highway, and this will be discussed by Cable Sands with the Main Roads Department.

The 35km along Vasse Highway from Stewart Road to Nannup are acknowledged by the Shire of Nannup, the Main Roads Department and Cable Sands as being inadequate for the proposed use. Currently this road is being improved by eliminating narrow sections and some bends so that it will have a uniform width of 6.2 metres. Should this section of Vasse Highway be widened to 7.2 metres then Cable Sands is prepared to contribute seed capital to the value of $30,000 towards this widening which is estimated to cost about $120,000.

The Heavy Minerals Concentrate is very heavy, and usually has a moisture content of 4% to 5%. Should stockpiled Heavy Minerals Concentrate at the mine become dry, then immediately after loading it will be sprayed with water. Internal tarpaulins will then be stretched across the loaded Heavy Minerals Concentrate and the load will remain covered for the entire transportation to Bunbury.

It is a contract requirement by Cable Sands for the transportation of all of its Heavy Minerals Concentrate that it is covered by tarpaulins to prevent the Heavy Minerals Concentrate from drying out and for reducing losses due to wind blowing.

The trucks transporting the Heavy Minerals Concentrate will thus not present a dust problem.

On the September 1987 figures, there will be an increase of about 12% in total traffic. In the town of Nannup there will be a noticeable increase in noise due to trucks. The current noise from logging trucks is accepted by the residents of Nannup because it is based on forest activity which is fundamental to the economy (McFarlane Research Pty Ltd, 1988). Cable Sands considers that the proposed trucking should be considered in a similar light because of the economic benefits to the town.

The Heavy Minerals Concentrate from Jangardup is radioactive material under the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1987), but not under the Transport Code because the level of radiation is low. Consequently, conditions of transport under the Australian Code of Practice for the Safe Transport of Radioactive Substances are not required. Nevertheless, Cable Sands will manage the transportation with respect to radiation issues as directed by the Department of Mines.

The small component of radioactive materials in the Heavy Minerals Concentrate is dispersed in the ilmenite, and the emanation of radiation is low and typically 1-2 microGray per hour. Although radiation rates of the Heavy Minerals Concentrate are above background rates, the potential for additional radiation exposure to the public due to the trucking of Heavy Minerals Concentrate is very small and, in fact, indistinguishable from natural background rates. The Heavy Minerals Concentrate will not escape because the trucks are fully covered to prevent any dust blowing and the Heavy Minerals Concentrate is moist.

Spillage of Heavy Minerals Concentrate from the trucks will not occur because of the high specific gravity of the Heavy Minerals Concentrate which will occupy only 55% of the available storage of the trucks. In the event of a traffic accident all of the spilled Heavy Minerals Concentrate will be removed by Cable Sands or the haulage contractor. A front-end-loader will be used to completely remove the concentrate and, if necessary, additional cleaning by hand will be undertaken until monitoring confirms the absence of any Heavy Minerals Concentrate.

5.8 Dieback

Dieback has already affected most susceptible areas in the mine path on the private property and in the State Forest, as well as in surrounding areas. Mining will not increase the risk of spreading the dieback fungus by water flowing away from the mine because the area is already infected extensively.

There are small areas in the mine path which are not infected. During mining, uninfected topsoil will be separated as far as possible and used for rehabilitation along the edge of uninfected areas in the State Forest. There will be an ongoing programme of monitoring dieback, and all vegetation which is affected by dieback will be replaced by other species.

To prevent the spread of dieback to other uninfected areas in the South-West, trucks transporting the Heavy Minerals Concentrate will be driven only on roads which are raised above surface flood waters, and the trucks will load the Heavy Minerals Concentrate from the stockpile which will be located on high ground.

5.9 Regional environmental and social impacts

The proposed mining will have no long-term environmental impacts which will adversely affect the private property on which the deposit is located, the State Forest or the D'Entrecasteaux National Park. All landforms, soils, vegetation types, flora and fauna are common, widespread and well represented outside of the proposed mining area.

There will be no significant changes to the long-term conservation values of the effected areas of the State Forest. The restoration of the landforms and the establishment of vegetation which is native to the region will re-establish habitats which will be similar to those which existed prior to mining, with differences related to the establishment of plant species that are resistant to dieback. These restored habitats will be colonised by fauna from surrounding areas.

Precautions will be taken to prevent the spread of dieback to uninfected areas outside of the proposed mine site.

There will be a need for new gravel sources for road building and maintenance. Cable will require some gravel for internal road construction, and suitable sources will be negotiated with the Department of Mines and the Department of Conservation and Land Management. The need for and the use of such gravel pits is widely accepted in the region and in Western Australia in general.

At the completion of mining, the plant with all of its ancillary equipment, including offices and ablution blocks, will be dismantled and removed from Jangardup.

The site on which Heavy Minerals Concentrate was stockpiled will be cleaned up, and all concentrate will be transported to Bunbury. The area will be topsoiled, fertilized and sown with vegetation in keeping with the local environment and landuse.

On State land and on private property all roads which will no longer be required by the owners will be ripped, topsoiled and seeded.

There will be no long-term environmental or social impact caused by the rehabilitated mine site.

Cable Sands has agreed to recruit local people wherever possible. Consequently, the mining project at Jangardup will stimulate employment in mining and in related service industries. In 1989 Cable Sands asked in the Warren/Blackwood Times and the Busselton/Margaret River Times, for expressions of interest for services at Jangardup and to date Cable has received responses from 40 businesses in these areas.

A large proportion of the required workforce, including those employed from outside the Shires of Nannup and Manjimup, are expected to move to the area and to stimulate growth in goods and services. Cable Sands intends to house between 12 to 18 employees in Nannup and is holding discussions with the Shire and Homeswest, for additional housing in Nannup. There may also be a need by the Shire of Nannup to employ extra staff to undertake annually $100,000 - $150,000 of road maintenance associated with the Jangardup project. There will be an injection of capital expenditure for the employment of staff and materials to widen the Pemberton to Nannup section of the Vasse Highway, and to upgrade Stewart and Black Point Roads. This does not include the 27 cartage drivers and other contract services to the mine, which will be provided locally. With current exploration results and ongoing exploration it is anticipated that Cable Sands' involvement in the area will be long-term.

The mining operation will have a large economic benefit locally, particularly in Nannup.

The only other review of the economic benefit of the project is the review of the impact on Nannup by MacFarlane Research Pty Ltd (1988). In the report the urgent need for employment is clearly identified, namely: "...small changes in existing employment have significant repercussions in the labour market and the community. For example the proposal to close the CALM nursery means the loss of 9 part-time jobs. In a static local economy alternative employment is unlikely, so unemployment inevitably increases." (page 7), and, "...the economy of Nannup currently relies almost entirely on the hardwood timber industry, which is scheduled to decrease by 22-28% in the Central and Northern Regions by AD 2000. (Timber Production in WA - A Strategy). Nannup's exclusive economic reliance on the timber industry is of concern to the

Shire Council because the industry is tenuous, and wholly dependent on CALM activities." (page 20). Curiously, the report by McFarlane Research comes to the conclusion that, "there will be little economic benefit to the Shire of Nannup from this mining venture", (page 48). This is clearly in conflict with information provided and discussed in the MacFarlane Research report and it is obviously wrong.

Besides negating the positive impact of the Jangardup Project on the Nannup economy the MacFarlane Report also tends to overstate the existing and potential impact of tourism for the area. It states that the additional traffic due to mining of heavy minerals will impair this development. Currently tourism is very small but is expanding in conjunction with existing road users, including timber trucks. This standard is accepted by Nannup residents and Cable Sands believes the added road use due to its trucking operation will not impair tourist traffic but allow both operations to continue to grow, thereby benefiting everybody in the area.

Similarly, the acquisition of 28 extra staff in Bunbury will have a positive impact on employment and expenditure on goods and services in the Bunbury area.

The impact of the proposed mine on public movement into D'Entrecasteaux National Park via Black Point Road is not expected to be great. People will be aware that there is a mining operation nearby, and this will be highlighted by appropriate sign posting and increased truck movements along the roads used by Cable Sands.

There will be very little if any physical impact on the adjacent D'Entrecasteaux National Park. The proposed method of dredging permits the deposit to be mined as a continuous cut and fill operation, so that there is no final mine pit. Rehabilitation can be completely integrated with mine production and it can follow closely behind the mining front.

The mine will be marginally visible from existing tracks which are several kilometres away, and this impact will be very small.

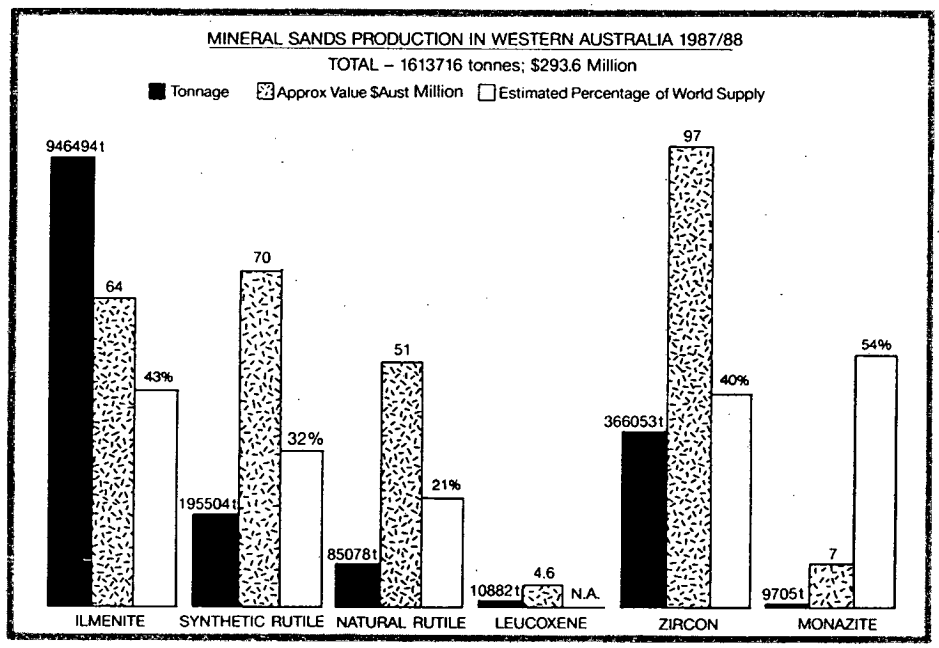
On completion of rehabilitation there will be no indication in the D'Entrecasteaux National Park that mining ever took place in the adjacent private property and the State Forest.

6.0 CONCLUSION, COSTS AND BENEFITS

Australia's position in the worlds heavy minerals industry is substantial, and in recent years Western Australia has become the leading producer in the international heavy minerals market. A graphic illustration of Western Australia's heavy minerals production was prepared in 1989 by the Department of Resources Development and it is reproduced below. From this it can be seen

that the State supplies the world market with 43% of its ilmenite, 21% of its rutile, 40% of its zircon and 54% of its monazite.

The heavy minerals industry has seen marked growth in the last few years. During 1987-88 the annual production of heavy minerals in Western Australia increased by over 6% to 1.67 million tonnes. This was worth $293 million and presented a 48% increase in income, and it reflected a growth in the heavy minerals industry which was exceeded only by gold. The demand for heavy minerals is continuing, and according to the Department of Resources Development it is estimated to reach $1 billion in the early 1990's.



The products of the proposed mining operation have a wide range of uses, including the production of titanium and the manufacture of paints, steel, glass, ceramics, welding electrodes, petroleum catalysts and electronic components. All of these products are essential as indicated by the strong demand for them and none can be considered to be undesirable. The only potentially hazardous product is monazite which is slightly radioactive and is present in low concentrations. The monazite fraction is not extracted at the mine site and the proposed mining operations will decrease sources of radiation in the Jangardup region.

The Jangardup deposit consists of 2.1 million tonnes of Heavy Minerals, and this will make a major contribution to the annual production of heavy minerals in Western Australia as well as to the known resources of heavy minerals in this State.

The estimated total revenue from the Jangardup deposit in 1989 dollar terms is approximately $196 million. Of this the Federal Government will receive about $22 million in the form of taxes and the Western Australian Government will receive a further $10 million in the form of royalty payments.

The mining of the Jangardup deposit and the associated services will provide much needed employment and income for the communities of Pemberton and Nannup. These towns have a need for employment, particularly with the long-term decline in employment in the traditional industries of farming and timber production. The skills of persons displaced from these industries are relevant to the mining of heavy minerals. It is estimated that 50 people will be employed directly at the mine. Six of these will be living on site and the balance will probably be living in nearby towns, particularly Nannup. Cable Sands is anticipating that people already living in Nannup will join the Company and Cable Sands has asked Homeswest to build 12 houses in Nannup to meet the expected shortfall of accommodation in Nannup. These estimates do not include directly employed contractors, such as for trucking and other services which will be provided in the region. This will provide direct employment for a further 27 people, bringing the total number of new positions in the region to 77.

The operations in Bunbury will also generate additional employment and income. Bunbury has a need for local employment and an additional 28 people will be employed in Bunbury to attend to tasks associated with the Jangardup operations. This is exclusive of the use of outside services and contractors.

Considerable income and industrial development will be generated by the Jangardup project with minimal environmental and social costs. The proposed mining uses no chemicals and produces no toxic wastes, and mined land will be returned to its long-term landuses on completion of rehabilitation.

The potentially adverse impacts of the proposed operations are minimal and temporary, and they include:-

- an increase in traffic along the Vasse and Bussell Highways between Jangardup and Bunbury and through the town of Nannup,
- a temporary loss of the use of approximately 200ha of pasture and 30ha of State Forest, and
- a minor aesthetic intrusion on visitors to the adjacent D'Entrecasteaux National Park.

The mine will be partially visible from Black Point Road where this road enters the D'Entrecasteaux National Park. Black Point Road is a major four-wheel drive track which provides access to

the coast. The mine will be visible from within the D'Entrecasteaux National Park, but the area is relatively remote, trackless and little visited.

On completion of mining all facilities will be removed and the land will look very similar to its pre-mining condition, with pastures and shelter belts of trees and shrubs which will be very similar to the pre-mining pastures.

In conclusion, the operations will be a major source of income and employment, both locally and at State and Federal levels, and on completion of rehabilitation the proposed operations will have resulted in no important social or environmental costs or detriments. On this basis, the project can clearly be justified to the Government and the public.

7.0 SUMMARY OF COMMITMENTS

1. Cable Sands agrees to comply with the relevant statutory requirements of both the State of Western Australian and the Commonwealth of Australia.

2. Site preparation prior to mining will be as described in this ERMP.

3. The mining operations, the heavy minerals separation process and the transportation will comply with the descriptions presented in this ERMP.

4. All topsoil will be used for covering restored landforms, and there will be no loss of topsoil.

5. Rehabilitation will be fully integrated with mine production and it will be undertaken continuously, some one to two months behind the dredging front. Rehabilitation will comply with the guidelines presented in this ERMP.

6. Cable Sands will be operating in the area for many years and will maintain the responsibility for rehabilitation until the defined endpoints are achieved. Successful rehabilitation will be determined by the Department of Mines, using the endpoints outlined in this ERMP. The endpoints will be accepted by Cable Sands as a condition.

7. Water usage, electricity generation, access roads, and sewerage and rubbish disposal will be carried out as described in this ERMP and will not be varied greatly without prior consultation with the authorities.

8. All workers will be kept within radiation standards set by the Department of Mines for the heavy minerals mining industry in compliance with the Australian Code of Practice

on radiation protection in the mining and milling of radioactive ores of 1987.

9. Every effort will be made to protect regrowth of plants on the rehabilitated areas from fire and weed encroachment.

10. Part of the rehabilitation process will be to create a range of habitat types.

11. In the event that material of Aboriginal origin is uncovered during the operations, all work will cease within that area and the Western Australian Museum will be called upon to advise.

12. Dust and noise levels will be kept below the standards which are currently set for the mining industry.

13. Groundwater levels and the quality of groundwater around the dredge pond and the production bore will be monitored by Cable Sands. All data will be analysed and should there be any evidence of unacceptable changes, action will be implemented immediately to avoid any harmful changes to the water regimes of the area. The authorities will be notified immediately.

14. Monitoring of the rehabilitation will be undertaken by Cable Sands and reported annually to the Department of Mines, the Department of Conservation and Land Management and the Environmental Protection Authority.

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9.0 STUDY TEAM

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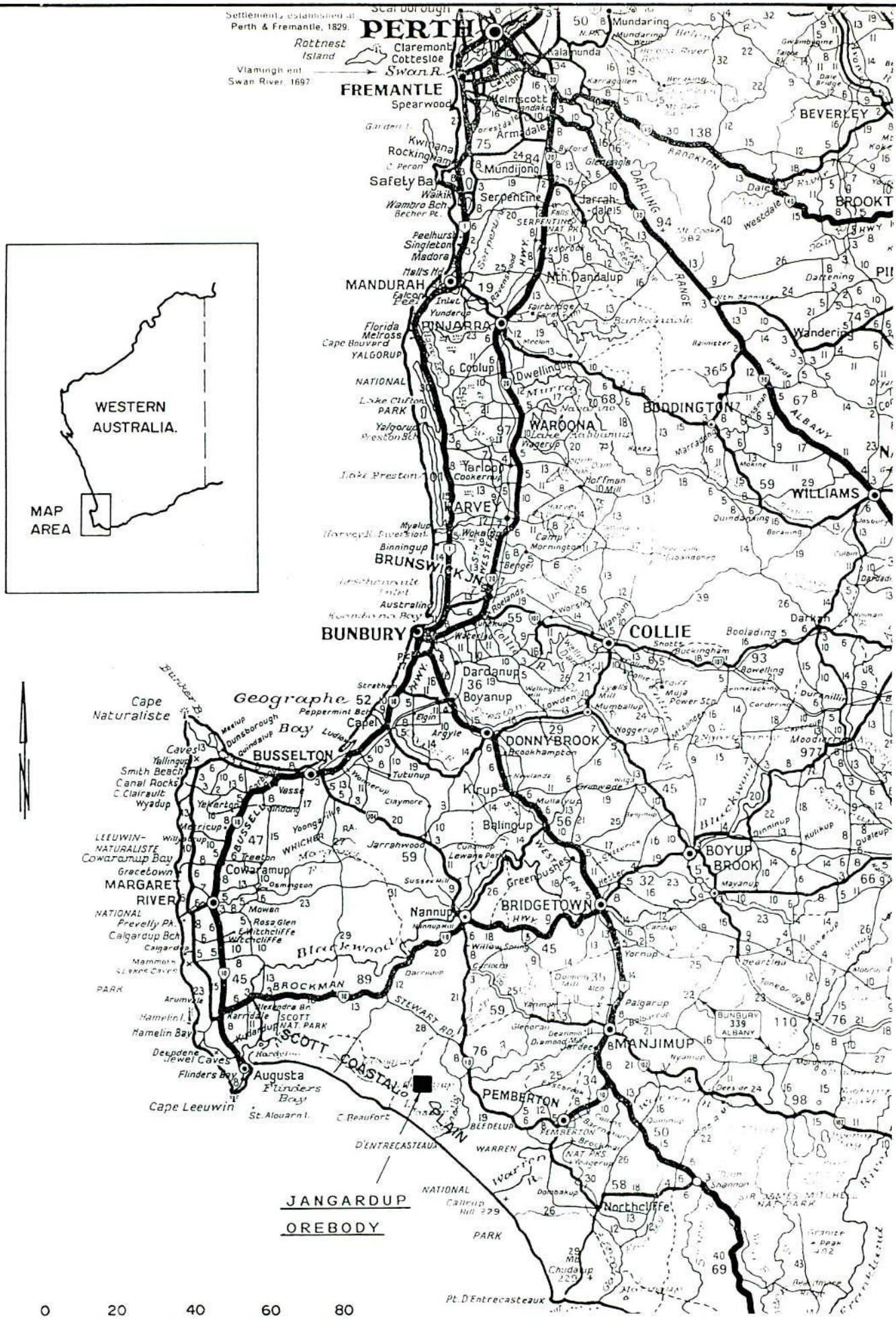


FIGURE 1
LOCATION OF
JANGARDUP OREBODY

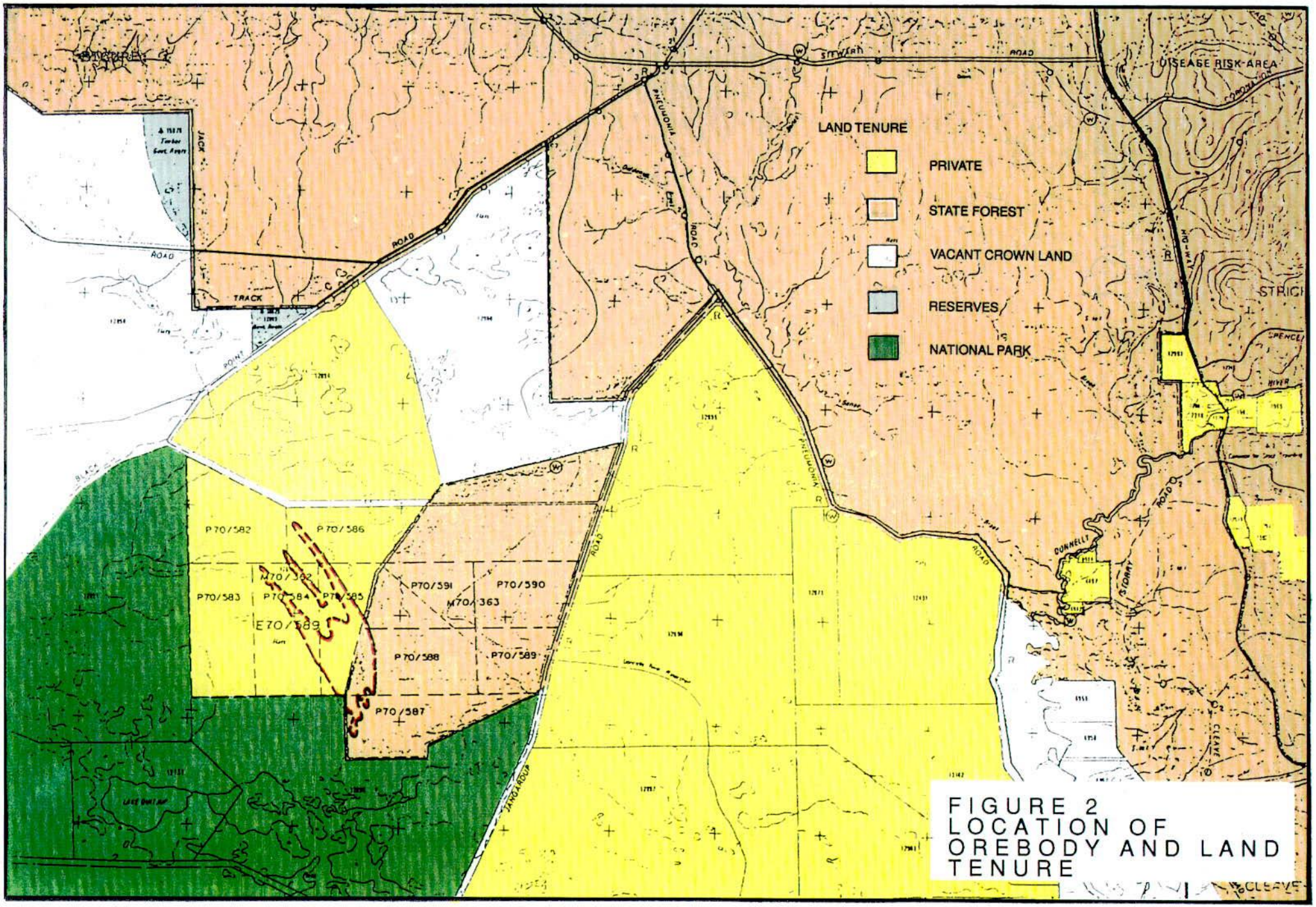


FIGURE 2
LOCATION OF
OREBODY AND LAND
TENURE

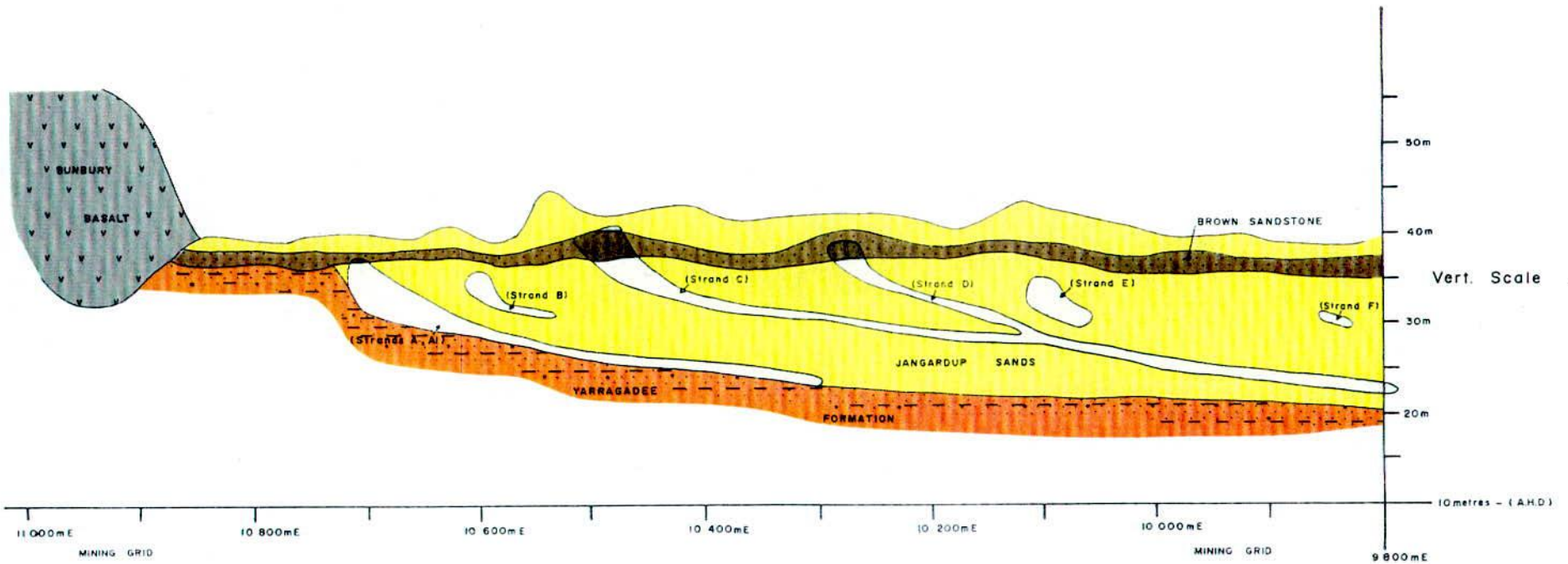


FIGURE 3
SCHEMATIC CROSS SECTION OF JANGARDUP OREBODY (LOOKING SOUTH)

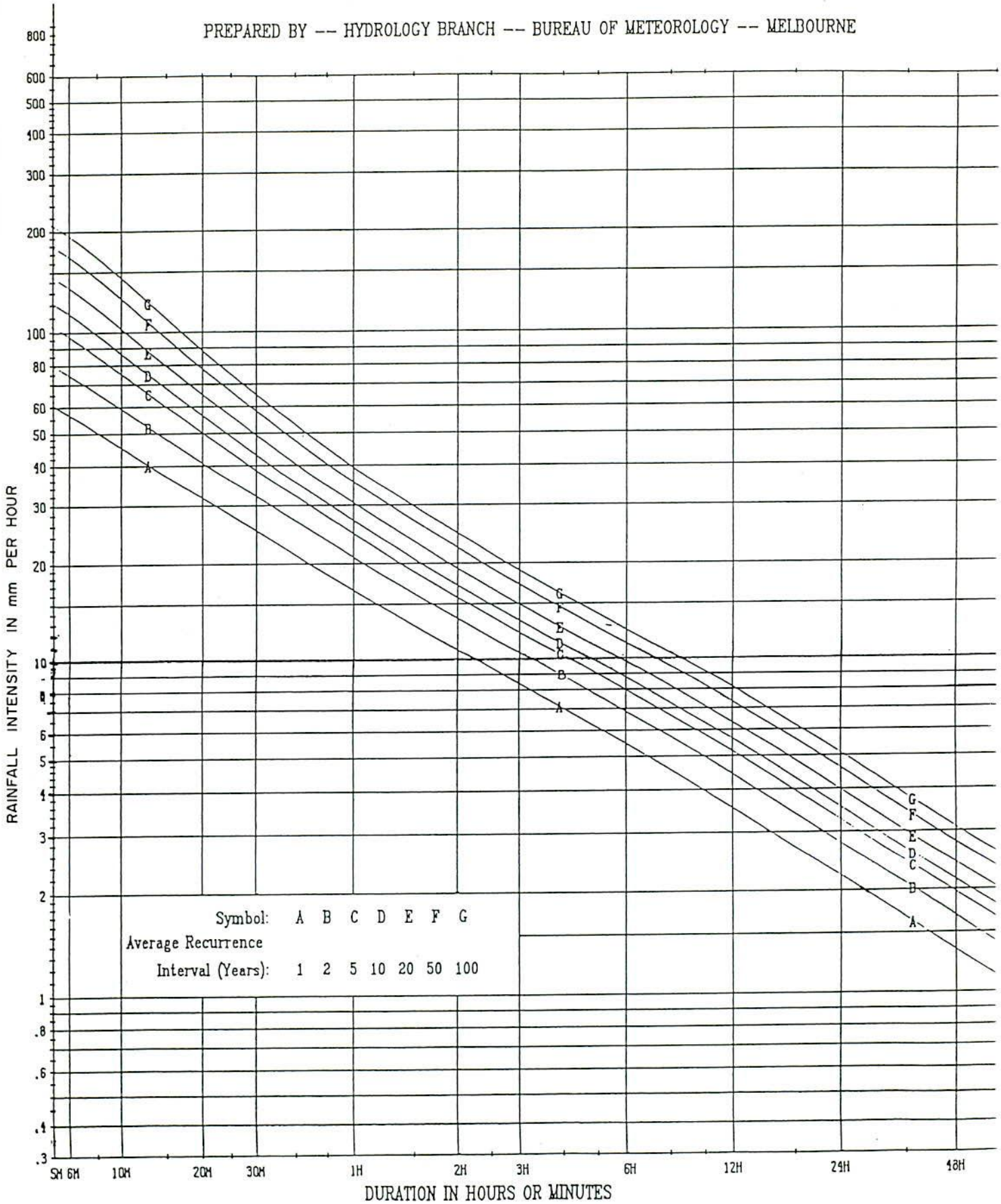


FIGURE 4
RAINFALL INTENSITY
DIAGRAM-NEAR AUGUSTA

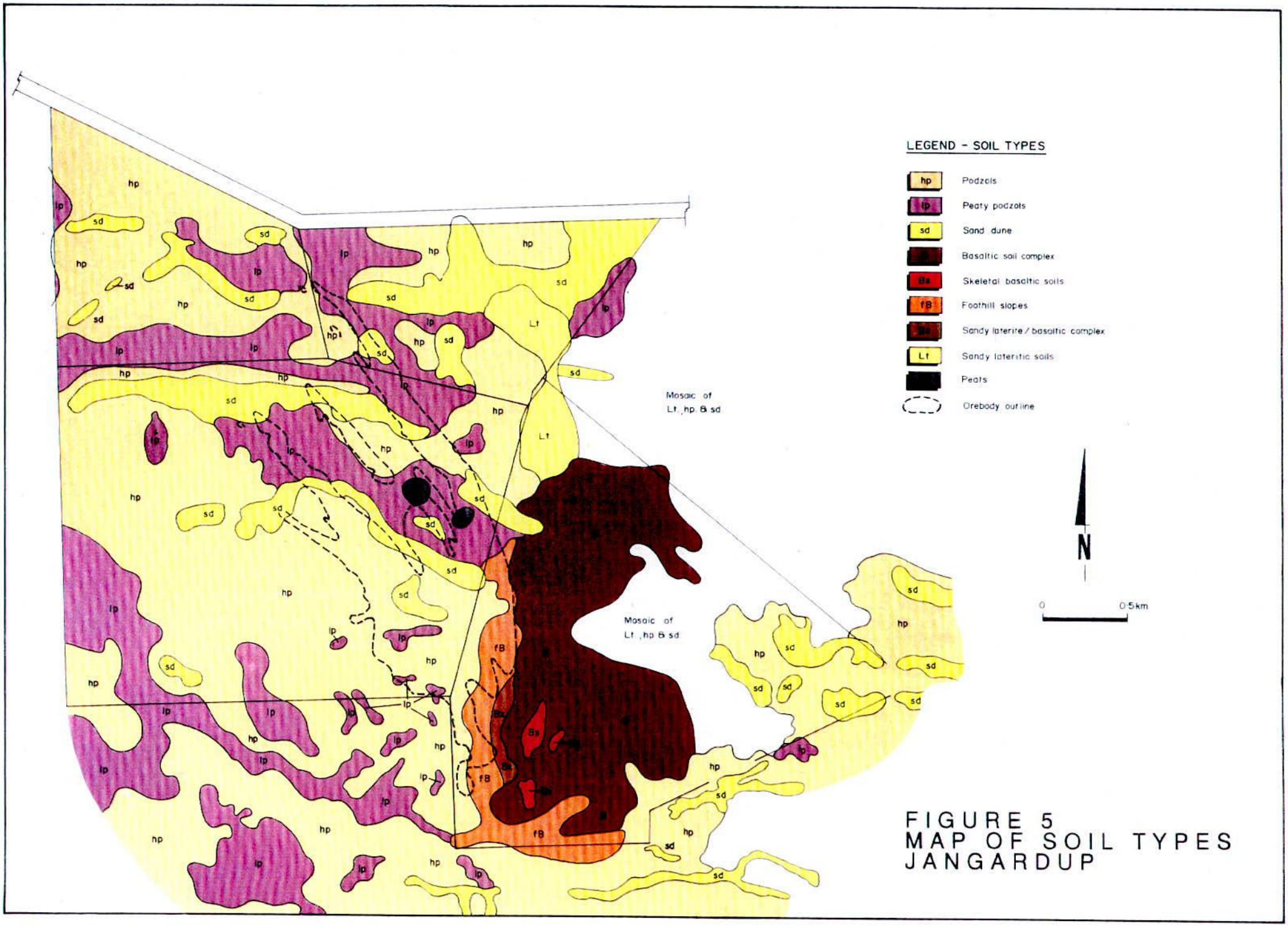
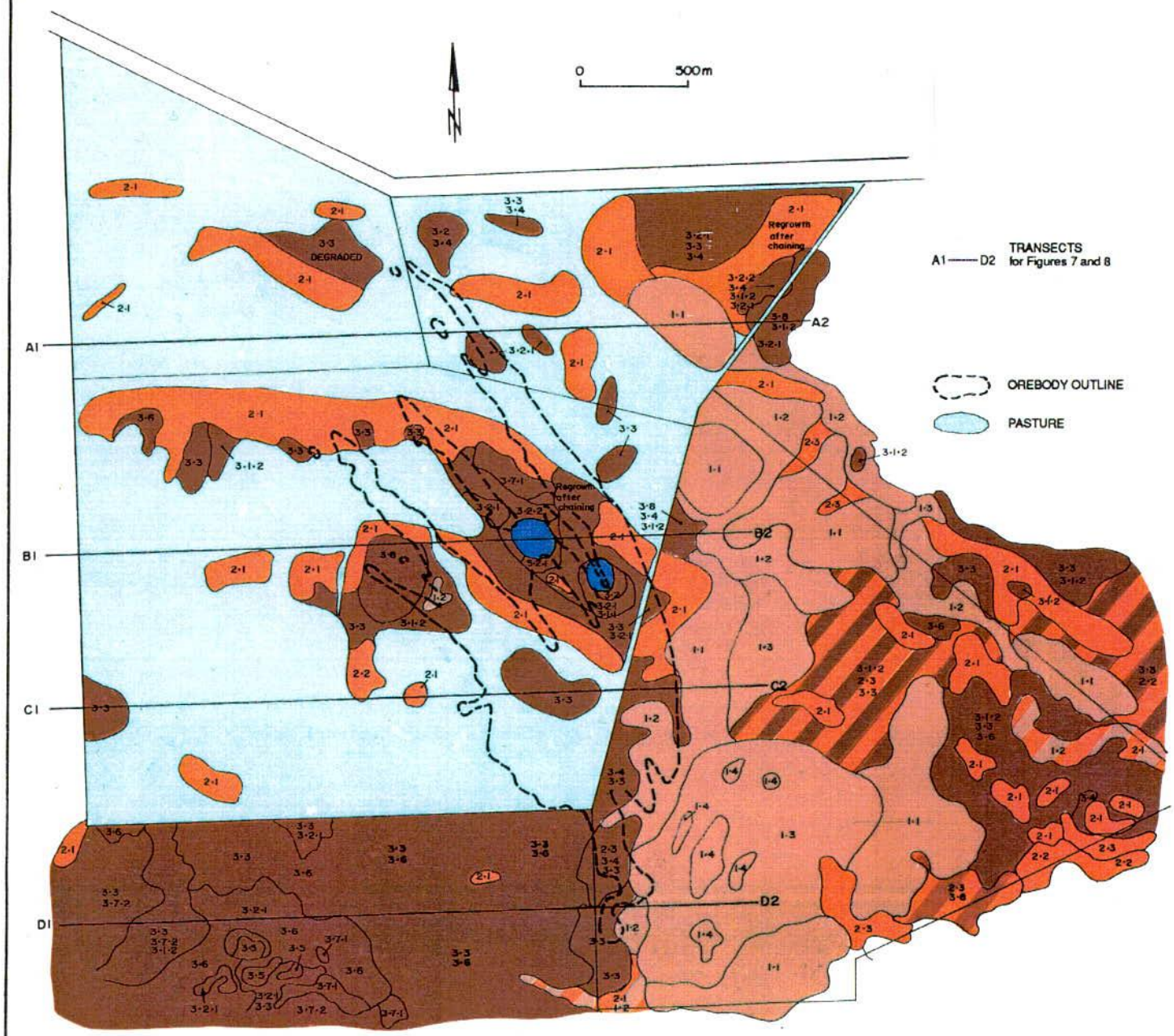


FIGURE 5
MAP OF SOIL TYPES
JANGARDUP



CODE	VEGETATION TYPE and LANDFORM LOCATION	HEIGHT (m) of TALLEST STRATUM (m)	and COVER (%) STRATUM (%)
1·0	**Upland slopes and crest formations**		
1·1	Jarrah forest	15 - 30	30 - 70
1·2	Jarrah low forest	5 - 15	30 - 90
1·3	Marri - Blackbutt forest and tall forest	15 - 30	30 - 70
1·4	Dense Heath	1 - 2	70 - 100
2·0	**Lower slopes and dune formations**		
2·1	Jarrah - Banksia low woodland	<15	10 - 30
2·2	Jarrah low woodland	15	10 - 30
2·3	Blackbutt open low woodland	15	2 - 10
3·0	**Lowland plains and swamp formations**		
3·1	**Low forest formation**		
3·1·1	Agonis juniperina low forest	5-15	30-70
3·1·2	Melaleuca preissiana low forest	5-15	30-70
3·2	**Dense thicket formation**		
3·2·1	Dense swamp thicket	< 2	70-100
3·2·2	Dense Kunzea thicket	< 2	70-100
3·3	Low scrub - heath over sedges	1 - 2	10 - 70
3·4	Open scrub over heath	<1·5	2 - 10
3·5	Dense low heath	1	70 - 100
3·6	Low heath over sedges	1	30 - 70
3·7	Tall sedgeland	0·5	30 - 70
3·7·1	Baumea articulata tall sedgeland	0·5	30 - 70
3·7·2	Baumea vaginalis tall sedgeland	0·5	30 - 70
3·8	Leptocarpus low sedgeland	0·5	30 - 70

FIGURE 6
VEGETATION TYPES AND AREAS OF DIEBACK

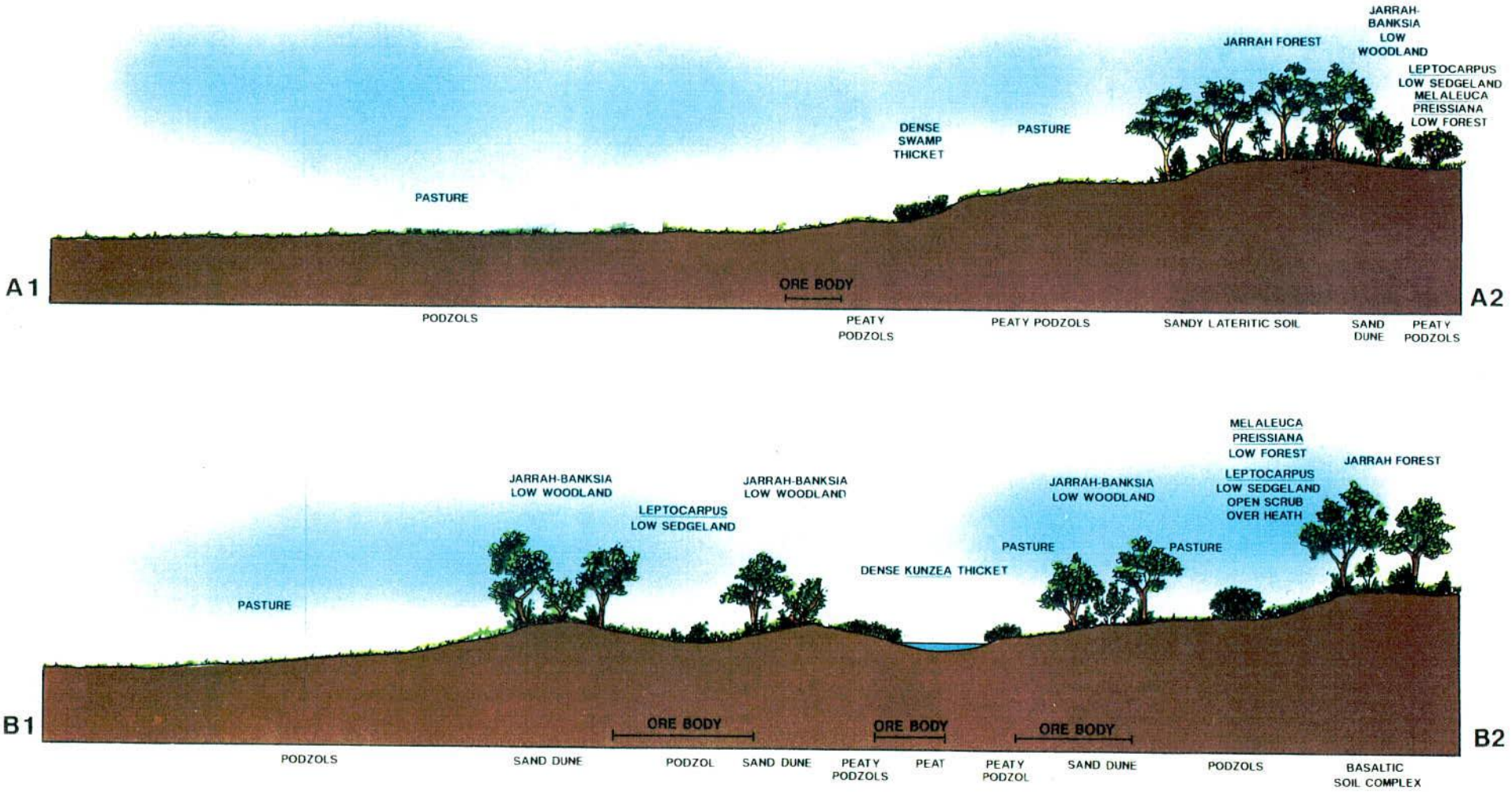


FIGURE 7
SCHEMATIC PROFILES OF TRANSECTS A & B FROM FIGURE 6, SHOWING RELATIONSHIP BETWEEN VEGETATION AND TOPOGRAPHY

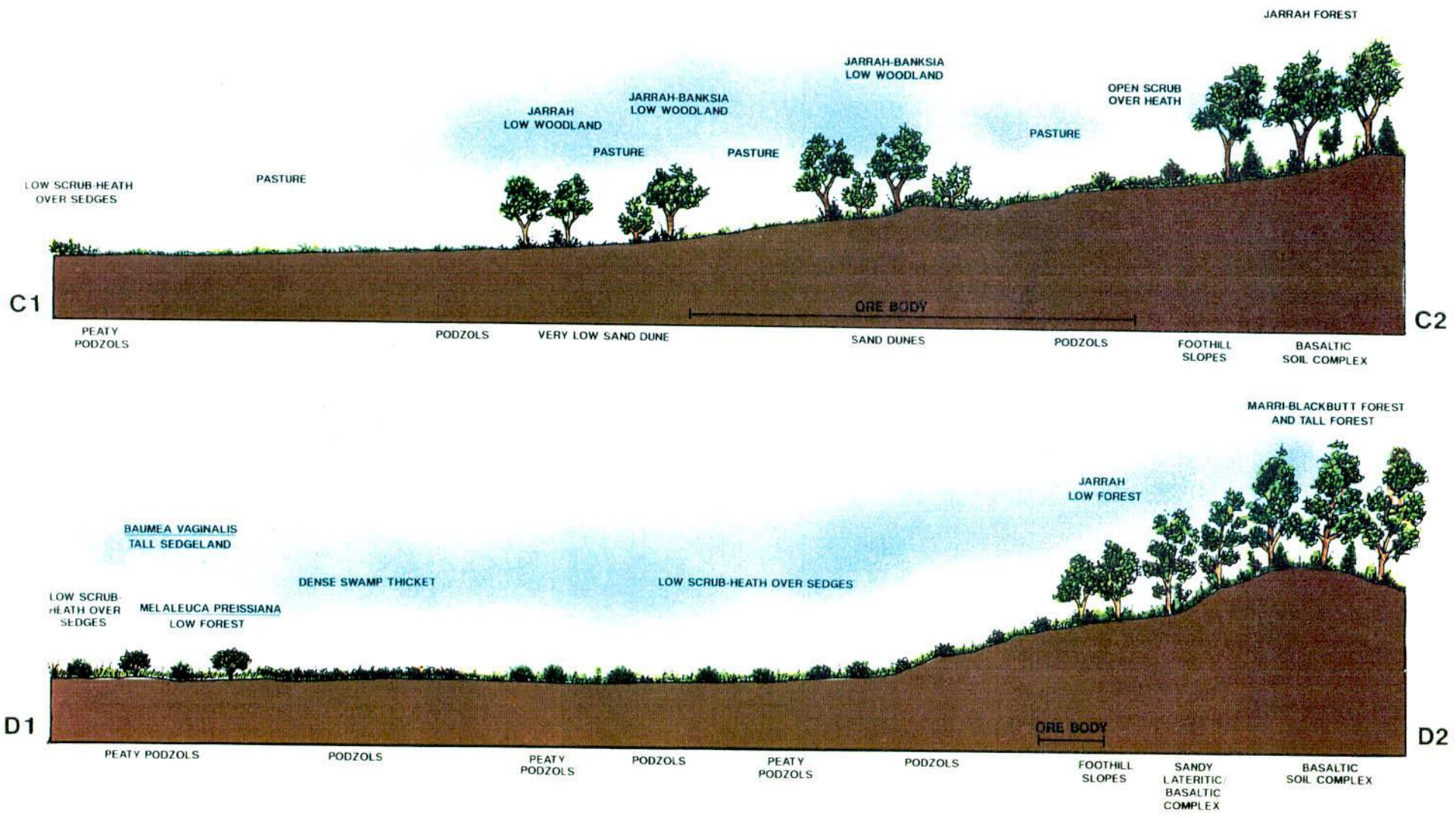
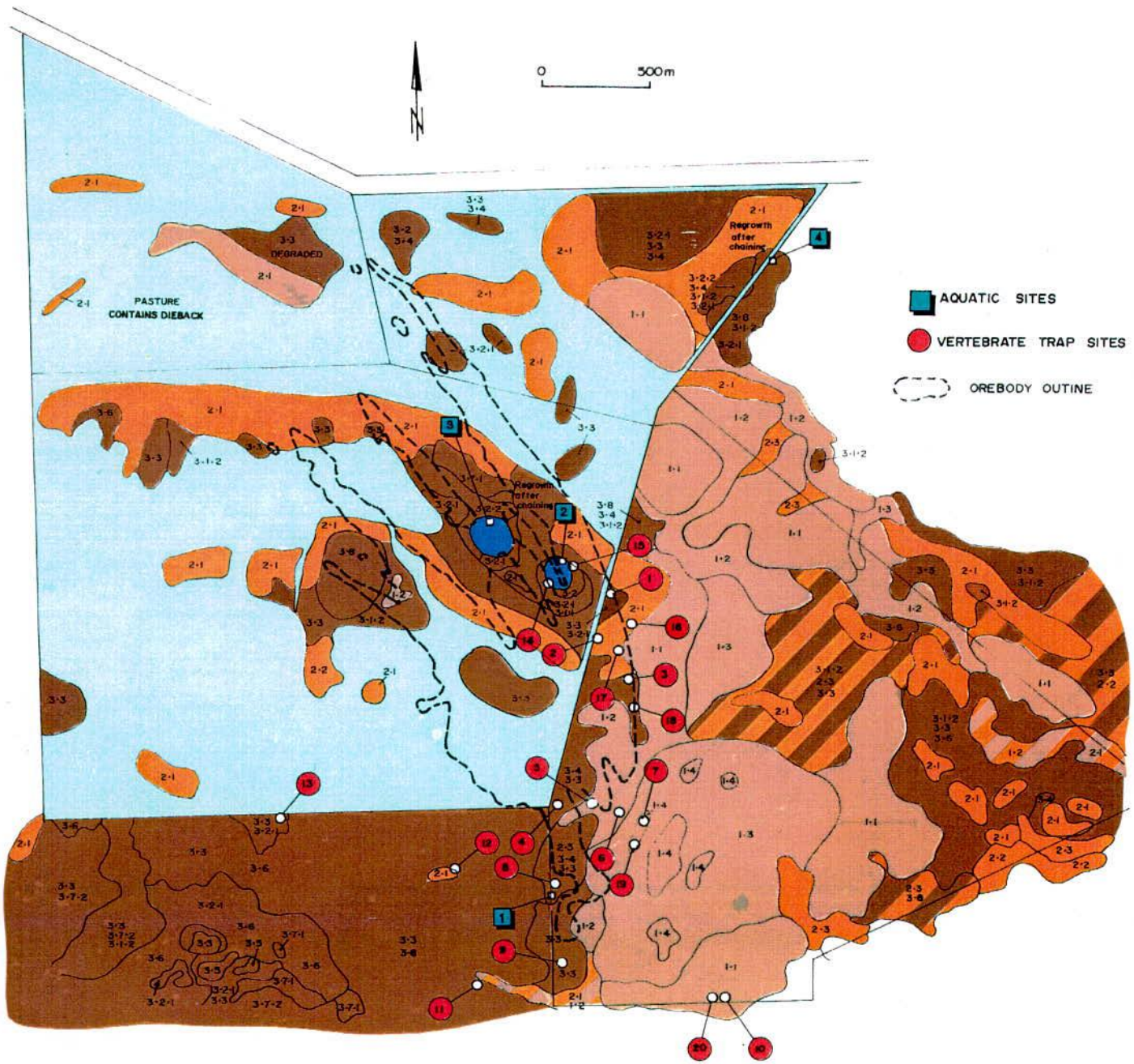
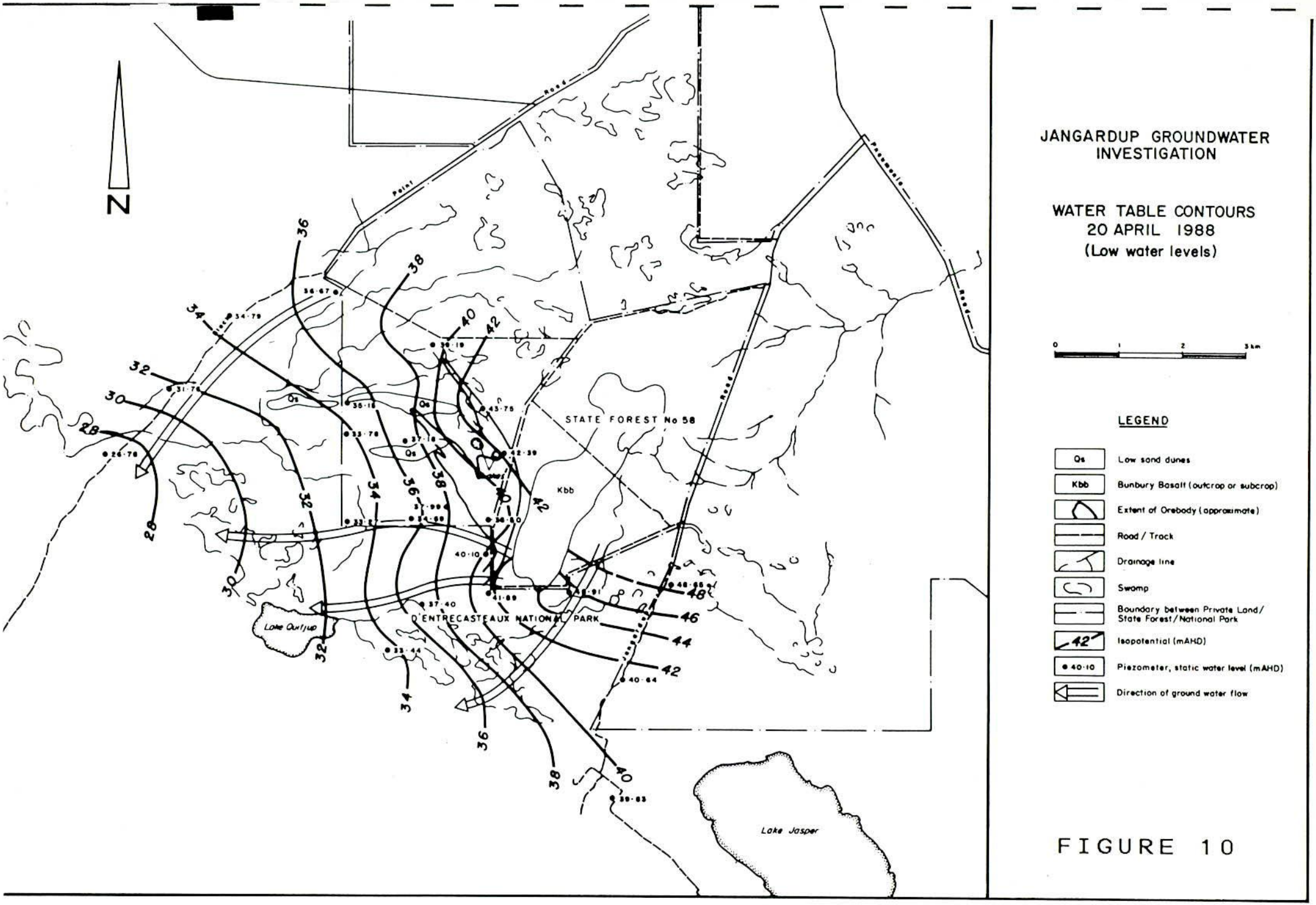


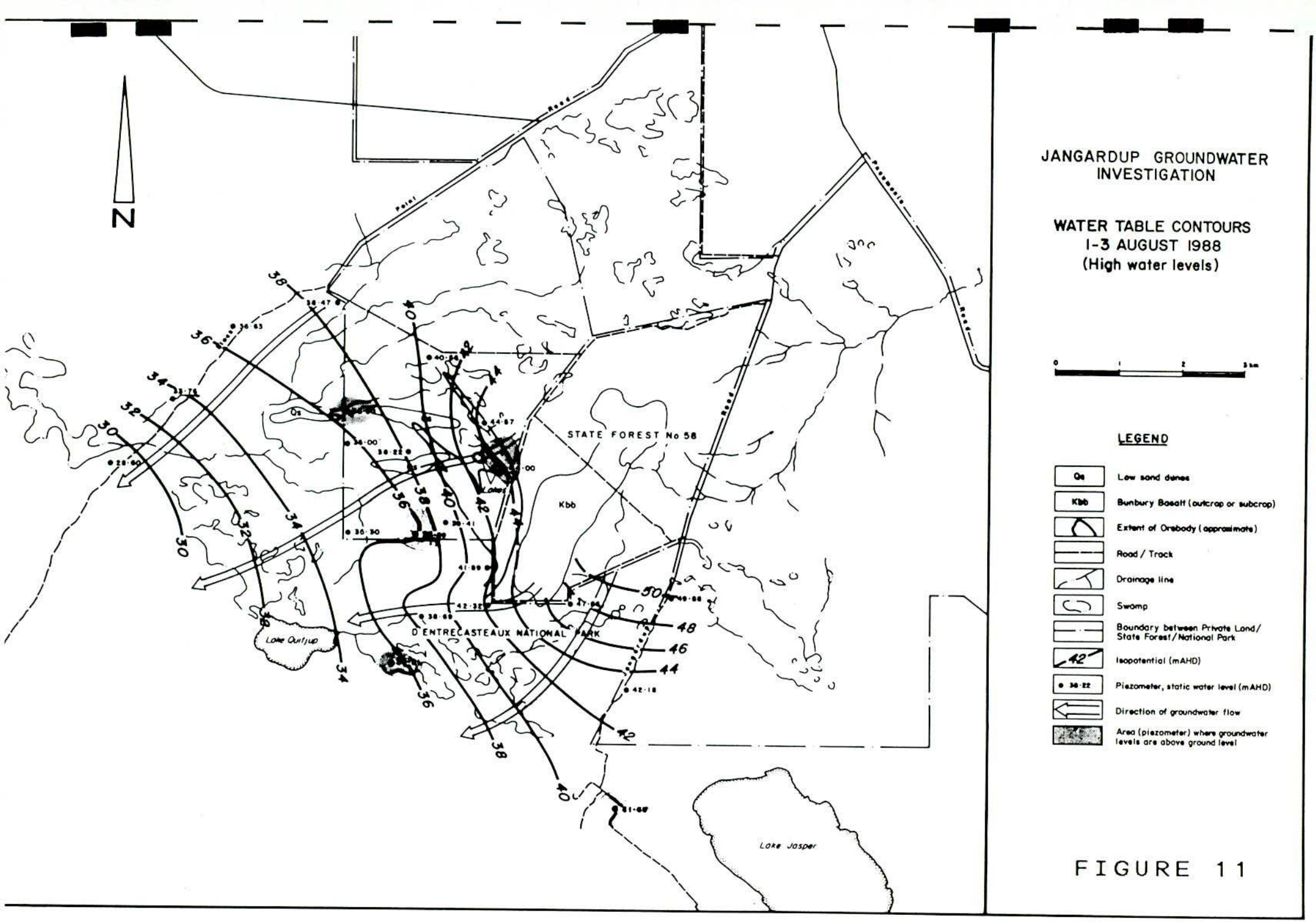
FIGURE 8
SCHEMATIC PROFILES OF TRANSECTS C & D FROM FIGURE 6, SHOWING RELATIONSHIP BETWEEN VEGETATION AND TOPOGRAPHY

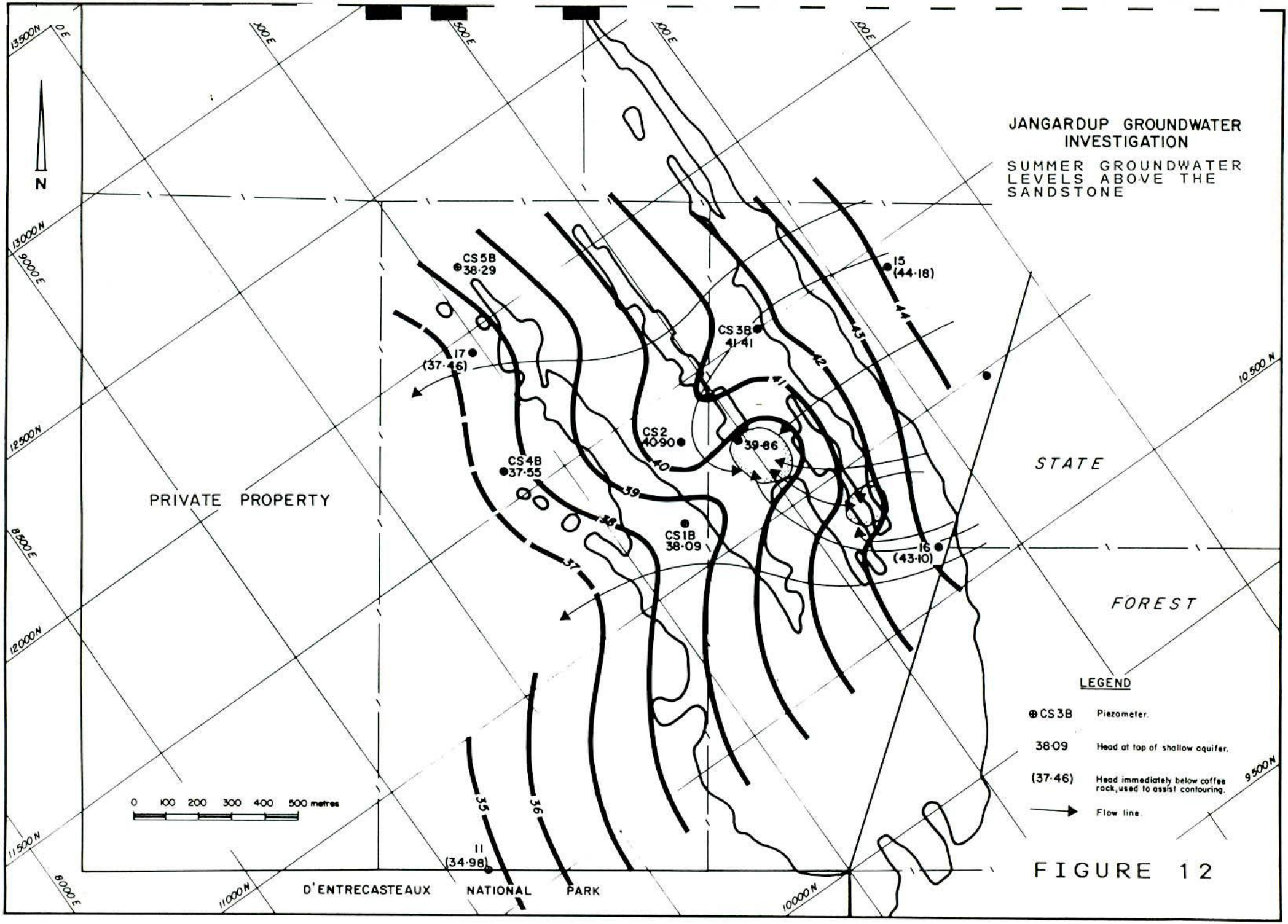


CODE	VEGETATION TYPE and LANDFORM LOCATION	HEIGHT (m) of TALLEST STRATUM (m)	and COVER (%) STRATUM (%)
1·0	**Upland slopes and crest formations**		
1·1	Jarrah forest	15 - 30	30 - 70
1·2	Jarrah low forest	5 - 15	30 - 90
1·3	Marri - Blackbutt forest and tall forest	15 - 30	30 - 70
1·4	Dense Heath	1 - 2	70 - 100
2·0	**Lower slopes and dune formations**		
2·1	Jarrah - Banksia low woodland	<15	10 - 30
2·2	Jarrah low woodland	15	10 - 30
2·3	Blackbutt open low woodland	15	2 - 10
3·0	**Lowland plains and swamp formations**		
3·1	**Low forest formation**		
3·1·1	Agonis juniperina low forest	5-15	30 - 70
3·1·2	Melaleuca preissiana low forest	5-15	30 - 70
3·2	**Dense thicket formation**		
3·2·1	Dense swamp thicket	<2	70 - 100
3·2·2	Dense Kunzea thicket	<2	70 - 100
3·3	Low scrub - heath over sedges	1 - 2	10 - 70
3·4	Open scrub over heath	<1·5	2 - 10
3·5	Dense low heath	1	70 - 100
3·6	Low heath over sedges	1	30 - 70
3·7	Tall sedgeland	0·5	30 - 70
3·7·1	Baumea articulata tall sedgeland	0·5	30 - 70
3·7·2	Baumea vaginalis tall sedgeland	0·5	30 - 70
3·8	Leptocarpus low sedgeland	0·5	30 - 70

FIGURE 9
VERTEBRATE TRAPPING & AQUATIC SAMPLING SITES


N
JANGARDUP GROUNDWATER INVESTIGATION
WATER TABLE CONTOURS
20 APRIL 1988
(Low water levels)
0 1 2 3 km
LEGEND
Qs Low sand dunes
Kbb Bunbury Basalt (outcrop or subcrop)
Extent of Orebody (approximate)
Road / Track
Drainage line
Swamp
Boundary between Private Land/ State Forest/National Park
42 Isopotential (mAHD)
40·10 Piezometer, static water level (mAHD)
Direction of ground water flow
STATE FOREST No 58
D'ENTRECASTEAUX NATIONAL PARK
Lake Jasper
Lake Quitjup
Kbb
Qs
FIGURE 10


N
JANGARDUP GROUNDWATER INVESTIGATION
WATER TABLE CONTOURS
1-3 AUGUST 1988
(High water levels)
0
1
2
3 km
LEGEND
Qs
Low sand dunes
Kbb
Bunbury Basalt (outcrop or subcrop)
Extent of Orebody (approximate)
Road / Track
Drainage line
Swamp
Boundary between Private Land/ State Forest/National Park
42
Isopotential (mAHD)
36·22
Piezometer, static water level (mAHD)
Direction of groundwater flow
Area (piezometer) where groundwater levels are above ground level
STATE FOREST No 58
D'ENTRECASTEAUX NATIONAL PARK
Lake Quitup
Lake Jasper
Kbb
Qs
FIGURE 11


JANGARDUP GROUNDWATER INVESTIGATION
SUMMER GROUNDWATER LEVELS ABOVE THE SANDSTONE
N
PRIVATE PROPERTY
STATE FOREST
D'ENTRECASTEAUX NATIONAL PARK
CS5B 38·29
CS3B 41·41
15 (44·18)
17 (37·46)
CS2 40·90
39·86
CS4B 37·55
CS1B 38·09
16 (43·10)
11 (34·98)
35
36
37
38
39
40
41
42
43
44
0 100 200 300 400 500 metres
LEGEND
⊕CS3B Piezometer.
38·09 Head at top of shallow aquifer.
(37·46) Head immediately below coffee rock, used to assist contouring.
Flow line.
13500N
13000N
12500N
12000N
11500N
11000N
10500N
10000N
9500N
9000E
8500E
8000E
500E
FIGURE 12

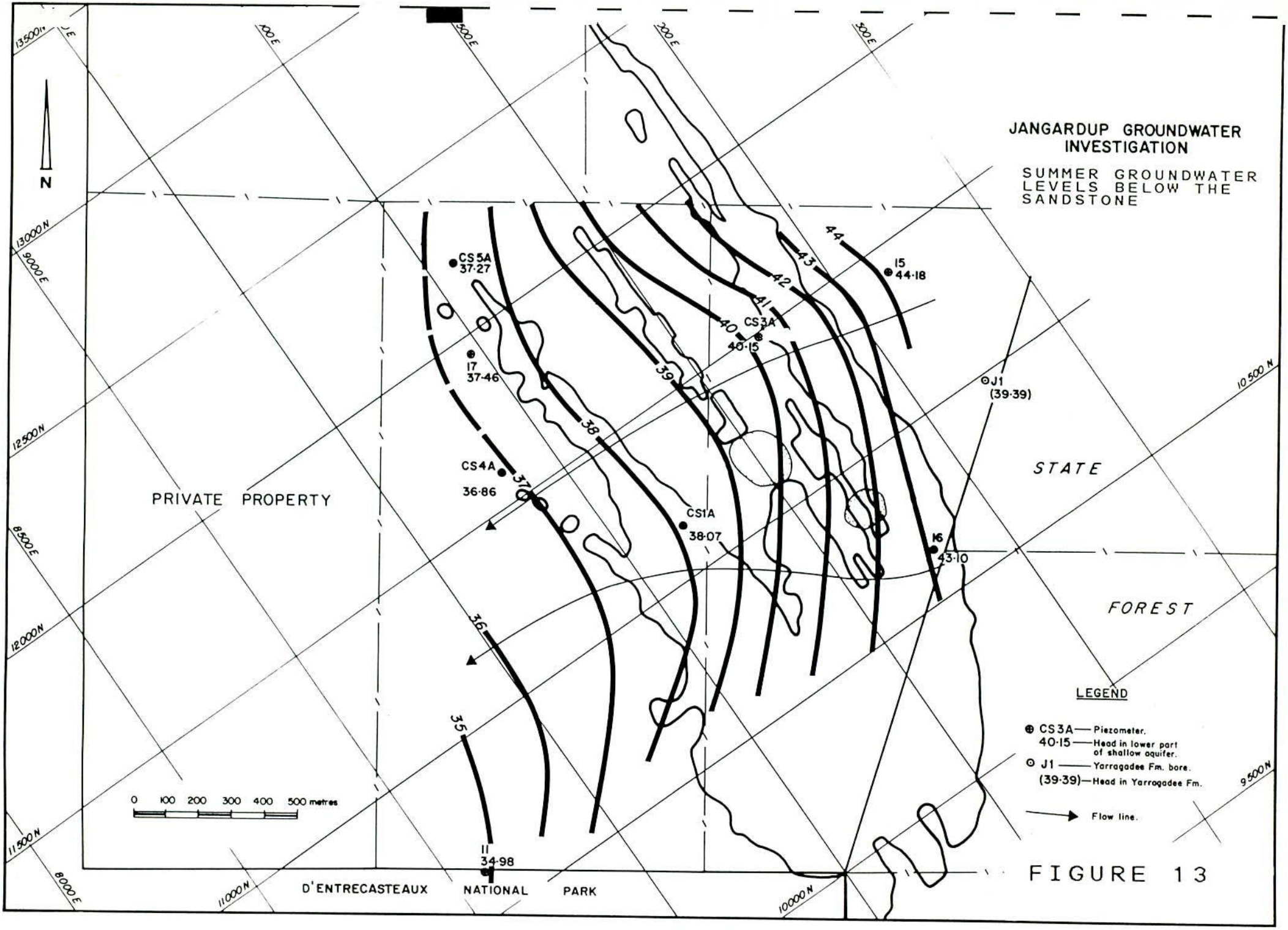

JANGARDUP GROUNDWATER INVESTIGATION
SUMMER GROUNDWATER LEVELS BELOW THE SANDSTONE
N
CS5A 37·27
17 37·46
CS4A 36·86
CS3A 40·15
15 44·18
J1 (39·39)
CS1A 38·07
16 43·10
11 34·98
PRIVATE PROPERTY
STATE FOREST
D'ENTRECASTEAUX NATIONAL PARK
0 100 200 300 400 500 metres
LEGEND
CS3A — Piezometer.
40·15 — Head in lower part of shallow aquifer.
J1 — Yarragadee Fm. bore.
(39·39) — Head in Yarragadee Fm.
Flow line.

FIGURE 13

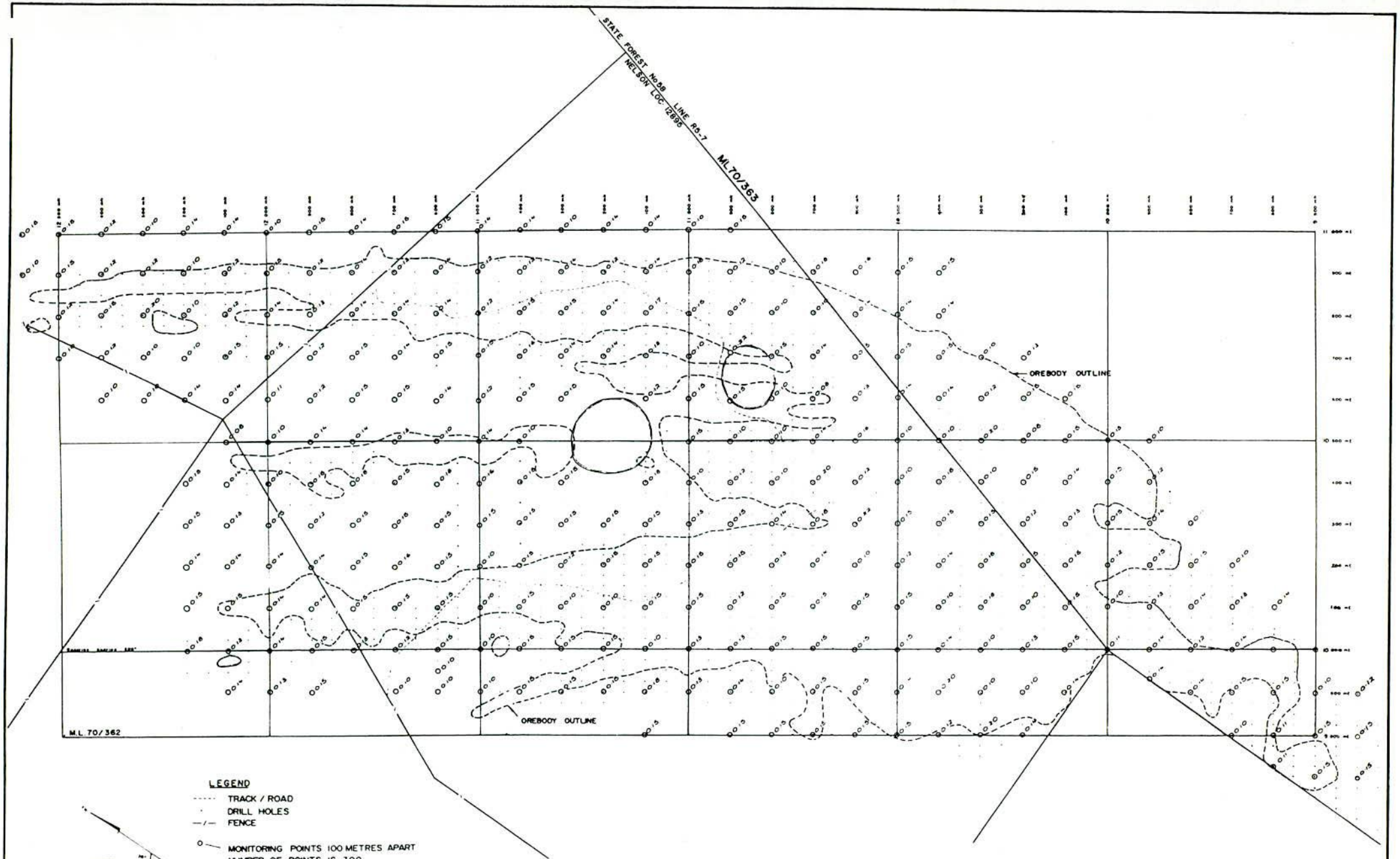
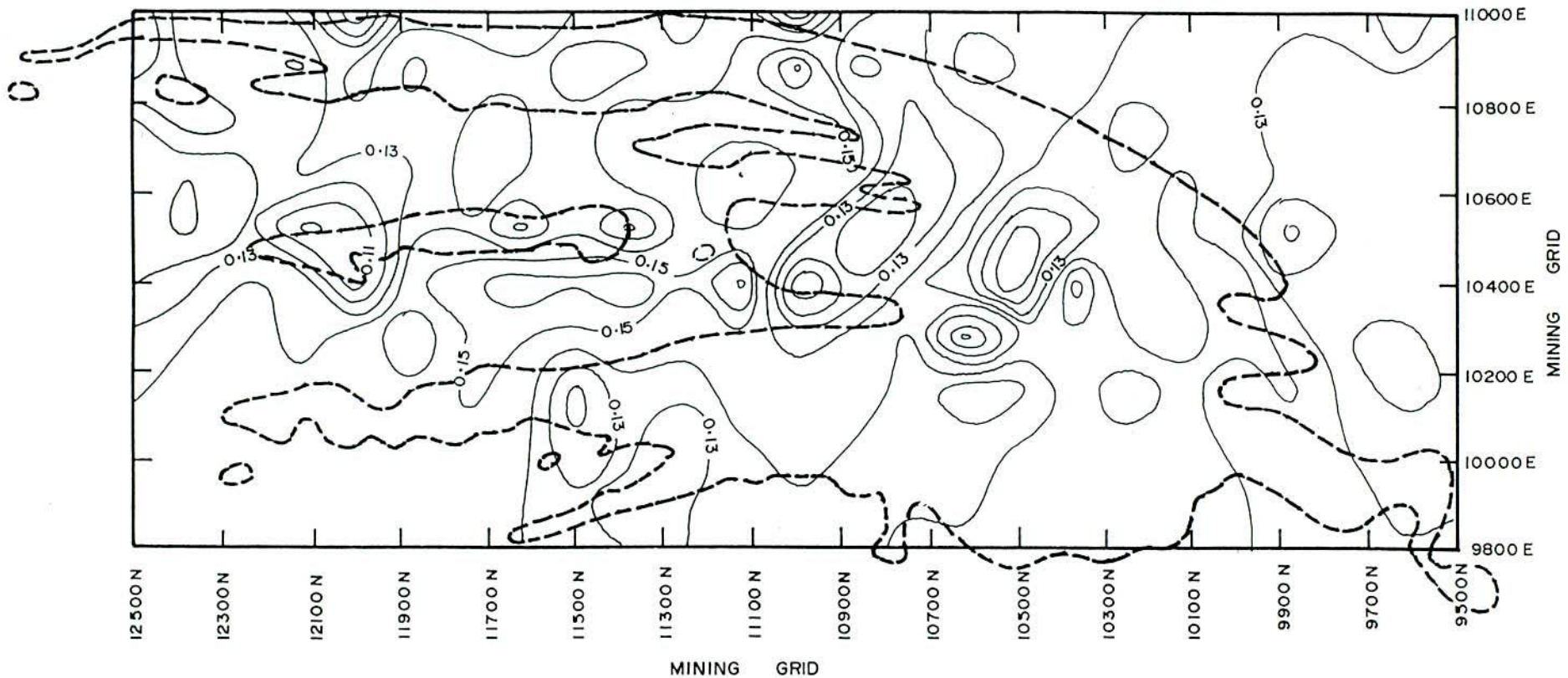


FIGURE 14
NATURAL GAMMA
RADIATION RATES
uGy/h



OREBODY OUTLINE

FIGURE 15
NATURAL GAMMA
RADIATION CONTOURS
(μGy/h)

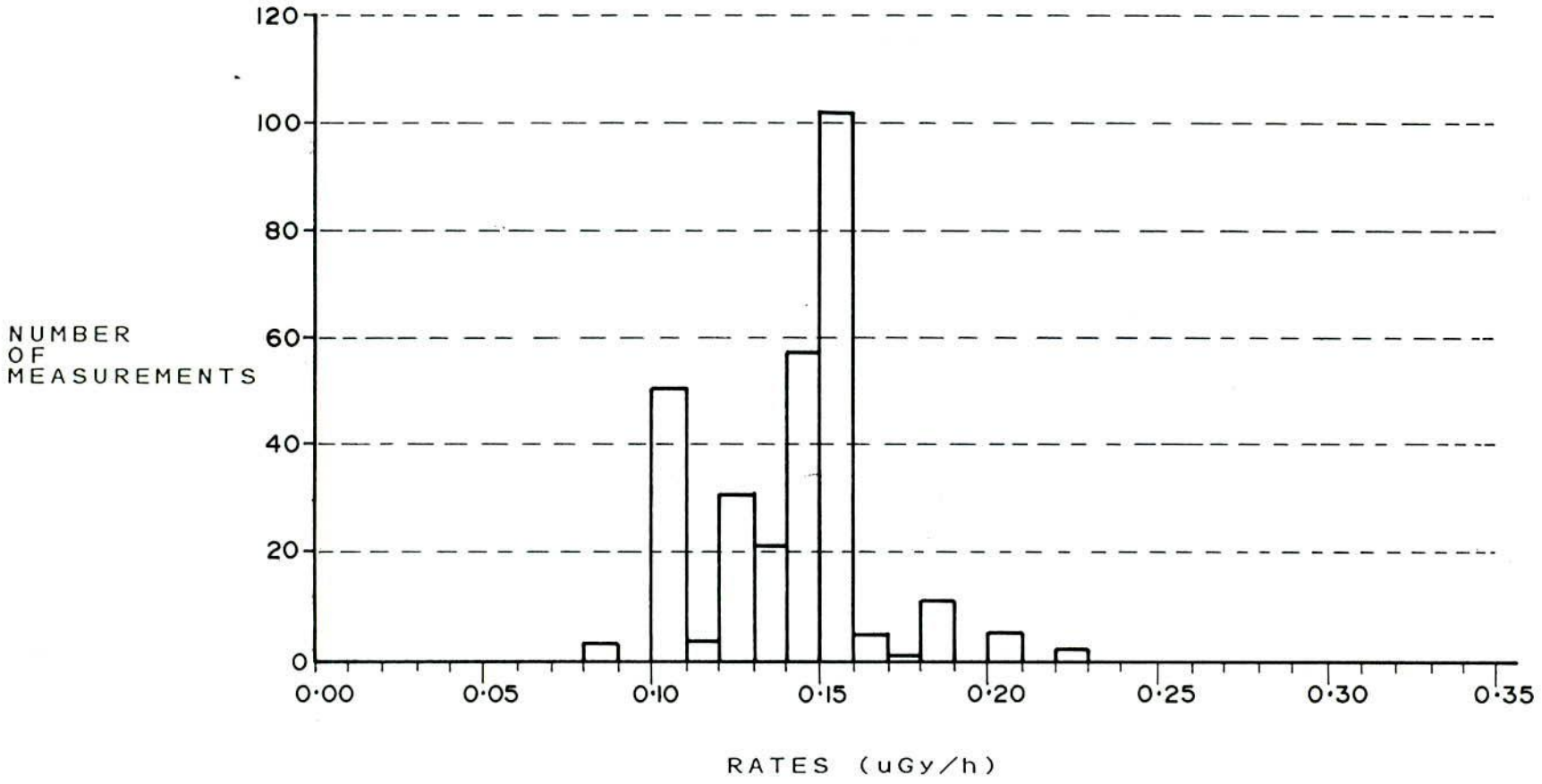


FIGURE 16
HISTOGRAM OF GAMMA
RADIATION MEASUREMENTS

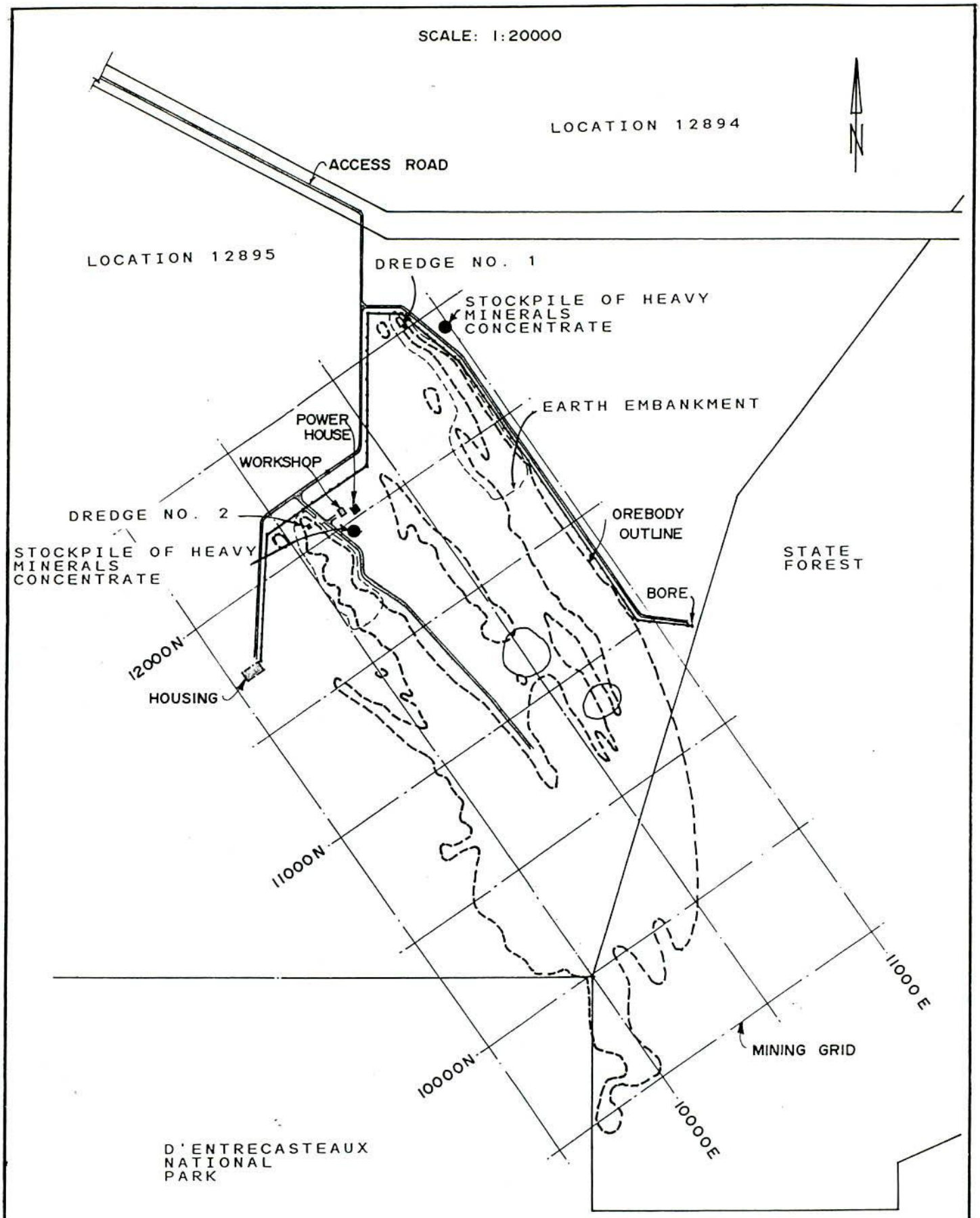


FIGURE 17
OVERALL LAYOUT OF
JANGARDUP MINE AREA

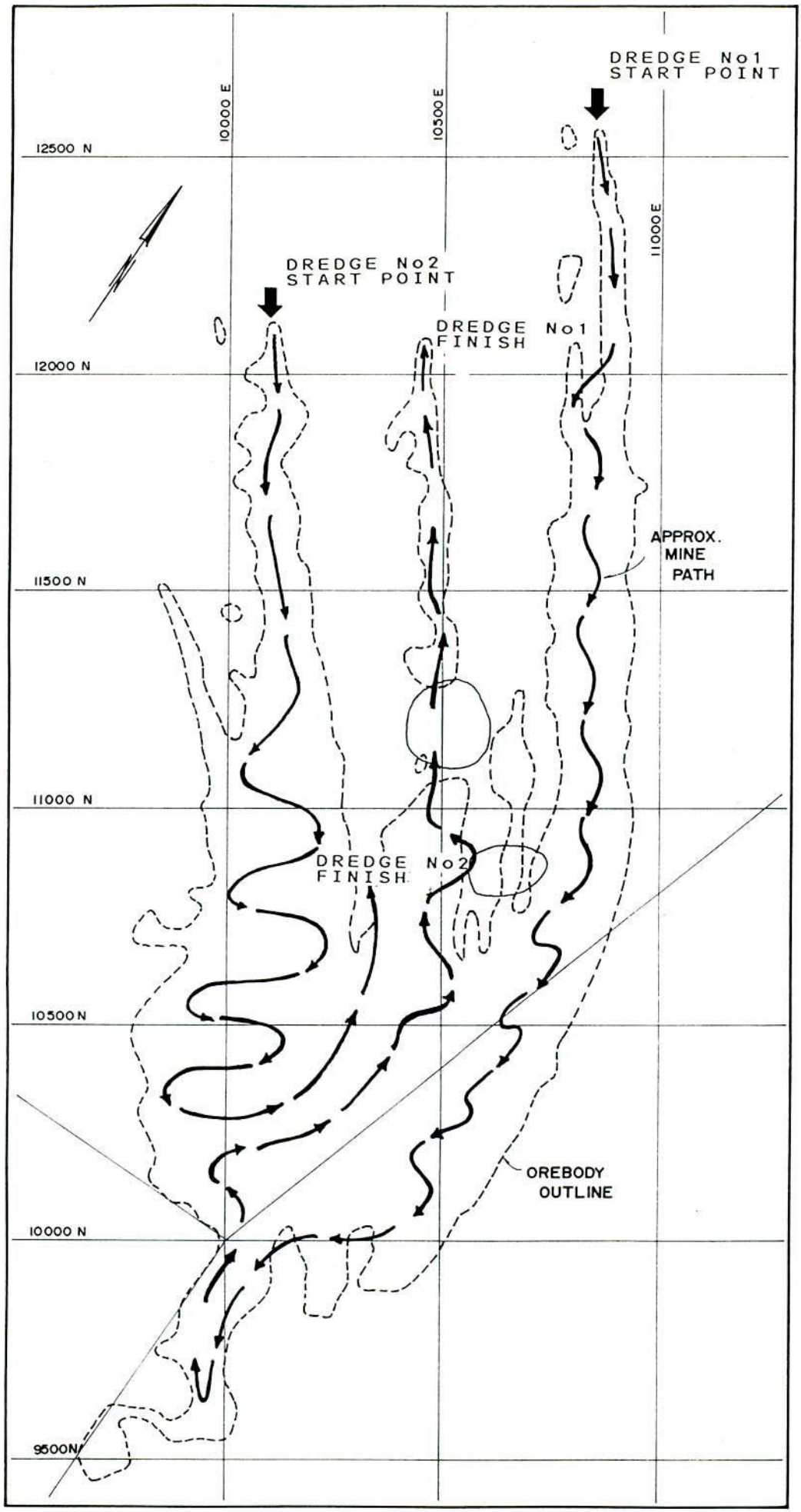
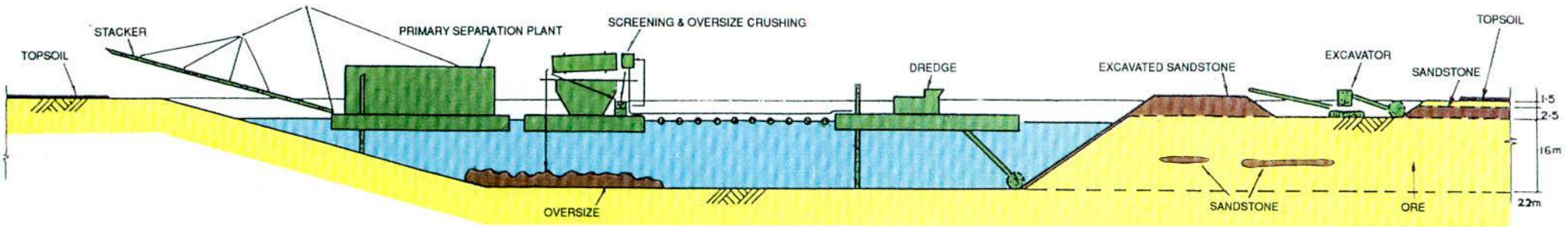
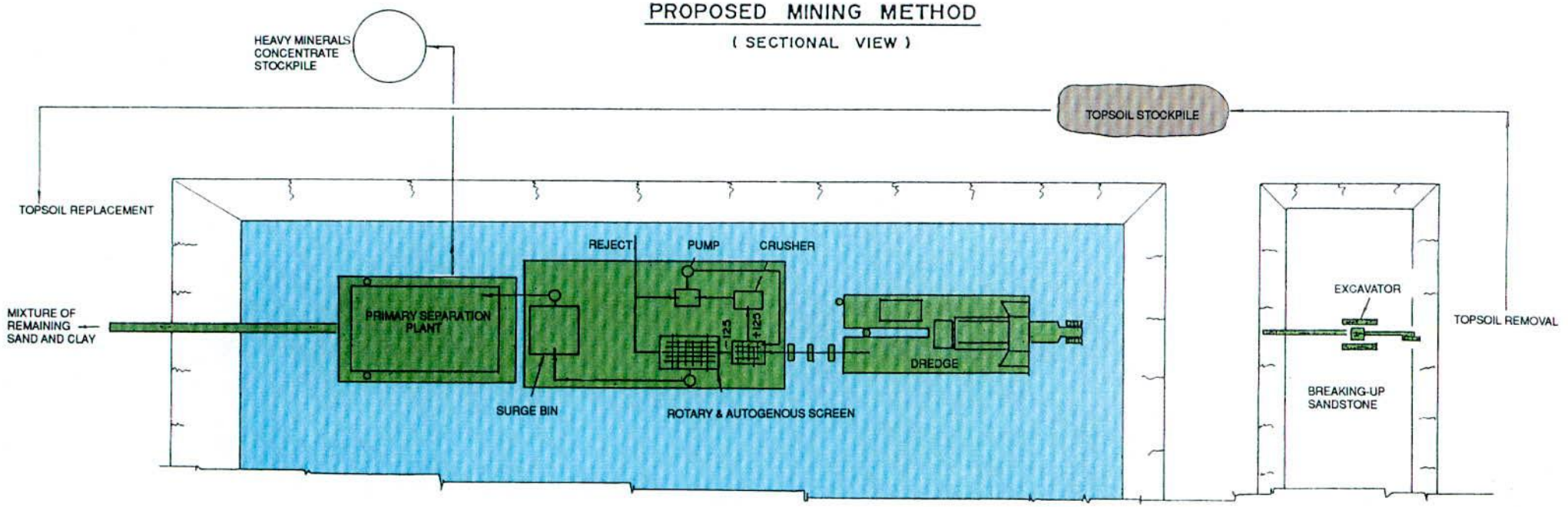


FIGURE 18
JANGARDUP
MINE PATH



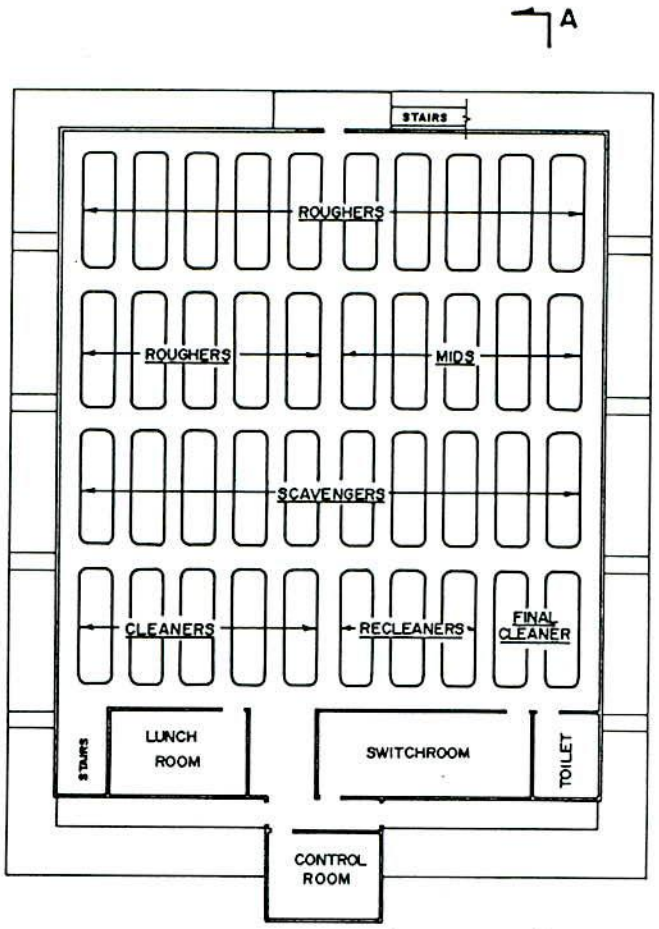
PROPOSED MINING METHOD

(SECTIONAL VIEW)



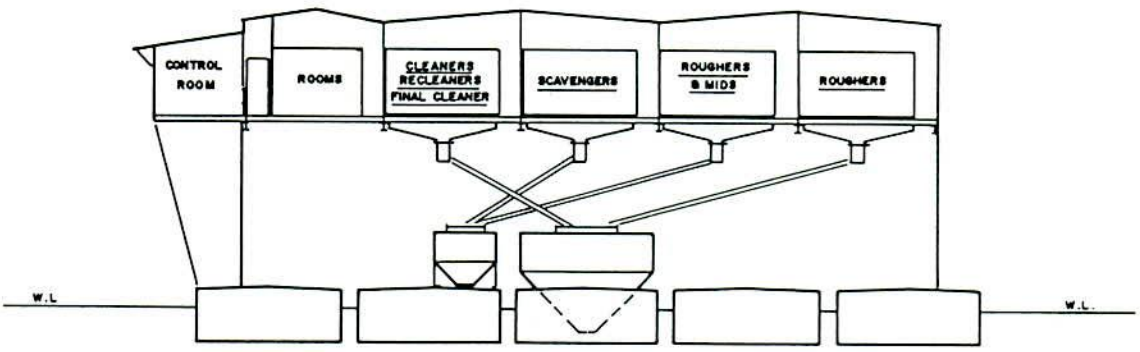
PLAN VIEW

FIGURE 19
MINING PLANT
SHOWING BREAK-UP
OF SANDSTONE AND
DREDGING SYSTEMS



PLAN

(1st FLOOR LAYOUT)



SECTION AA

FIGURE 20
GENERAL
ARRANGEMENT OF
PRIMARY SEPARATION
PLANT

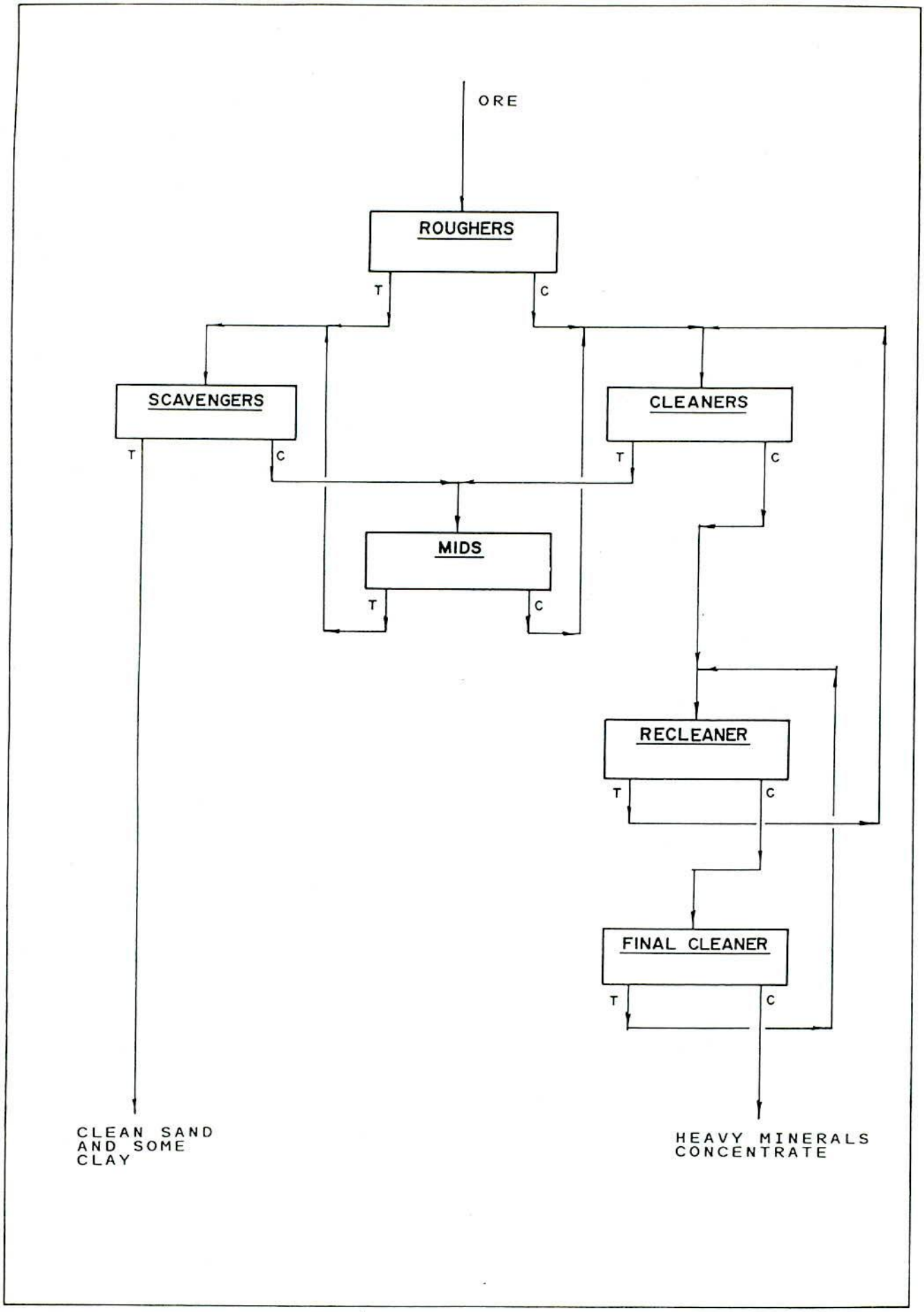


FIGURE 21
FLOWSHEET OF
PRIMARY SEPARATION
PLANT

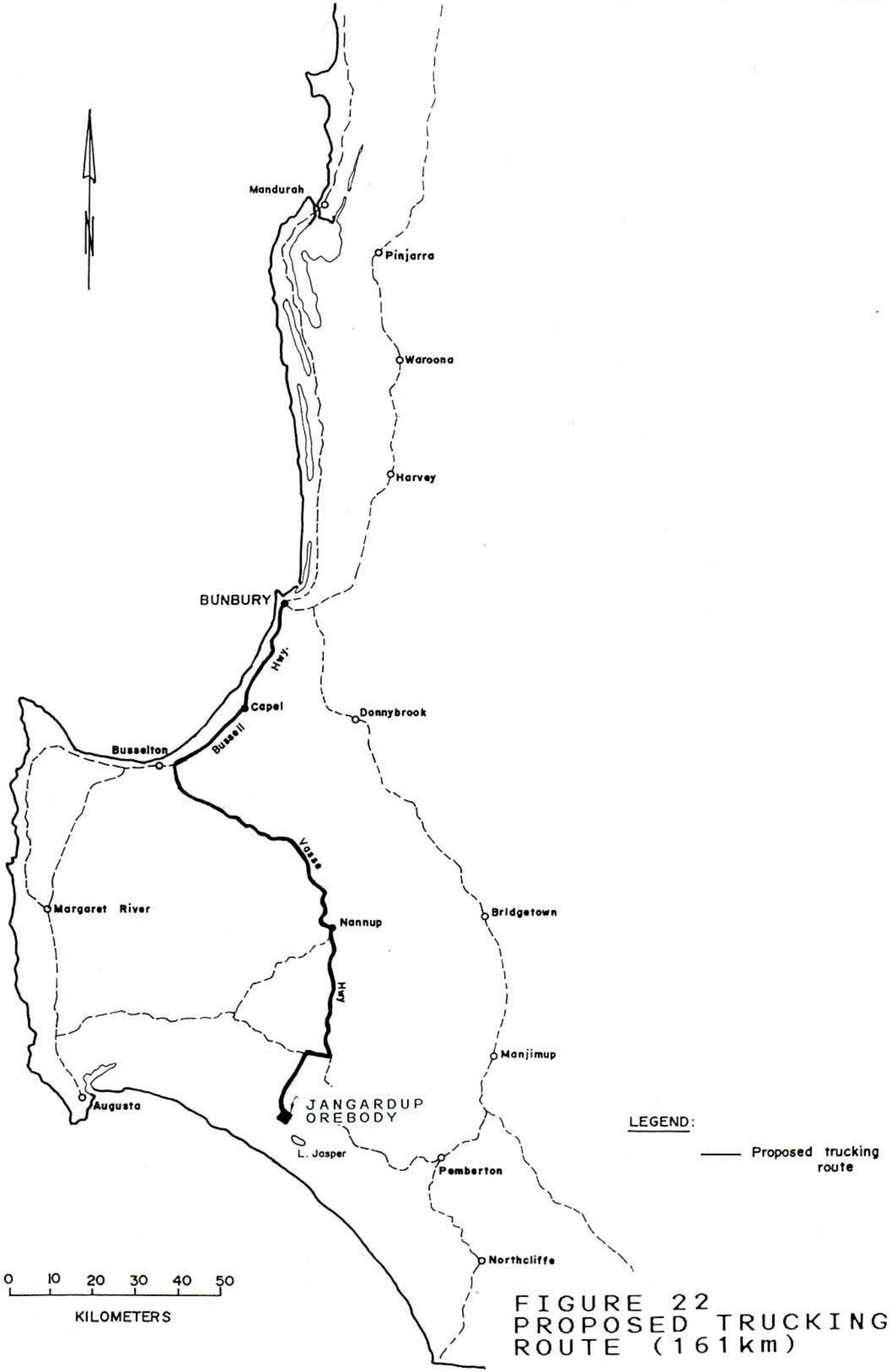


FIGURE 22
PROPOSED TRUCKING
ROUTE (161km)

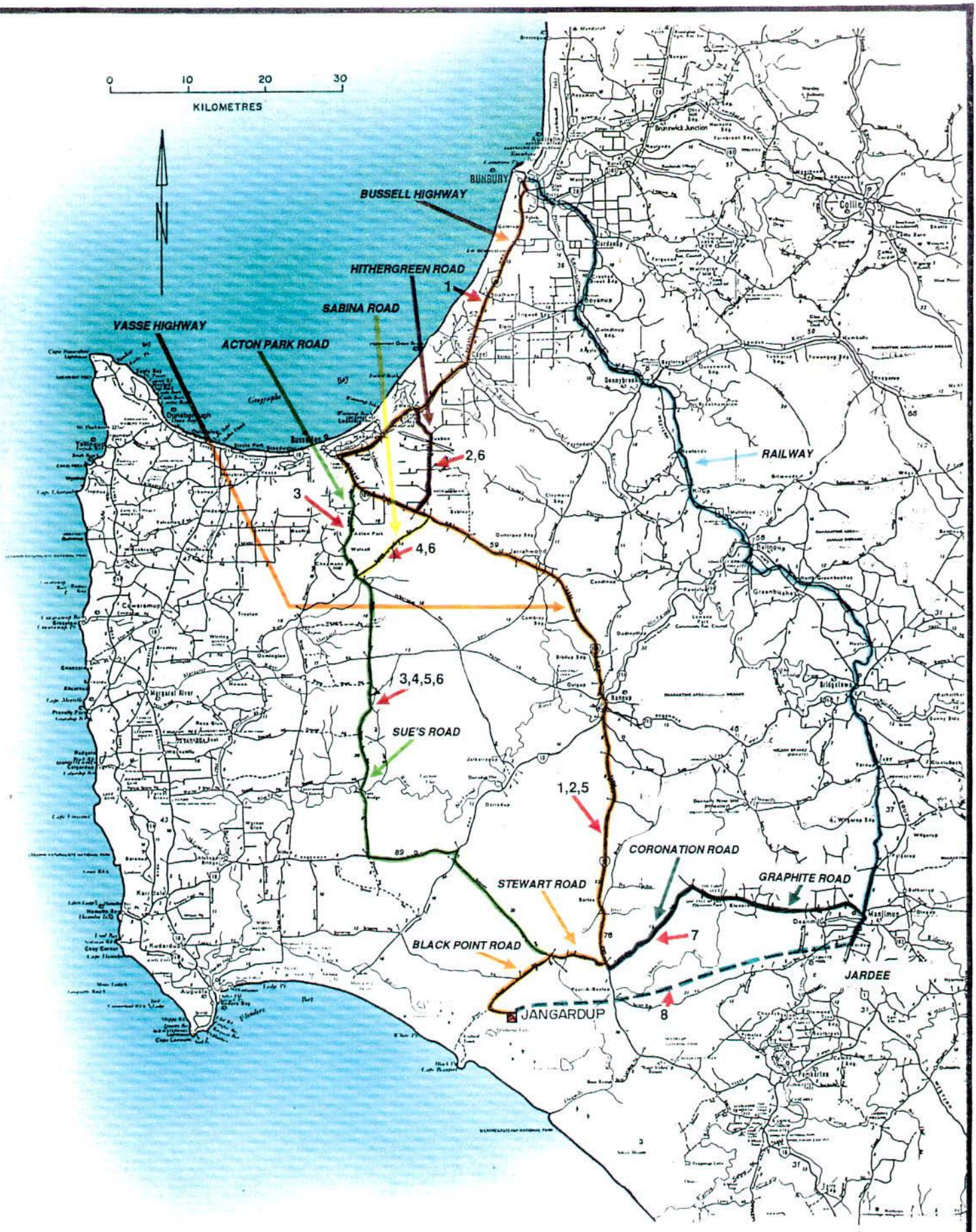


FIGURE 23
POSSIBLE
TRANSPORTATION
ROUTES AS PER
TABLE 14

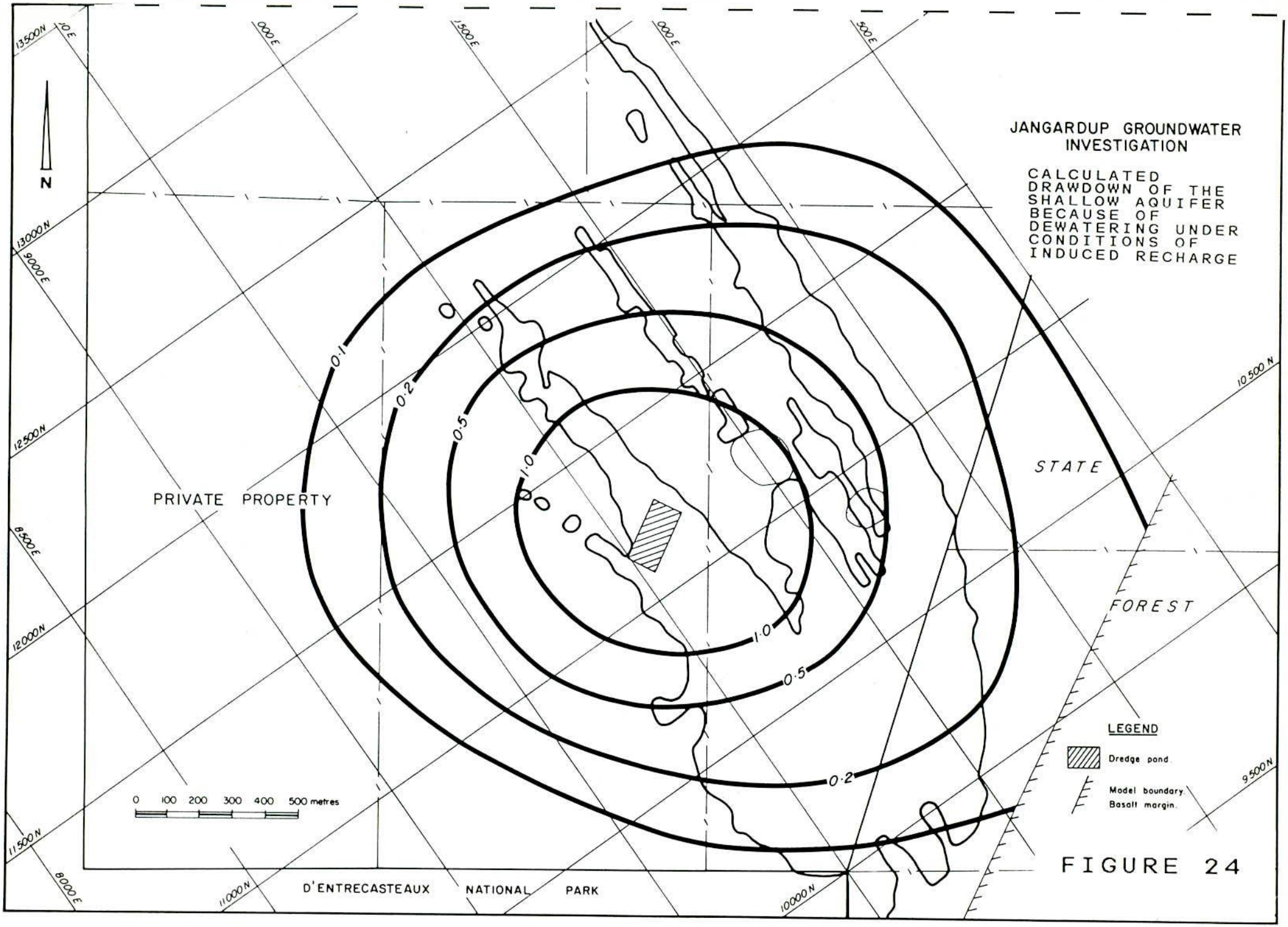

JANGARDUP GROUNDWATER INVESTIGATION
CALCULATED DRAWDOWN OF THE SHALLOW AQUIFER BECAUSE OF DEWATERING UNDER CONDITIONS OF INDUCED RECHARGE
N
PRIVATE PROPERTY
STATE FOREST
D'ENTRECASTEAUX NATIONAL PARK
0.1
0.2
0.5
1.0
1.0
0.5
0.2
0 100 200 300 400 500 metres
LEGEND
Dredge pond
Model boundary
Basalt margin
13500N
13000N
12500N
12000N
11500N
11000N
10500N
10000N
9500N
10E
000E
500E
000E
500E
9000E
8500E
8000E

FIGURE 24

TABLE 1

RAINFALL FOR PEMBERTON AND RAINFALL AND EVAPORATION FOR CAPE LEEUWIN

MEAN ANNUAL RAINFALL (mm) FOR PEMBERTON

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
MEAN AVERAGE	21	20	38	81	155	199	219	165	118	92	62	35	1205
HIGHEST MONTH	80	86	128	213	337	365	391	388	214	189	160	92	2643
LOWEST MONTH	1	1	5	6	36	89	130	50	45	13	6	3	385
HIGHEST ONE DAY	60.4	29.5	77.2	53.1	76.7	59.4	66.8	50.8	45.2	41.7	90.0	42.2	693
MEAN RAIN DAYS	6	6	8	12	18	20	22	21	18	16	12	9	168

Based on 33 years of data

MEAN RAINFALL (mm) AND EVAPORATION FOR CAPE LEEUWIN

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
RAINFALL	17	16	30	63	145	183	187	138	91	69	37	22	998
EVAPORAT.	140	130	110	65	50	25	25	40	50	80	100	150	965

Estimated from Bureau of Meteorology maps and data.

TABLE 2 SUMMARY OF SOIL TYPES

SOIL TYPE AND LOCATION	SOIL PROPERTIES
UPLANDS	
Basaltic soil complex (B):	duplex soils. A Horizon brown fine sandy clay loams, to 35cm. B Horizon grey massive fine clay.
Skeletal basaltic soil: loams and clays.	shallow, gravel and pebble strew, (Bs)
Sandy lateritic/ basaltic complex (Bx):	a mosaic of duplex soils, deep sands and foothill slope soils of variable depth.
Sandy Lateritic Soils (Lt):	white greyish, acid sands of variable depth with abundant inclusions over laterite.
Foothill slopes (fB):	freely drained deep white to greyish acid siliceous sands to over 100cm.
DUNES AND DRAINAGE PLAINS	
Sand Dunes (sd):	deep white and greyish acid infertile sands.
Podzols (hp):	A Horizon medium to fine grained, grey siliceous sands to about 60cm. B Horizon yellow to orange medium grained acid siliceous sands.
Humic podzols (lp):	poorly drained, frequently inundated sands. A Horizon dark grey and black acid sands above lighter grey sands to about 50cm. B Horizon gravelly fine and clayey sands, often with bands of clay.
Peaty Swamps (p):	juvenile peats of variable depth above poorly formed podzols; local drainage sumps.

TABLE 3 SUMMARY OF VEGETATION TYPES

CODE	VEGETATION TYPE	TALLEST STRATUM HEIGHT (m)	TALLEST STRATUM COVER (%)
1.0	**UPLANDS**		
1.1	Jarrah Forest	15-30	30-70
1.2	Jarrah Low Forest	5-15	30-70
1.3	Marri-Blackbutt Forest and Tall Forest	15-30	30-70
1.4	Dense Heath	1-2	30-100
2.0	**LOWER SLOPES AND DUNES**		
2.1	Jarrah-*Banksia* Low Woodland	<15	10-30
2.2	Jarrah Low Woodland	<15	10-30
2.3	Blackbutt Open Low Woodland	<15	2-10
3.0	**LOWLAND PLAINS AND SWAMP**		
3.1	Low Forests		
3.1.1	*Agonis juniperina* Low Forest	5-15	30-70
3.1.2	*Melaleuca preissiana* Low Forest	5-15	30-70
3.2	Thickets		
3.2.1	Dense Swamp Thicket	<2	70-100
3.2.2	Dense *Kunzea* Thicket	<2	70-100
3.3	Low Scrub-Heath Over Sedges	1-2	10-30
3.4	Open Scrub Over Heath	<1.5	2-10
3.5	Dense Low Heath	<1	70-100
3.6	Low Heath Over Sedges	<1	30-70
3.7	Tall Sedgeland	<0.5	30-70
3.7.1	*Baumea articulata* Tall Sedgeland	<0.5	30-70
3.7.2	*Baumea vaginalis* Tall Sedgeland	<0.5	30-70
3.8	*Leptocarpus* Low Sedgeland	<0.5	30-70

TABLE 4 VEGETATION IN RELATION TO TERRAIN AND SOILS

VEGETATION STRUCTURAL FORMATIONS	LANDFORMS AND SOILS							
	UPLANDS			LOWER SLOPES	FOOTHILL SLOPES AND DRAINAGE LINES	LOW DUNES	SEASONALLY WET PLAINS	SWAMP DEPRESSIONS AND LAKE MARGINS
	SANDY LOAMS, BASALTIC (B),(Bx)	SKELETAL SANDS OVER BASALT (Bs)	GRAVELLY SANDS LATERITIC (Lt)	LEACHED SANDS (fB)	COLLUVIAL SANDS (fB)	LEACHED SANDS (Sd)	PODZOLS (hp),(lp)	PODZOLS AND PEAT (lp),(p)
FOREST	Marri-Blackbutt Forest Jarrah Forest		Jarrah Forest	Jarrah Low Forest				Agonis juniperina Low Forest, Melaleuca preissiana Low Forest
WOODLAND					Blackbutt Open Low Woodland	Jarrah-Banksia Low Woodland Jarrah Low Woodland		
THICKET					Thicket			Thicket
SCRUB					Scrub-Heath		Low Scrub-Heath	Low Scrub-Heath Scrub Heath
HEATH		Dense Heath						Low Heath Dense Low Heath
SEDGELAND							Low Sedgeland	Tall Sedgeland Low Sedgeland

TABLE 5 VEGETATION TYPES SHOWING IMPACT OF AND SUSCEPTIBILITY TO DIEBACK

CODE	VEGETATION TYPE	IMPACT	SUSCEPTIBILITY
1.1	Jarrah Forest	Low	Low
1.2	Jarrah Low Forest	Moderate	Moderate
1.3	Marri - Blackbutt Forest and Tall Forest	Low	Low
1.4	Dense Heath	Not Known	Low
2.1	Jarrah - Banksia Low Woodland	High	High
2.2	Jarrah Low Woodland	Moderate	Moderate
2.3	Blackbutt Open Low Woodland	Not Known	High
3.1	Low Forests		
3.1.1	Agonis juniperina Low Forest	Not Known	High
3.1.2	Melaleuca preissiana Low Forest	Low?	High
3.2	Dense Thicket Formation		
3.2.1	Dense Swamp Thicket	Low?	High
3.2.2	Dense Kunzea Thicket	Low?	High
3.3	Low Scrub-Heath Over Sedges	Low?	High
3.4	Open Scrub Over Heath	Low?	High
3.5	Dense Low Heath	Low?	High
3.6	Low Heath Over Sedges	Low?	High
3.7	Tall Sedgeland	Low	High
3.7.1	Baumea articulata Tall Sedgeland	Low	High
3.7.2	Baumea vaginalis Tall Sedgeland	Low	High
3.8	Leptocarpus Low Sedgeland	Low	High

TABLE 6 DESCRIPTIONS OF FAUNA TRAP SITES

TRAP-SITE	VEGETATION TYPE	SOIL	LANDFORM
1	Heath and swamp thicket	Peaty podzol	Swamp
2	Jarrah-Banksia woodland	Sand	Dune
3	Jarrah-Banksia woodland, open scrub over heath	Sand	Dune
4	Open scrub over heath	Podzol	Wet plain
5	Transitional woodland over scrub heath	Sand	Base of slope
6	Marri-Blackbutt forest	Loam	Upland
7	Dense heath	Loamy clay	Upland
8	Low scrub-heath over sedges	Podzol	Wet plain
9	Low scrub-heath over sedges	Podzol	Wet plain
10	Jarrah forest	Sand	Upland
11	Low-heath over sedges	Podzol	Wet plain
12	Jarrah-Banksia low woodland	Sand	Dune
13	Swamp thicket	Peaty podzol	Drainage line
14	Dense swamp thicket	Peaty podzol	Lake margin
15	Dense swamp thicket	Peaty podzol	Lake margin
16	Jarrah-Banksia low woodland	Sand	Dune
17	Jarrah-Banksia low woodland	Sand	Dune
18	Edge of Jarrah forest	Sand	Base of slope
19	Jarrah forest	Sand	Upland
20	Jarrah forest (disturbed)	Sand	Upland

TABLE 7

AMPHIBIANS AND REPTILES RECORDED BY PIT TRAPPING OR OBSERVATION

OBS = Seen but not trapped

SPECIES	NOVEMBER 1987 TRAP-LINE															MAY 1988 TRAP-LINE										GRAND TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	OBS	TOTAL	14	15	16	17	18	19	20	OBS	TOTAL	
Frogs																										
Crinia georgiana	4	3			1	2	1			4			3		18		1	1	1	1	1	2		7	25
Geocrinia leai		2		1	2			1					3		9	3	4	2	1	1	1			12	21
Heleioporus eyrei										2					2									-	2
Heleioporus psammophilus	2	4	4	16	2	1	4	4	14	7	14	11	14		97	1	1	6			1	7		16	113
Litoria adelaidensis			2							1				14	17									-	17
Lymnodynastes dorsalis															-								1	1	1
Pseudophryne guentheri									1			2			3							3		3	6
Pseudophryne nichollsi										1					1									-	1
Ranidella glaverti	3		1	2	2			5	2		21	3	10	1	50	1		1				3		5	55
Tortoises																									
Chelodina oblonga														1	1									-	1
Lizards																									
Phyllodactylus marmoratus															-								1	1	1
Ctenotus catenifer	1	1		1					3		6	2	1	3	18									-	18
Ctenotus labillardieri	1	2	4	1	1	1	1	1	2	4			1	18	37								1	1	38
Egernia luctuosa									1					1	2									-	2
Egernia napoleonis		1			1		1	1						1	5									-	5
Hemiergis peronii	1				1	2	2			1					7								4	4	11
Leiolopisma trilineatum		13	3	5	3	3	2	2	6	4	1	2	2	7	53						1	3	9	13	66
Lerista microtis														1	1									-	1
Sphenomorphus australis	2	1		7				3	4		3		3	1	24									-	24
Tiliqua rugosa								1			1	1		1	4							1		1	5
Varanus rosenbergi														1	1									-	1
Snakes																									
Ramphotyphlops australis		1							1					2	4								1	1	5
Notechis coronatus			1					1						8	10								4	4	14
Notechis scutatus														1	1									-	1
Pseudonaja affinis					1									1	2									-	2
Rhinoplocephalus bicolor														1	1									-	1

TABLE 8

BIRDS RECORDED ON PRIVATE PROPERTY, OR IN STATE FOREST AND THE D'ENTRECASTEAUX NATIONAL PARK, DURING 1987 AND 1988

SPECIES		PRIVATE PROPERTY				STATE FOREST AND NATIONAL PARK			
		AUG 1987	NOV 1987	FEB 1988	MAR 1988	AUG 1987	NOV 1987	FEB 1988	MAY 1988
Emu	Dromaius novaehollandiae	*	*	*	*	*	*		
Little Pied Cormorant	Phalacrocorax melanoleucos								
White-faced Heron	Ardea novaehollandiae	*	*	*					
Straw-necked Ibis	Threskiornis spinicollis	*							
Black Swan	Cygnus atratus	*							
Chestnut-breasted Shelduck	Tadorna tadornoides	*			*				
Australian Wood Duck	Chenonetta jubata					*			
Musk Duck	Biziura lobata	*							
Black Duck	Anas superciliosa		*						
Wedge-tailed Eagle	Aquila audax			*			*		
Swamp Harrier	Circus aeruginosa	*	*		*				
Brown Falcon	Falco berigora		*		*			*	
Little Falcon	Falco longipennis						*		
Peregrine Falcon	Falco peregrinus				*				
Nankeen Kestrel	Falco cenchroides	*		*			*		
Stubble Quail	Coturnix pectoralis		*	*			*		
Common Bronzewing	Phaps chalcoptera		*		*		*	*	*
Red-tailed Black Cockatoo	Calyptorhynchus magnificus		*		*	*	*		*
White-tailed Black Cockatoo	Calyptorhynchus sp.	*			*		*	*	
Purple-crowned Lorikeet	Glossopsitta porphyrocephala					*		*	*
Red-capped Parrot	Purpureicephalus spurius							*	
Western Rosella	Platycercus icterotis				*			*	*
Ringneck Parrot	Barnardius zonarius						*		*
Rock Parrot	Neophema petrophila	*							
Pallid Cuckoo	Cuculus pallidus			*	*		*		
Fan-tailed Cuckoo	Cuculus pyrrhophanus					*			*
Horsfield's Bronze-cuckoo	Chrysococcyx basalis						*		
Golden Bronze-cuckoo	Chrysococcyx lucidus	*				*	*		
Laughing Kookaburra	Dacelo novaeguineae	*	*	*	*	*	*	*	
Sacred Kingfisher	Halcyon sancta			*				*	
Welcome Swallow	Hirundo neoxena	*	*		*			*	
Tree Martin	Cecropis nigricans	*	*	*		*	*	*	
Richard's Pipit	Anthus novaeseelandiae	*	*	*			*		
Black-faced Cuckoo-Shrike	Coracina novaehollandiae	*	*	*	*	*	*	*	
White-winged Triller	Lalage sueurii			*			*		
Scarlet Robin	Petroica multicolor			*	*	*	*	*	*
White-breasted Robin	Eopsaltria georgiana		*	*					
Golden Whistler	Pachycephala pectoralis						*		*
Grey Shrike-thrush	Colluricincla harmonica					*	*		
Grey Fantail	Rhipidura fuliginosa	*		*	*	*	*	*	*
Willie Wagtail	Rhipidura leucophrys	*	*	*	*		*	*	
Splendid Wren	Malurus splendens		*				*	*	
White-browed Scrubwren	Sericornis frontalis				*		*	*	
Western Warbler	Gerygone fusca			*			*	*	
Inland Thornbill	Acanthiza apicalis			*		*	*		*
Western Thornbill	Acanthiza inornata						*	*	*
Yellow-rumped Thornbill	Acanthiza uropygialis	*	*	*	*		*	*	
Varied Sittella	Daphoenositta chrysoptera						*		
Red Wattlebird	Anthochaera carunculata	*		*		*	*	*	
Little Wattlebird	Anthochaera chrysoptera						*		
Brown Honeyeater	Lichmera indistincta						*		
New Holland Honeyeater	Phylidonyris novaehollandiae			*	*	*	*	*	*
Tawny-crowned Honeyeater	Phylidonyris melanops	*	*			*	*	*	
Western Spinebill	Acanthorhynchus superciliosus			*	*	*	*	*	*
White-fronted Chat	Epthianura albifrons	*	*	*	*		*		
Striated Pardalote	Pardolotus substriatus						*		
Silvereye	Zosterops lateralis				*		*	*	*
Red-eared Firetail	Emblema oculata								*
Dusky Woodswallow	Artamus cyanopterus	*	*	*	*	*	*	*	*
Magpie Lark	Grallina cyanoleuca	*	*	*	*		*		
Grey Currawong	Strepera versicolor		*		*	*	*	*	*
Grey Butcherbird	Cracticus torquatus	*		*			*	*	*
Australian Magpie	Gymnorhina tibicen	*	*	*	*				
Australian Raven	Corvus coronoides	*	*	*	*	*			*

TABLE 9 MAMMALS RECORDED BY TRAPPING OR OBSERVATION

A. Trapping

SPECIES	NOVEMBER 1987 TRAP-LINE														MAY 1988 TRAP-LINE								
	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	14	15	16	17	18	19	20	TOTAL	GRAND TOTAL
Honey Possum Tarsipes rostratus		2	2		2		1				1			8								-	8
Sminthopsis griseoventer		2	1				1			2	1			7		1	4				4	9	16
House Mouse Mus musculus		1					1			2				4			1					1	5
Bush Rat Rattus fuscipes	1												1	2	1							1	3

B. Observation

SPECIES	ABUNDANCE
Grey kangaroo, Macropus fuliginosus	Common
Brush-tailed Wallaby, Macropus irma	One seen
Feral pig, Sus scrofa	Two groups seen
Fox, Vulpes vulpes	Occasional
Dingo/Dog, Canis familiaris	Tracks common

TABLE 10

PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER BODIES

NO.	DESCRIPTION	SIZE	SUBSTRATE	pH	CONDUCTIVITY us/cm	COLOUR	TOTAL P ug/l	TOTAL N ug/l	CHLOROPHYLL A ug/l
1	Seasonal pool on drainage line in thickets	50m along track 300mm deep	Muddy sand	6.06	409	Yellow	<1	723	37
2	Circular lake with fringing thickets and paperbarks above sandy beach. Dries in summer	150m diameter, greater than 1m deep?	Peaty mud	4.14	354	Yellow/ brown	6.32	1678	32
3	Same as 2	250m diameter, greater than 1m deep?	Peaty mud	4.47	380	Yellow/ brown	13.9	1090	51
4	Seasonal water-bodies much divided into pools of various sizes	50m long, typically less than 20cm deep	Sand	4.82	522	Yellow/ brown	31.58	698	53

TABLE 11 AQUATIC INVERTEBRATES AND FISH RECORDED IN FOUR WATER-BODIES

* = < 10 specimens ** = 11-100 specimens
*** = 101-1000 specimens **** = 1000+ specimens

TAXON	COMMON NAME	SITE 1	SITE 2	SITE 3	SITE 4
ARTHROPODA					
CRUSTACEA					
Cladocera	Water Flea				
Moinidae sp.		**			*
Chydoridae sp.			*	**	
Copepoda					
Calanoida sp.		***	****	**	**
Cyclopoida sp.				**	
Harpacticoida sp.				****	
Ostracoda					
Alboa wooroa		**			*
Amphipoda					
Perthia sp.		*			
Perthia acutitelson			*	**	*
Isopoda					
Paramphisopus palustris		*			
Decapoda					
Cherax quinquecarinatus	Gilgie				*
ARACHNIDA					
Araneae					
Species 1	Aquatic Spider				*
Species 2	Aquatic Spider	*			
Species 3	Aquatic Spider	*			
Species 4	Aquatic Spider	*			
Species 5	Aquatic Spider	*			
Species 6	Aquatic Spider	*			
Species 7	Aquatic Spider	**			
Species 8	Aquatic Spider	*			
Species 9	Aquatic Spider	*			
Species 10	Aquatic Spider			*	
Species 11	Aquatic Spider		*		
Acarina					
Orabatidae		*	*		
Hydracarina					
Hydracarina sp. 1	Water Mite				*
Hydracarina sp. 2	Water Mite	*			
Collembola					
Collembola sp. 1		*			

Collembola sp. 2			*		
INSECTA					
Odonata					
Hemicordula tau	Dragonfly (nymph)				*
Hemianax papuensis	Dragonfly (nymph)		*		
Austrolestes analis	Damselfly (nymph)	*	*	*	
Austrolestes io	Damselfly (nymph)			**	
Hemiptera					
Diaprepocoris sp.	Waterboatman			**	**
Sigara mullaka	Waterboatman	**	*	**	**
Anisops thienemanni	Backswimmer	*	**	*	**
Nychia sp.	Backswimmer		**	**	
Veliidae sp.1	Waterbug	*			
Vellidae sp.2	Waterbug		**		
Mesoveliidae sp.	Waterbug		*		
Coleoptera					
Sternopriscus sp.	Aquatic Beetle(adult)	*		*	*
Hydrochus sp.	Aquatic Beetle(adult)	*			
Paracymus pygmaeus?	Aquatic Beetle(adult)	*			
Hydrophilidae	Aquatic Beetle(adult)	*	*		
Sternopriscus sp.	Aquatic Beetle(larvae)	*			*
Antiporus femoralis	Aquatic Beetle(larvae)	*			
Cybister tripunctatus	Aquatic Beetle(larvae)	*			
Cybister sp.	Aquatic Beetle(larvae)		*		
Hydrophilidae sp. 1	Aquatic Beetle(larvae)		*		
Dytiscidae sp. 1	Aquatic Beetle(larvae)	*			
Diptera (larvae)					
Ceratopogonidae	Sandfly	*			*
Chironomidae	Midges				
Limnophyes pullulus		***	**	**	*
Pentaneura levidensis		***	**	**	**
Procladius villosimanus		*			*
Chironomus alternans		*			
Dicrotendipes conjunctus			*		
Tanytarsus fuscithorax			*		*
Paraborniella tonnoiri					*
Trichoptera (larvae)					
Hellyethira litua	Caddisfly	*		*	
Triplectides australis	Caddisfly		*		*
Leptoceridae sp.	Caddisfly			*	
TOTAL NUMBER OF SPECIES		35	21	17	20
VERTEBRATA					
Pisces					
Lepidogalaxias salamandroides	Salamanderfish	*			
Galaxiella nigrostriata	Black-stripe Minnow	*			*

TABLE 12 CHEMICAL PROPERTIES OF WATER SAMPLED IN FEBRUARY 1989

AQUIFER:	YARRAGADEE FORMATION	LAKE	SHALLOW AQUIFER		
TEST HOLE:	J1		CS2	CS3B	CS3P
DEPTH (m)	184		3.74	1.39	17.6
	---------- mg/l ----------				
Calcium	2	6	3	3	2
Magnesium	4	9	9	4	7
Sodium	32	77	66	30	54
Potassium	1	4	2	2	1
Iron	1.2	ND	1.0	2.6	1.4
Manganese	<0.02	ND	<0.01	<0.01	0.02
Bicarbonate	7	5	0	0	12
Sulphate	10	33	36	10	11
Chloride	56	120	105	56	99
Nitrate	<1	<1	<1	<1	<1
Silica	10	ND	ND	ND	8
TOTAL DISSOLVED SOLIDS (SUM.)	122	254	222	108	194
CONDUCTIVITY (mS/cm) (at 25°C)	0.220	0.407	0.383	0.190	0.370
pH	5.1	5.10	4.35	4.10	5.1

ND = not determined

TABLE 13 EMPLOYMENT IN THE SHIRES OF NANNUP AND MANJIMUP (AUSTRALIAN BUREAU OF STATISTICS, 1986 CENSUS).

INDUSTRY	NANNUP	MANJIMUP	TOTAL	(%)
Agriculture, forestry, fishing and hunting	189	1134	1323	(31%)
Manufacturing	84	888	972	(23%)
Wholesale and retail trade	37	563	600	(14%)
Community Services	64	531	595	(14%)
Recreational, personal and other services	17	160	177	(4%)
Finance, property and business services	18	104	122	(3%)
Construction	8	114	122	(3%)
Transport and storage	10	103	113	(3%)
Public administration, defense	22	89	111	(3%)
Communication	4	40	44	(1%)
Electricity, gas, water	2	28	30	(1%)
Mining	2	5	7	(0.2%)
TOTAL	457	3759	4216	

TABLE 14 COST ESTIMATES (IN 1989 DOLLAR VALUES PER TONNE) OF TRANSPORTATION BY ALTERNATIVE ROUTES AND VEHICLES BASED ON PAYLOADS OF 38 TONNES

OPTION	HIGHWAYS AND ROADS	DOLLARS
1	Major public roads via Nannup, along Vasse and Bussell Highways, 161 kms	10.35
2	Most direct roads via Nannup, Vasse Highway, Hithergreen Road to Ludlow, Bussell Highway 149 km	10.12
3	Sue's Road, entering Vasse Highway from Acton Park Road, 167 km	12.19 (Sue's Rd sealed) 12.46 (Sue's Rd unsealed)
4	Sue's Road entering Vasse Highway from Sabina Road, 181 km	12.39 (Sue's Rd sealed) 12.63 (Sue's Rd unsealed)
5	Loaded through Nannup, return empty along Sue's Road, 180 km	14.21
6	Sue's, Sabina and Hithergreen Roads to bypass Ludlow, Bussell Highway 160km	12.59 (Sue's Rd sealed) 12.42 (Sue's Rd unsealed)
7	Coronation and Graphite Roads to Jardee then rail to North Shore, Bunbury	17.18
8	New Crown road to Jardee, then rail to North Shore Bunbury (Westrail operation)	19.33

OPTION	VEHICLE	NET TONNAGE	LOADS PER DAY	HOURS PER DAY	DOLLARS PER TONNE
1	Road train	46	23	13	9.56
2	8 wheeled truck with triaxle dog trailer	42	25	13	9.84
3	8 wheeled truck with dual axle dog trailer	38	28	13	10.35
4	Single tray	23	46	24	12.21
5	Truck and rail	530	2	13	17.18
6	Rail on crown land	530	2	13	19.33

APPENDIX A

Proposed Jangardup heavy minerals operation
EPA Guidelines* for an Environmental Review and Management Programme (ERMP)

* These guidelines may be amended if a joint State-Commonwealth environmental assessment is necessary by virtue of the Commonwealth's Environment Protection (Impact of Proposals) Act applying to the project through, for example, the requirement for export approval.

SUMMARY

This section should contain a clear and concise summary of the salient features of the proposal, existing environment, the magnitude and extent of environmental impacts and environmental safeguards and management.

1. INTRODUCTION

This section should include:

- background and objectives of the proposal,
- details of the proponent,
- why the document has been prepared,
- scope and timing of the proposal,
- other existing mineral sand mining operations, and
- relevant legislative requirements and approval processes (State and Commonwealth).

2. NEED FOR PROPOSAL

This section presents an opportunity for the proponent to describe in a general way the broad costs and benefits of the project to the Company and community. These should be described at local, State and National levels.

3. THE PROPOSAL

The document should provide descriptions of the various components of the development, and should also cover the various stages from site preparation through to decommissioning as well as covering operational aspects, such as overburden handling and ore transport. Auxiliary services, such as power and water supply, should also be described. matters to discuss would include:

- description of mineral deposits and exploration,
- the mining operation including rehabilitation,
- on-site mineral concentration,
- secondary concentration,
- project infrastructure,
- transport,

- water supply, and

- sewage treatment.

Where there are in-build environmental controls of safeguards as part of the project design, they should be described as part of the proposal, and cross-referenced in the later environmental management discussion.

As rehabilitation will be a key part of the project, it can either be considered as a separate issue or integrated into the various project components.

4. EVALUATION OF ALTERNATIVES

The evaluation of alternatives should demonstrate to the reader how choices on location, technology, techniques, etc, have been proposed as to protect the environment. A description should be given of how the proposal has developed and the degree to which development alternatives have been examined.

Consideration of alternatives should be integrated throughout the document as well. For example consideration of alternative environmental management proposals should demonstrate their consequences on potential environmental impacts. As such this would be best discussed in the environmental management section.

Special attention should be given to the discussion on alternative options in respect to:

- mining and mineral processing techniques,

- rates of production and project development,

- mine site rehabilitation, in particular end landuse,

- water supply,

- ore transportation, and

- land tenure.

When alternatives are rejected, the factors which led to their rejection should be clearly identified.

The aim of this section is to lead the reader through the thought processes which led to the desired proposal, and to outline the factors which control its present form.

5. EXISTING ENVIRONMENT

This section should provide an overall description of the environment and an appraisal of the physical and ecological

systems likely to be affected by all aspects of the proposal, but should concentrate on the significant aspects of the environment subject to potential impact from the development. Only the habitats, resources and potential resources which could be influenced by the project should be described. Excessive descriptions which are irrelevant to the impact of the proposal tend to detract from the document.

Discussion of the regional situation within which the project site is situated should be provided before discussing the project site. Conceptual models or diagrams could be provided to illustrate and synthesize the interactions between the physical and biological aspects of the habitats and resources discussed.

In particular, the aspects of the environment relevant to, or impacted by mining, transport links, mineral processing and project work force should be discussed. A good understanding of the local meteorology, soils and geology, landuse, groundwater and biota and their interaction with existing water resources, levels of dust and other possible pollutants, including radionuclides, should be demonstrated for the mine, work force accommodation, transport corridor and port. It is important to consider the conservation status of flora, and fauna.

Discuss the physical biological processes which maintain the various habitats and resources. Assess the resilience of these habitats and resources to natural and man-made pressures, particularly with regard to the incidence of and forest susceptibility to dieback disease.

The discussion of the human environment should include information on landuse and planning, features and sites of cultural and scientific interests including any historical, archaeological or ethnographic sites. Also, infrastructure and public and private utilities and facilities, should be considered.

6. ENVIRONMENTAL IMPACTS

The proposal will impact on some aspects of the environment, and it is necessary to discuss the individual impacts and then synthesize these so as to show the overall effect on the total environment. This is necessary for two reasons: firstly, to allow the reader of the document to draw conclusions on whether the proposal is environmentally acceptable, and secondly, to show that management programmes can be devised for various aspects of the proposal to manage potential impacts.

Consideration should be given to both the long-term and short-term effects of the project development and operation at the various locations where the project and associated activities may significantly impact on the environment.

A thorough evaluation of the hydrological, and botanical impact, including potential for spread of Phytophthora pathogens, of the proposal should be provided. Discuss effects of project and associated population on the existing environment, including any archaeological, ethnographic and heritage aspects, existing local population, and proposed or existing nature conservation areas.

As part of the area proposed to be mined is within State Forest assessment of the area's values with respect to the management priority will be required.

This section should show the overall effect of the proposal on the total ecosystem and surroundings of the area. It will be necessary to address the impacts on the individual environmental components before a final overall synthesis can be made. In all cases where an assessment is made the criteria employed to assess impacts should be clearly stated. Wherever possible effects should be quantified and uncertainties highlighted. The synthesis should also include an assessment of the significance and timing of the various impacts identified. For example:

- it may be useful to examine construction impacts separately from operational and decommissioning impacts, and

- some of the infrastructure elements (such as the power supply) will have little or no ongoing interaction with the environment once they are established.

7. ENVIRONMENTAL MANAGEMENT

An environmental management programme should be described on the basis of (and cross-referenced to) the synthesis of environmental impacts previously outlined. The objectives, the scope and details of the programme should be described. Assignment of responsibility for environmental management structure should also be stated and commitments given.

It will be essential to discuss the proposed management programme in relation to current practice elsewhere in WA and Australia for various aspects of the proposal. A description of research programmes that would provide information on the means of rehabilitation should be included in this section.

Emphasis should be given to as to how the environmental management programme will be adapted to response to results from the monitoring programme.

The procedures for reporting results of monitoring and environmental management to the appropriate authorities should be provided. Also summarize and, where necessary, detail management commitments described in this and earlier sections.

8. CONCLUSIONS

Conclusions of the overall impact of the proposal (including the role of ameliorative measures) should be stated together with an assessment of the environmental acceptability of the project.

9. SUMMARY OF ENVIRONMENTAL MANAGEMENT COMMITMENTS

Environmental management commitments should be summarised and numerically listed in this section.

10. REFERENCE (BIBLIOGRAPHY/ABBREVIATIONS)

. Glossary

Provide definitions of technical terms used. Also define and explain units of measurement which may not normally be understood by the interested layman.

. ERMP Guidelines

Guidelines which have been approved by the EPA should be reproduced in the document.

APPENDIX B

Descriptions of soil types

UPLANDS

Basaltic soil complex (B)

Landform and location

Low, rounded ridge lying north-south standing up to 25 metres above the adjoining sandy drainage plains, about 2.5km long and up to 800m wide though locally constricted, lateritised in part.

Drainage and use

Forms the watershed between plains on each flank of the Jangardup area, run-off water dispersing into these sandy tracts. It is uncleared land within the State Forest.

Soil profiles

Duplex soils predominate in the basaltic complex. A typical profile would be:-

A Horizon: Surface to 25/35cm

Fine, sandy, clay loam tending to massive.
Colour brown 7.5YR 3/4
Slightly acid pH 6.1.

A sharp discontinuity to -

B Horizon: 25/35cm+

Massive, fine clay tending to apedal.
Colour grey 10YR 5/1
Clay tending to neutrality, pH 6.0 to 6.5

Skeletal basaltic soils (Bs)

Landform and location

Isolated patches occurring near the crest of the rounded basaltic ridge.

Drainage and use

The crests shed water onto adjacent Marri-Blackbutt forest. The unit is restricted to the State Forest.

Soil profiles

Shallow, brown sandy loam soils with basaltic and lateritic strew over basalt at shallow depth.

Sandy lateritic basaltic complex (Bx)

This complex of soils with basaltic and lateritic influences occurs on the margins of the basaltic uplands. It forms the connecting link between the higher land and the lower drainage plains in all but the northern sector of the ridge.

Drainage and use

Freely drained sandy soils are found with basaltic soils of characteristically sluggish drainage. The soils are contained within the State Forest and have not been developed for agriculture.

Soil profiles

Duplex soils resembling those on the basaltic soil complex are common. Other soils include those found on the foot hill slopes, laterites and in the higher drained plains.

The duplex soils are well developed and a characteristic profile would be:

A Horizon: Surface to 25cm

Fine sandy clay with limited pedal development
Yellow-grey 10YR 5-1 Yellow 10YR 4-2
Acid soils pH 5.5
Organic matter staining in the surface layers.

B1 Horizon: 25cm+

Gritty clay loam.
Weak pedal development
Red-brown 5YR 4/3 2.5YR 3/4
Fine gritty inclusions in this horizon.

Sandy lateritic soils (Lt)

Landform and location

Level to gently rounded plains and rises developed on lateritic profiles.

Drainage and use

Well drained sands, not used for agriculture, contained within the State Forest.

Soil profiles

A Horizon: Surface to 5-20cm.

Medium to coarse grained siliceous sand
Apedal, single grained, sandy fabric

Colour light grey 10YR 4/3
Acid sands pH 5.5
Abundant inclusions: gravels, water-worn quartz.

Some sites have heavy un-decomposed organic matter in the surface layers.

A2 Horizon: 5-20cm to variable depth to lateritic layers.

Medium to coarse grained siliceous sand
Apedal, single grained, sandy fabric
Colour whitish 10YR 8-1
Acid to neutral pH 5.0 to 7.0

Foothill slopes (fB)

Landform and location

Sandy plains and slopes marginal to and subtending to basaltic ridge. Sandy soils probably originating from aeolian deposits from the dunes further south.

Drainage and use

Freely drained soils receiving run-on from the ridge slopes above, not used for agriculture and occurring principally in the State Forest.

Soil profile

A1 Horizon: Surface to 20/30cm

Medium to fine sand.
Apedal, single grained with sandy fabric
Mid grey to light grey 2.5YR 4.0 10YR 5/2
Acid sands pH 4.8 - 5.2
Containing much fine un-decomposed root material in the surface 4cm.

A2 Horizon: 20/30cm to 120cm+

Medium to fine grained sand.
Apedal, single grained with a sandy fabric
Light grey to creamy white 10YR 5.2 10YR 8/1
Acid sand pH 5-6.
Some increase in yellowing with depth to 10YR 7/6 possible above secondary rocks. Virtually free of organic matter.

DUNES AND DRAINAGE PLAINS

Sand dunes (Sd)

Landform and location

Low sandy rises or linear dunes on the otherwise flat or slightly undulating plain. They are up to 150m wide and vary in length from about 300m to almost two kilometres. They rise up to 20 metres above the plain, but are generally much less. They generally have gentle side slopes.

Drainage and use

The rises are well drained compared to the plain and not used for agricultural purposes.

Soil profiles

A1 Horizon: Surface to 25cm

Medium to fine grained siliceous sand, apedal, single grained, sandy fabric.
Light grey to dark grey 2.5YR 4.0 to 2.5YR 3.2.
Acid sands pH 4.7 to 5.0.
Free of stones, and variable in organic matter content.

A2 Horizon: 25cm +

Medium to fine grained siliceous sand, apedal, single grained, sandy fabric.
White 10YR 6/1 to light grey 10YR 5/2
Acid sands pH 4.8 to 5.2
Free of stones, and almost devoid of organic matter.

Podzols (hp)

Landform and location

Extensive flats, level to very gently undulating with relief less than one metre, occurring above the humic podzols of the lower drainage plains. Developed extensively on the west and extending on the east of the basalt ridge into the State Forest.

Drainage and use

Poorly drained in winter and may be submerged, little organised drainage, principally sheet flow. Generally cleared on the farmland, but areas in the adjoining State Forest are not cleared. Used for cattle grazing and late summer cereal production.

Soil profiles

A1 Horizon: Surface to 20cm

Medium to fine grained siliceous sand
Apedal, single grained, sandy fabric
Grey 2.5YR 4/0 to dark grey 10YR 2.2.
Acid sands pH 4.9 to 5.0

A2 Horizon: 20cm to 30/75cm

Medium to fine grained siliceous sand
Apedal, single grained, sandy fabric
Light grey 10YR 5/2
Acid sands pH 5.
Almost free or organic matter
Sharp discontinuity to:

B1 Horizon: from 30/75 to 70/100cm

Medium to coarse grained clayey sand.
Apedal, single grained, sandy fabric,
Yellow to brown 10YR 5/8 10YR 3.4
Acid sands pH 5.7
Grading to:

B2 Horizon: 70/100cm+

Coarse grained sand with sub-rounded and sub-angular inclusions. (Often fine coffee rock)
Dark yellow and yellow 10YR 4.6 10YR 3.4
Slightly acid pH 6.1 to 6.3.

A discontinuous "coffee rock" horizon occurs at variable depth beneath the A Horizon in the podzol group and lies above the B Horizon. The distribution was not mapped.

Humic podzols (lp)

Landform and location

Low lying, poorly drained plains often serving as internal drainage foci, slightly undulating to level, relief less than one metre, an element of the extensive flat drainage plains in the western half of the area.

Drainage and use

Very poorly drained with no organised through drainage, watertable close to the surface in summer (about 60-75cm) and almost certainly above the surface for extended periods in the winter. Used for cattle grazing on summer moist pastures.

Soil profiles

A1 Horizon: Surface to 50/70cm.

Immediate surface often bleached white with clearing of vegetation.
Medium to coarse grained, sandy fabric
Apedal, single grained, sandy fabric
Dark grey to black 10YR 3/1 to 10YR 2/1
Acid sands pH 4.0 to 5.5
Very abundant organic matter.

A2 Horizon: 50/70cm to 75/130cm

Medium to coarse grained siliceous sand
Apedal, single grained, sandy fabric
Mid grey to light grey 10YR 2/2 10YR 2/1
Acid sands pH 4.6 to 5.2

B1 Horizon: 75/130cm

Gravelly, fine or clayey sand with smooth quartz pebbles, some bands of clay.
Mostly apedal, single grained.
Dark brown to black 2.5YR 3/2 10YR 2/2 10YR 2/1
Acid sands pH 4.2 to 5.2

Peaty sumps (p)

Landform and location

Two distinctive, circular, peaty drainage sumps occur within the drainage plains west of the basaltic ridge.

Drainage and use

The sumps receive drainage from their associated higher plains and are inundated for most of the year.

Land surfaces emerge only at the end of the summer in dry years.

Soil profiles

The soil profiles in these small soil units were not recorded. The soils consist of peaty deposits of variable depth. They crack slightly in drying. The profile gradually changes to brownish/black peaty podzols.

APPENDIX C

Descriptions of the vegetation types

1.0 UPLANDS

1.1 Jarrah forest

Dominant stratum: Eucalyptus marginata (Jarrah), Eucalyptus calophylla (Marri)

Height: 15-30m

Cover: 30-70%

A second stratum of low trees is formed by Banksia grandis, Allocasuarina fraseriana, Persoonia longifolia and Xylomelum occidentale. An understorey of tall shrubs typically includes Leucopogon verticillatus, Xanthorrhoea preissii, Petrophile diversifolia, Acacia myrtifolia, Acacia browniana and Acacia extensa. The lowest stratum of shrubs and herbaceous perennials includes Hypocalymma robustum, Hibbertia amplexicaulis, Podocarpus drouyanianus, Agrostocrinum scabrum and Patersonia occidentalis.

Jarrah is dominant on the more gravelly soils, while Marri becomes co-dominant or dominant on the deeper sandy loam soils overlaying gravel or clay.

This vegetation occurs on the lateritic gravelly sands and sandy loams in the north east section of the State Forest.

1.2 Jarrah low forest

Dominant stratum: Eucalyptus marginata, Banksia grandis, Allocasuarina fraseriana

Height: 5-15m

Cover: 30-70%

The understorey is predominantly that of the Jarrah Forest, although elements of adjacent lowland communities also occur.

This vegetation occurs on the sandier soils of lower slopes, and usually fringes lowland swamp or plains formations.

1.3 Marri-Blackbutt forest and tall forest

Dominant stratum: Eucalyptus calophylla, Eucalyptus patens (Blackbutt)

Height: 15-30m

Cover: 30-70%

Marri forest which is variably mixed with Blackbutt occurs on loamy soils associated with a basalt ridge in the southern section of the State Forest.

There is a tall shrub understorey which often forms a dense thicket, and includes Acacia browniana, Acacia divergens, Acacia pulchella, Tremandra stelligera and Thomasia pauciflora. Shrubs of the lower strata are common to the Jarrah Forest understorey. Typical species are Macrozamia riedlei, Podocarpus drouynianus, Leucopogon australis and Petrophile diversifolia.

1.4 Dense heath

Dominant stratum: Acacia pulchella or Melaleuca lateritia

Height: 1-2m

Cover: 30-100%

The dominant species vary according to site, with Acacia pulchella, Thomasia grandiflora and Xanthorrhoea preissii being important dominants of some heaths, and Melaleuca lateritia with Dodonaea ceratocarpa may be dominant in other areas. These heaths occur on shallow sandy loam soils over basalt.

2.0 LOWER SLOPES AND DUNES

2.1 Jarrah-Banksia low woodland

Dominant stratum: Eucalyptus marginata, Banksia attentuata, Banksia ilicifolia, Agonis flexuosa

Height: < 15m

Cover: 10-30%

The understorey is typically a low stratum which includes Pimelea angustifolia, Melaleuca thymoides, Leptomeria scrobiculata, Hypocalymma robustum, Boronia crenulata, Petrophile linearis and Dasypogon bromeliifolius. These woodlands occur in low sandy dunes or ridges, on the flat plain or adjoining the lower slopes of the lateritic plateau.

2.2 Jarrah low woodland

Dominant stratum: Eucalyptus marginata, Nuytsia floribunda, Agonis flexuosa

Height: < 15m

Cover: 10-30%

This vegetation occurs on the lowest sandy rises on the seasonally wet flats. There is usually insufficient depth of sand above the watertable to allow the establishment of Banksia species, although in some areas Banksia species may have been removed by dieback.

2.3 Blackbutt open low woodland

Dominant stratum: Eucalyptus patens

Height: < 15m

Cover: 2-10%

This vegetation usually has a particularly dense, tall shrub understorey which includes Viminaria juncea, Agonis linearifolia, Agonis parviceps, Tremandra stelligera, Thomasia pauciflora, Thomasia grandiflora, Pultenaea reticulata and Boronia megastigma. Eucalyptus megacarpa, Banksia littoralis and Oxylobium lanceolatum may be emergent. Eucalyptus megacarpa may be present in drainage lines or on wet flats. In the wettest areas, Melaleuca preissiana and Banksia littoralis may become locally dominant.

This vegetation occupies broad valleys and flats in the central areas of the State Forest, and also intrudes into the Jarrah Forest areas to the north via shallow valleys. On the south western edge of the State Forest, Blackbutt forms an open woodland over a lower scrub and heath understorey.

3.0 LOWLAND PLAINS AND SWAMPS

3.1 Low forest

3.1.1 Agonis juniperina

Dominant stratum: Agonis juniperina (White Cedar)

Height: 5-15m

Cover: 30-70%

Small stands of Agonis juniperina low forest occurs on the farm in swamp soils with a deep peaty surface soil over peaty sands. These soils are typically soils on the margins of lakes, swamps or drainage lines. It is generally a monospecific stand with little or no understorey.

3.1.2 Melaleuca preissiana

Dominant stratum: Melaleuca preissiana

Height: 5-15m

Cover: 30-70%

Banksia littoralis may also occur, with an understorey of Oxylobium lanceolatum, Agonis parviflora, Beaufortia sparsa, Lepidosperma longitudinale and Leptocarpus aristatus. This vegetation forms small stands in depressions located in sedge swamps or wet flats, or near lake margins. M. preissiana also forms a more open canopy cover on better drained soils.

3.2 Thicket

3.2.1 Dense swamp thicket

Dominant stratum: Agonis parviceps, Agonis floribunda, Agonis juniperina, Agonis linearifolia

Height: < 2m

Cover: 70-100%

These species form dense thickets in peaty, seasonally wet swamps either as monospecific stands or in combination. There is very little understorey. This formation is predominantly located on the farm and has been extensively cleared.

3.2.2 Dense Kunzea thicket

Dominant stratum: Kunzea ericifolia

Height: < 2m

Cover: 70-100%

Kunzea is usually dominant, although the tall shrubs Pultenaea reticulata and Agonis parviceps may occur. Boronia crenulata, Acacia hastulata, Stylidium scandens and Leptocarpus spp. may occur as an understorey.

Kunzea thicket occurs on slightly elevated grey sands on the margins of lakes or swamp depressions.

3.3 Low scrub over sedges

Dominant stratum: Melaleuca lateritia, Pultenaea reticulata, Leptospermum firmum, Astartea fascicularis, Agonis parviceps, Agonis floribunda.

Height: 1-2m

Cover: 10-30%

The tall shrub stratum usually shows a clumped distribution pattern over diverse low sedges and shrubs which may include

Leptocarpus scariosus, L. tenax, L. aristatus, Juncus pallidus, Cyathochaeta clandestina, Bossiaea rufa and Anarthria gracilis. This vegetation is common in wet depressions on the farm and in the State Forest, and also forms isolated stands on the sloping flat plains of the adjacent National Park.

3.4 Open scrub over heath

Dominant stratum: Nuytsia floribunda, Xanthorrhoea preissii, Agonis parviceps, Kunzea recurva, Pericalymma ellipticum, Adenanthos obovatus

Height: < 1.5m

Cover: 2-10%

The taller stratum forms an open scrub over a diverse low heath on better drained low lands slopes. Typical heath species include Andersonia caerulea, Lysinema ciliatum, Eriostemon spicatus, Gompholobium tomentosum, Johnsonia lupulina, Stylidium repens, Acacia divergens and Patersonia occidentalis.

3.5 Dense low heath

Dominant stratum: Pericalymma aff. ellipticum

Height: < 1.0m

Cover: 70-100%

Pericalymma aff. ellipticum forms a dense low heath with Leptocarpus spp. on poorly drained flat plains and swamp depressions.

3.6 Low heath over sedges

Dominant stratum: Diverse shrubs and sedges

Height: < 1.0m

Cover: 30-70%

This formation is rich in low shrubs and sedges and is common on the gently sloping plains of the National Park. Tall shrubs may be present, although scattered. Sphenotoma gracile, Dasypogon bromeliifolius, Adenanthos obovatus, Xyris lanata, Beaufortia squarrosa, Evandra aristida and Hibbertia stellaris are important species.

3.7 Tall sedgeland

3.7.1. Baumea articulata

Dominant stratum: Baumea articulata

Height: < 0.5m

Cover: 30-70%

Baumea articulata tall sedgeland occurs in seasonal swamp areas on the farm and in the National Park. Baumea articulata forms pure stands in the wettest areas, but Leptocarpus spp., Agonis spp., and Astartea fascicularis also occur in mixed stands.

3.7.2. Baumea vaginalis

Dominant stratum: Baumea vaginalis

Height: < 0.5m

Cover: 30-70%

A tall sedgeland of Baumea vaginalis and Leptocarpus aristatus occurs in broad wash areas of the National Park, with scattered tall shrubs of Agonis floribunda, Melaleuca lateritia and Astartea fascicularis.

3.8 Leptocarpus low sedgeland

Dominant stratum: Leptocarpus spp.

Height: < 0.5m

Cover: 30-70%

Leptocarpus aristatus, Leptocarpus scariosus and Leptocarpus tenax are dominant, with Lepidosperma longitudinale, Boronia juncea, Hakea ceratophylla, Villarsia lasiosperma and Pericalymma aff. ellipticum also significant. This type occurs on extensive flats subject to long periods of flooding. A tall shrub layer is absent.

APPENDIX D

List of plant species identified, in relation to landforms.

Introduced species are marked with an asterisk and species occurring typically in disturbed vegetation are marked with a cross.

FAMILY AND SPECIES	LANDFORMS					
	UPLANDS	LOWER SLOPES AND DUNES	FOOTHILL SLOPES & DRAINAGE LINES	SEASONALLY WET PLAINS	DRAINAGE LINES ON PLAIN	SWAMP DEPRESSIONS AND LAKE MARGINS
11C DENNSTAEDTIACEAE						
Pteridium esculentum (G.Forster) Cockayne	+					+
11D LINDSAEACEAE						
Lindsaea sp.	+					
16C ZAMIACEAE						
Macrozamia riedlei (Fisher ex Gaudich.) C. Gardner	+	+	+			
17 PODOCARPACEAE						
Podocarpus drouynianus F. Muell.	+	+	+			
26 JUNCAGINACEAE						
Triglochlin procera R. Br.				+		
31 POACEAE						
Amphipogon turbinatus R.Br.					+	
+ Pentaschistis airoides (Nees) Stapf in Dyer						
Tetrarrhena laevis R.Br.	+		+			
32 CYPERACEAE						
Baumea articulata (R.Br.) S.T. Blake					+	+
Baumea riparia (Nees) Boeckler				+		+
Baumea vaginalis (Benth.) S.T. Blake				+	+	+
Chorizandra cymbaria R.Br.				+		
Cyathochaeta avenacea Benth.				+		
+ Cyathochaeta clandestina (R.Br.) Benth.						
* Cyperus tenellus L.f.				+		+
Evandra aristata R.Br.				+		+
Gahnia decomposita (R.Br.) Benth.				+		
Gymnoschoenus anceps (R.Br.) C.B. Clarke		+				+
Lepidosperma longitudinale Labill.				+		
Mesomelaena graciliceps (C.B. Clarke) K.L. Wilson		+				+
Mesomelaena tetragona (R.Br.) Benth.				+		
Mesomelaena aff. preissii Nees in Lehm.				+		
Schoenus rodwayanus W. Fitzg.				+		
39 RESTIONACEAE						
Anarthria gracilis R.Br.				+		+
Anarthria prolifera R.Br.				+		+
Anarthria scabra R.Br.				+		+
Anarthria aff. laevis R.Br.				+		+
Loxocarya c.f. flexuosa (R.Br.) Benth.				+		
Leptocarpus ?aristatus R.Br.				+	+	+
Leptocarpus scariosus R.Br.				+	+	+
Leptocarpus tenax (Labill.) R.Br.					+	+
Loxocarya fasciculata (R.Bc.) Benth.				+		
Meeboldina denmarkica Suesseng				+		
Restio ?applanatus Sprengel				+		
40 CENTROLEPIDACEAE						
+ Aphelia brizula F. Muell.						
+ Centrolepis aristata (R.Br.) Roemer & Schultes						
42 XYRIDACEAE						
Xyris lacera R.Br.				+		+
Xyris lanata R.Br.				+		+
50 PHILYDRACEAE						
+ Philydrella pygmaea (R.Br.) Caruel						
52 JUNCACEAE						
*+ Juncus bufonius L.						
Juncus pallidus R.Br.				+		+
Luzula ?meridionalis Nordensk.					+	
54C DASYPOGONACEAE						
Dasypogon bromeliifolius R.Br.		+		+		
54D XANTHORRHOEACEAE						
Xanthorrhoea preissii Endl. in Lehm.	+			+		+
54E PHORMIACEAE						
Dianella revoluta R.Br.	+	+				

FAMILY AND SPECIES	LANDFORMS					
	UPLANDS	LOWER SLOPES AND DUNES	FOOTHILL SLOPES & DRAINAGE LINES	SEASONALLY WET PLAINS	DRAINAGE LINES ON PLAIN	SWAMP DEPRESSIONS AND LAKE MARGINS
54F ANTHERICACEAE						
Agrostocrinum scabrum (R.Br.) Baillon	+					
Chamaescilla corymbosa (R.Br.) F.Muell. ex Benth.		+				
Johnsonia lupulina R.Br.				+	+	
Thysanotus tenellus Endl. in Lehm.	+					
54J COLCHICACEAE						
Burchardia multiflora Lindley		+				
55 HAEMODORACEAE						
Anigozanthos flavidus Redoute & DC.						+
Conostylis aculeata spp. aculeata R.Br.		+				
Conostylis serrulata R.Br.		+	+			
Phlebocarya ciliata R.Br.		+		+		+
60 IRIDACEAE						
Patersonia occidentalis R.Br.		+		+		
66 ORCHIDACEAE						
Acianthus reniformis (R.Br.) Schltr.						+
Caladenia flava R.Br.	+	+				
Caladenia huegelii H.G. Reichb.	+					
Calochilus robertsonii Benth.	+	+				
Diuris emarginata R.Br.					+	+
Elythranthera emarginata (Lindley) A.S. George	+	+				
Epiblema grandiflorum R.Br.		+				
Leporella fimbriata (Lindley) A.S. George	+	+				
Microtis atrata Lindley					+	+
Paracaleana nigrita (Lindley) Blaxell	+	+				
Pterostylis barbata Lindley	+					
Pterostylis nana R.Br.	+					
Pterostylis recurva Benth.	+					
Pterostylis vittata Lindley	+					
Thelymitra crinita Lindley	+					
Thelymitra fuscolutea ssp. fuscolutea R.Br.	+					
Thelymitra nuda R.Br.	+					
70 CASUARINACEAE						
Allocasuarina fraseriana (Miq.) L. Johnson	+	+				
90 PROTEACEAE						
Adenanthos obovatus Labill.		+		+		+
Banksia attenuata R.Br.		+				
Banksia grandis Willd.	+	+				
Banksia ilicifolia R.Br.		+				
Banksia littoralis R.Br.						+
Grevillea aff. diversifolia Meissner in Lehm.					+	
Hakea amplexicaulis R.Br.	+					
Hakea ceratophylla (Smith) R.Br.				+		
Hakea varia R.Br.					+	
Hakea aff. varia R.Br.	+					
Persoonia longifolia R.Br.	+					
Persoonia microcarpa R.Br.						+
Petrophile diversifolia R.Br.	+					
Petrophile linearis R.Br.		+				
Petrophile sp. DB882/6						+
Xylomelum occidentale R.Br		+				
92 SANTALACEAE						
Leptomeria scrobiculata R.Br.		+				
97 LORANTHACEAE						
Nuytsia floribunda (Labill.) R.Br. ex Fenzl in Endl., Fenzl, Benth. & Schott		+				
119 RANUNCULACEAE						
Clematis pubescens Huegel ex Endl. in Endl., Fenzl, Benth. & Schott	+					
131 LAURACEAE						
Cassytha glabella R.Br.			+			+
Cassytha ?racemosa Nees in Lehm.			+			+
143 DROSERACEAE						
Drosera menziesii R.Br. in DC.						+
Drosera modesta Diels in Diels & E. Pritzel	+					
Drosera myriantha Planchon						+

FAMILY AND SPECIES	LANDFORMS					
	UPLANDS	LOWER SLOPES AND DUNES	FOOTHILL SLOPES & DRAINAGE LINES	SEASONALLY WET PLAINS	DRAINAGE LINES ON PLAIN	SWAMP DEPRESSIONS AND LAKE MARGINS
Drosera neesii ssp. neesii Lehm.						+
Drosera nitidula Planchon						+
Drosera platystigma Lehm.	+					
Drosera pulchella Lehm.					+	
152 PITTOSPORACEAE						
Billardiera floribunda (Putterl.) F.Muell.	+					
Billardiera ?variifolia DC.	+					
163 MIMOSACEAE						
Acacia alata R.Br. in W.T. Aiton	+		+			
Acacia browniana H.L. Wendl.	+		+			
Acacia divergens Benth.	+		+			
Acacia extensa Lindley	+	+	+			
Acacia hastulata Smith in Rees		+				
Acacia myrtifolia (Smith) Willd.	+		+			
Acacia pulchella ssp. glaberrima R.Br. in W.T. Aiton	+	+	+		+	
Acacia semitrullata Maslin		+				
165 PAPILIONACEAE						
Aotus intermedia Meissner in Lehm.						+
Bossiaea rufa R.Br. in W.T. Aiton		+				
Chorizema rhombeum R.Br. in W.T. Aiton	+					
Daviesia inflata M.D. Crisp	+					+
Euchilopsis linearis (Benth.) F.Muell.						+
Eutaxia epacridoides Meissner in Lehm.	+	+	+			
Eutaxia virgata Benth in Endl., Fenzl, Benth. & Schott					+	+
Gompholobium ovatum Meissner in Lehm.	+					
Gompholobium tomentosum Labill.		+		+		
Hardenbergia comptoniana (Andrews) Benth. in Endl., Fenzl, Benth. & Schott	+					
Hovea chorizemifolia (Sweet) DC.	+					
Hovea elliptica (Smith) DC.	+					
Jacksonia horrida DC.		+				
Jacksonia furcellata (Bonpl.) DC.		+				
Kennedia coccinea Vent.		+				
Latrobea diosmifolia Benth.						+
Latrobea genistoides (Meissner) Meissner in Lehm.		+				
Oxylobium linariifolium (G.Don) Domin		+			+	
Pultenaea reticulata (Smith) Benth.		+			+	+
Sphaerolobium ?macranthum Meissner in Lehm.				+		
Spaerolobium sp. DB87069				+		
Viminaria juncea (Schrader & Wendl.) Hoffsgg.					+	+
175 RUTACEAE						
Boronia crenulata Smith	+	+				
Boronia juncea Bartling in Lehm.						+
Boronia megastigma Nees ex Bartling in Lehm.			+			
Boronia spathulata Lindley	+					
Boronia stricta Bartling in Lehm.	+					
Eriostemon spicatus A. Rich.		+		+		
182 TREMANDRACEAE						
Tremandra stelligera R.Br. ex DC.	+		+			
183 POLYGALACEAE						
Comesperma ciliatum Steetz in Lehm.			+			
Comesperma confertum Labill.	+					
Comesperma flavum DC.				+		
Comesperma virgatum Labill.	+					
185 EUPHORBIACEAE						
Amperea volubilis F.Muell. ex Benth.						+
Euphorbia sp.DB87131						+
Monotaxis occidentalis Endl. in Endl., Fenzl, Benth. & Schott						+
Phyllanthus calycinus Labill.	+					
Ricinocarpus glaucos Endl. in Endl., Fenzl, Benth. & Schott				+		
202 STACKHOUSIACEAE						
Stackhousia monogyna Labill.	+			+		

FAMILY AND SPECIES	LANDFORMS					
	UPLANDS	LOWER SLOPES AND DUNES	FOOTHILL SLOPES & DRAINAGE LINES	SEASONALLY WET PLAINS	DRAINAGE LINES ON PLAIN	SWAMP DEPRESSIONS AND LAKE MARGINS
207 SAPINDACEAE						
Dodonaea ceratocarpa Endl. in Endl., Fenzl, Benth. & Schott	+					
223 STERCULIACEAE						
Lasiopetalum floribundum Benth.	+		+			
Thomasia grandiflora Lindley	+		+			
Thomasia pauciflora Lindley			+			
226 DILLENIACEAE						
Hibbertia amplexicaulis Steudel in Lehm.	+					
Hibbertia cunninghamii W.T. Aiton ex Hook.	+					
Hibbertia stellaris Endl. in Endl., Fenzl, Benth. & Schott				+		
Hibbertia ?subvaginata (Steudel) F. Muell.		+				
Hibbertia aff. pulchra Ostenf.		+				
263 THYMELAECEAE						
Pimelea angustifolia R.Br.	+					
Pimelea rosea R.Br.	+	+		+		
273 MYRTACEAE						
Actinodium cunninghamii Schauer in Lindley				+		
Agonis flexuosa (Sprengel) Schauer in Lehm.		+				
Agonis floribunda Turcz.			+		+	+
Agonis juniperina Schauer in Lehm.			+		+	+
Agonis linearifolia (DC.) Schauer in Lehm.			+		+	+
Agonis parviceps Schauer in Lehm.					+	+
Astartea fascicularis (Labill.) DC.						+
Astartea sp. DB88233				+	+	+
Beaufortia sparsa R.Br. in W.T. Aiton				+		+
Calothamnus lateralis Lindley	+		+			
Eucalyptus calophylla Lindley	+	+				
Eucalyptus marginata Donn ex Smith			+			
Eucalpytus megacarpa F. Muell.			+			
Eucalyptus patens Benth.	+			+		
Homalospermum firmum Schauer						+
Hypocalymma linifolium Turcz.						+
Hypocalymma robustum Endl. in Endl., Fenzl, Benth. & Schott	+	+				
Kunzea ericifolia (Smith) Heynh.						+
Kunzea ?micrantha Schauer in Lehm.		+				
Kunzea recurva Schauer in Lehm.						+
Melaleuca basicephala Benth.						+
Melaleuca lateritia A. Dietr.				+		
Melaleuca pauciflora Turcz.						+
Melaleuca polygaloides Schauer in Lehm.					+	+
Melaleuca preissiana Schauer in Lehm.		+				
Melaleuca thymoides Labill.						+
Pericalymma ellipticum (Endl.) Schauer in Lehm.			+			+
Pericalymma aff. ellipticum (Endl.) Schauer in Lehm.				+		
281 APIACEAE						
Platysace tenuissima (Benth.) Norman	+					
Xanthosia candida (Benth.) Steudel	+					
288 EPACRIDACEAE						
Andersonia caerulea R.Br.				+		
Leucopogon alternifolius R.Br.				+		
Leucopogon australis R.Br.	+					
Leucopogon gilbertii Stschegl.						+
Leucopogon glabellus R.Br.						+
Leucopogon oxycedrus Sonder in Lehm.	+					
Leucopogon ?pendulus R.Br.		+				
Leucopogon ?pulchellus Sonder in Lehm.						+
Leucopogon verticillatus R.Br.	+					
Leucopogon aff. polymorphus Sonder in Lehm.		+				
Lysinema ciliatum R.Br.		+				
Sphenotoma gracile (R.Br.) Sweet						+
Sphenotoma squarrosum (R.Br.) Don				+		
293 PRIMULACEAE						
+ Anagallis arvensis L.						

FAMILY AND SPECIES	LANDFORMS					
	UPLANDS	LOWER SLOPES AND DUNES	FOOTHILL SLOPES & DRAINAGE LINES	SEASONALLY WET PLAINS	DRAINAGE LINES ON PLAIN	SWAMP DEPRESSIONS AND LAKE MARGINS
302 LOGANIACEAE						
+ Mitrasacme paradoxa R.Br.						
303A MENYANTHACEAE						
Villarsia albiflora F. Muell.						+
+ Villarsia lasiosperma F. Muell					+	+
Villarsia sp.					+	+
313 LAMIACEAE						
Hemigenia ramosissima Benth. in DC.		+				
316 SCROPHULARIACEAE						
+ Gratiola peruviana L.						
323 LENTIBULARIACEAE						
Utricularia multifida R.Br.						+
Utricularia ?violacea R.Br.						+
331 RUBIACEAE						
Opercularia apiciflora Labill.	+					
340 LOBELIACEAE						
Lobelia rariflora F. Wimmer	+					
341 GOODENIACEAE						
Dampiera alata Lindley	+					
Dampiera linearis R.Br.		+				
Dampiera trigona Vriese in Lehm.				+		
Goodenia tenella R.Br.				+		+
Scaevola ?calliptera Benth. in Endl., Fenzl. Benth. & Schott				+		
343 STYLIDIACEAE						
Levenhookia pusilla R.Br.	+					
Levenhookia sp.						+
Stylidium amoenum R.Br.	+	+				
Stylidium barleei F. Muell.						+
Stylidium caespitosum R.Br.						+
Stylidium calcaratum R.Br.	+					
Stylidium junceum R.Br.			+		+	
Stylidium repens R.Br.		+				+
Stylidium scandens R.Br.			+			
Stylidium schoenoides DC.	+					
345 ASTERACEAE						
Cotula coronopifolia L.		+				
*+ Hypochaeris glabra L.						
Lagenifera huegelii Benth. in Endl., Fenzl, Benth. & Schott	+					
Podolepis gracilis (Lehm.) Graham		+				
+ Siloxerus humifusus Labill.						
*+ Vellereophyton dealbatum (Thunb.) Hillard & B.L. Burtt						