# YAKABINDIE NICKEL PROJECT
# FEASIBILITY STUDY
# CONSULTATIVE ENVIRONMENTAL REVIEW
# VOLUME 2 OF 2

Report prepared for:

DOMINION MINING LIMITED
10 RICHARDSON STREET
WEST PERTH WA 6005

PROJECT MANAGERS:
MINPROC JR JOINT VENTURE
22 STIRLING HIGHWAY
NEDLANDS WA 6009

Report prepared by:

SOIL AND ROCK ENGINEERING PTY LTD
CONSULTING GEOTECHNICAL ENGINEERS
AND GEOLOGISTS
4TH FLOOR CENTREPOINT TOWER
123 COLIN STREET
WEST PERTH WA 6005

Ref: 2488/00/E/CL/st
Date: 20th April 1990
Copy: 03 of 30

Soil & Rock Engineering Pty. Ltd.

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# APPENDIX A

EPA

AN ENVIRONMENT WORTH PROTECTION

Project Manager
Dominion Mining Ltd
10 Richardson Street
WEST PERTH WA 6005

ATTENTION: MR G BECKER

Our Ref: 103/74; 033341
Enquiries: Mr R Griffiths

Dear Sir

**YAKABINDIE NICKEL PROJECT**

I attach for your information a copy of the Guidelines for preparation of the Consultative Environmental Review as issued by this Authority.

The Guidelines have been formulated in consultation with the Department of Mines.

Should you require any further information, please contact Mr Robert Griffiths on 222 7135.

Yours faithfully

R A D Sippe

R A D Sippe
DIRECTOR
EVALUATION DIVISION

6 March 1990

enc

cc: Mr G Cowrie
Minproc Engineers Pty Ltd
PO Box 403
NEDLANDS WA 6009

8/3/90

Mr K Lindbeck - Department of Mines

Mr I Kealley - CALM, Kalgoorlie

65RG YAKABINDIE:ma

E ronmental
P. tion Authority
1 Mount Street Perth
Western Australia 6000
Telephone (09) 222 7000
Facsimile (09) 322 1598

GUIDELINES FOR THE CONSULTATIVE ENVIRONMENTAL REVIEW (CER)
ON THE PROPOSAL BY DOMINION MINING LIMITED
FOR THE YAKABINDIE NICKEL PROJECT


SUMMARY

The CER should contain a brief summary of:

- salient features of the proposal;
- description of the local environment and analysis of potential impacts and their significance;
- environmental monitoring and management programmes, safeguards and commitments; and
- conclusions.


# 1. Introduction

## 1.1 Objectives

Brief summary of the scale, type, and timing of operation planned eg to develop an open-cut nickel mine and associated infrastructure in the area etc.

## 1.2 Location

A description of the location relative to the nearest town, existing or proposed mines and pastoral stations.

A plan to be provided showig tenements and location of various facilities, an aerial photograph with overlay of proposed location of facilities should also be provided.

## 1.3 Ownership

Lessees of all tenements covered by proposed operation, status on any joint ventures and name of managing/operating company.

## 1.4 History

Extent of previous mining activity in the area, amount of ground disturbance, exploration activities, etc. Outline of how the project has evolved to the point of seeking approval to mine.

## 1.5 Existing facilities

Brief description of existing facilities at operating site, and planned use of any nearby facilities, including the use of public roads and other infrastructure. The interaction with the Mt Keith Nickel Project should be discussed.

# 2. Existing Environment

## 2.1 Regional Setting

General description of geology and geomorphology, including description of land units. A contour map should be included covering a 5 km radius from the centre of the open pit.

## 2.2 Geology

Brief description of geology specific to the area of interest including a basic description of the mineralization and ore reserves.

## 2.3 Hydrology

Brief summary of surface and subsurface water flows and quality as they relate to the project and facilities. Details of the project water requirements including the source, quantities required and quality as well as details of existing water use, water reserves and catchment areas must be included. Any requirement for dewatering, proposed discharge point, quantity and quality. The development and extraction of groundwater usually requires WA Water Authority's approval and licence, as does any dewatering discharge.

## 2.4 Climatology

Regional weather patterns, average rainfall, average evaporation, prevailing winds, etc. Minimum drainage design should be based on the 50 year return rainfall event.

## 2.5 Flora and Fauna

Brief description of flora and fauna in area and reference to any previously published studies. Specific reference should be made to to the proximity of Wanjarri Nature Reserve. A table indicating rare and / or endangered species and their habitat requirements would be appropriate.

# 3. Project Description

## 3.1 Mining

Outline of proposed method of operation, pit design, waste dump design and location. Both a long term concept plan as well as detailed plans for the first few years of operation should be provided. Design sheets for for surface water diversions should be supplied.

## 3.2 Ore Processing

A Description of the treatment plant and general arrangement plan should be supplied. Details of dust control and chemical handling and storage safety measures should be provided. EPA Works Approval and Licence are required for all treatment plants.

## 3.3 Concentrate Handling

Outline method of concentrate storage and transport.

## 3.4 Tailings Storage

A description of the location, dimensions, construction methods, and operation is required for the tailings dam. EPA Works Approval and Licence are required for all tailings dams.

## 3.5 Support Facilities

Location of on-site offices, workshops, power supply, accommodation policy, etc. This section should outline the potential for sharing of facilities with the Mt Keith Nickel Project.

## 3.6 Workforce

Number and classification of workers. Provisions of the Mines Regulation Act and Regulations in relation to certification and working conditions should be acknowledged.

## 3.7 Transportation Corridors

Location of main access, power and water supply lines. The use, and maintenance of local roads to be agreed with Local Government. Use of highways for ore or concentrates haulage requires specific Main Roads Department approval.

## 3.8 Resource Requirements

Any other details on resources required for the project.

## 3.9 Housing and Accommodation

The housing and accommodation arrangements for the work force should be described.

It should be noted that the Government policy on accommodation on mine sites, in order of preference is:

1. Associated permanent accommodation ( not fly in - fly out)

    (a) accommodation to be provided in the nearest established township with workers travelling to and from the mine site on a daily basis;

    (b) accommodation to be provided in a new township that will service a number of nearby operations.

2. If 1 (a) and (b) are impractical and fly in - fly out operations are to be provided then such operations should be based on regional centres such as Kalgoorlie, and Geraldton.

In general, the Government is opposed to fly in - fly out operations based on centres outside the state.

# 4. Environmental Impact and Management

The aim of this section is to identify environmental impacts and make firm commitments to minimise disturbance and manage adverse impacts. This section should reflect the degree of planning that has been directed at the identification and management of environmental impacts.

## 4.1 Water

Water requirements for processing and domestic use, and the sources to be used.

Impact on local water resource and other users.

Dewatering requirements, drainage control and impact on regional drainage.

WA Water Authority approvals sought and those already obtained.

Diversion of surface water drainage lines.

## 4.2 Flora and Fauna

Extent of area to be disturbed and whether any restricted, rare or endangered species are present in the area.

### 4.3 Waste products

Methods of management of wastes including domestic waste and sewerage. Commitment to waste dump and tailings dam management to minimise the environmental impact of these structures during operation.

### 4.4 Hazardous Substances

A brief description should be given of the range of hazardous substances used at the site and management of their transport, storage, use and disposal.

### 4.5 Dust

Dust control methods for all phases of the operation, including rehabilitation. Both occupational health and environmental aspects must be addressed.

### 4.6 Noise

Noise control procedures for both blasting and normal operations. Occupational noise levels and anticipated community or environmental levels should be covered.

### 4.7 Infrastructure

The environmental impact of all infrastructure not directly related to the mining operation such as; power generation and supply, airstrips, and accommodation facilities should be outlined and the potential for reducing the impact by combining some facilities with the Mt Keith operation should be discussed.

### 4.8 Adjacent Land Uses

The impact of the operation on adjacent land uses should be discussed especially conservation and pastoral aspects.

### 4.9 Environmental Management and Rehabilitation

The management of the environmental impacts identified earlier in this section should be described with appropriate commitments.

The objectives of the rehabilitation programme should be clearly stated in terms of the final land use for the site.

Methods and approximate timing of rehabilitation for waste dumps, tailings dams, pits, camp sites and all other disturbed areas should be stated, with a commitment to undertake progressive and final rehabilitation and site clean up.

## 5. Social Impacts

### 5.1 Aboriginal sites

A commitment to abide by the provisions of the Aboriginal Heritage Act, extent of ethnographic and archaeological surveys carried out (if any), commitment to inform the WA Museum of any site of Aboriginal Heritage significance discovered in the course of the development.

### 5.2 Heritage

Items of European heritage value should be defined and a commitment to record, relocate or preserve such items as appropriate should be given.

### 5.3 Social environment

Positive and negative social impacts of the project for the region and State/Local Government opportunities should be highlighted. A discussion of the potential impacts on the townsites of Leonora and Leinster should be included in this section.

## 6. Specific Commitments

A summarised list of the proponents specific commitments for the protection of the environment is to be provided. Commitments should be referenced to a specific timetable and geographical area (where appropriate) defining who is responsible for which environmental impact, how it will be ameliorated and to whose satisfaction.

## 7. Conclusions

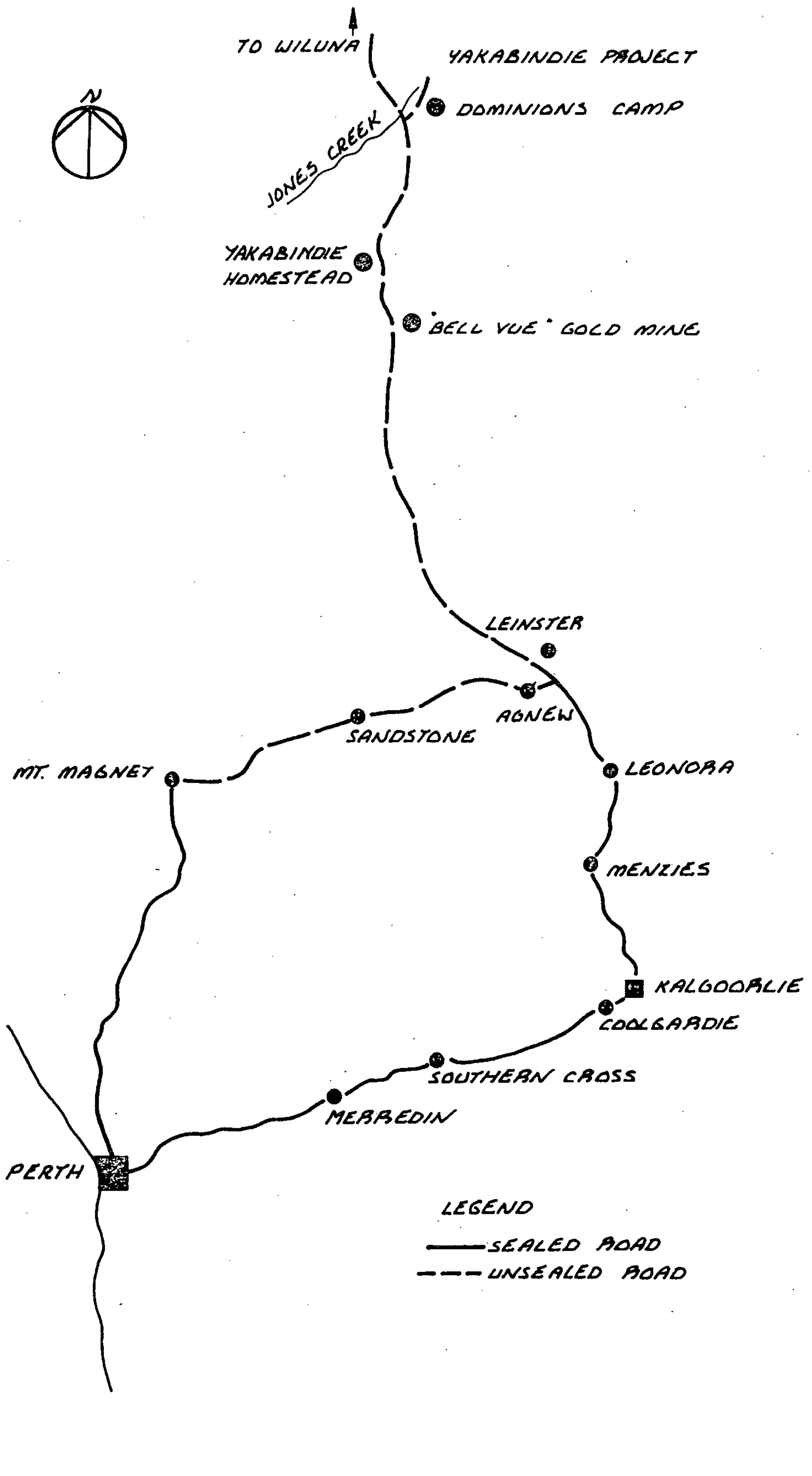
Outline conclusions including likely overall environmental acceptability of the project.

APPENDIX 1

Include a copy of these guidelines as an appendix to the document.

OTHFIMISTONGUIDE:fh

# APPENDIX B



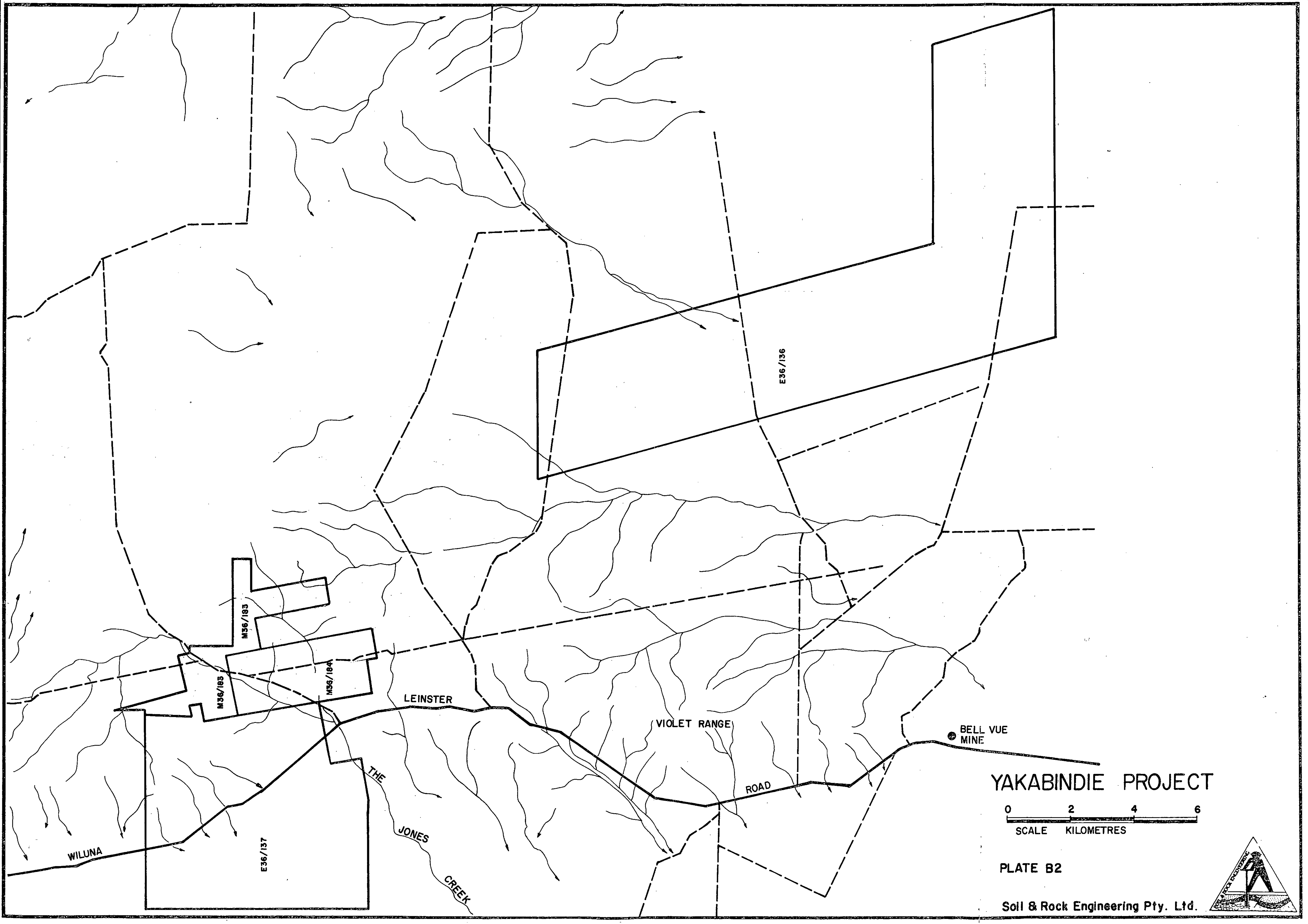

# YAKABINDIE PROJECT

NOT TO SCALE

LOCATION PROJECT AREA

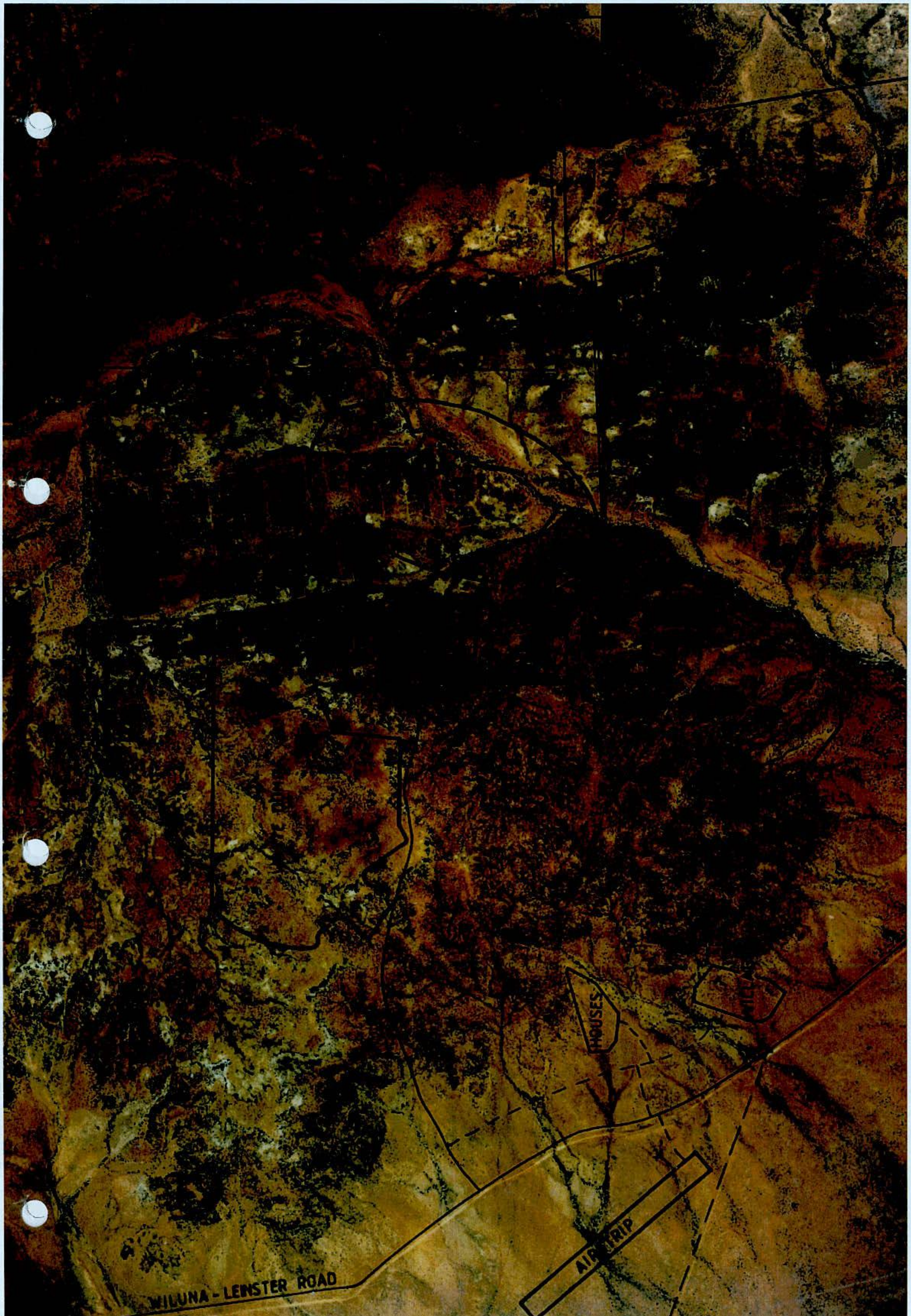
PLATE B1

Soil & Rock Engineering Pty. Ltd.

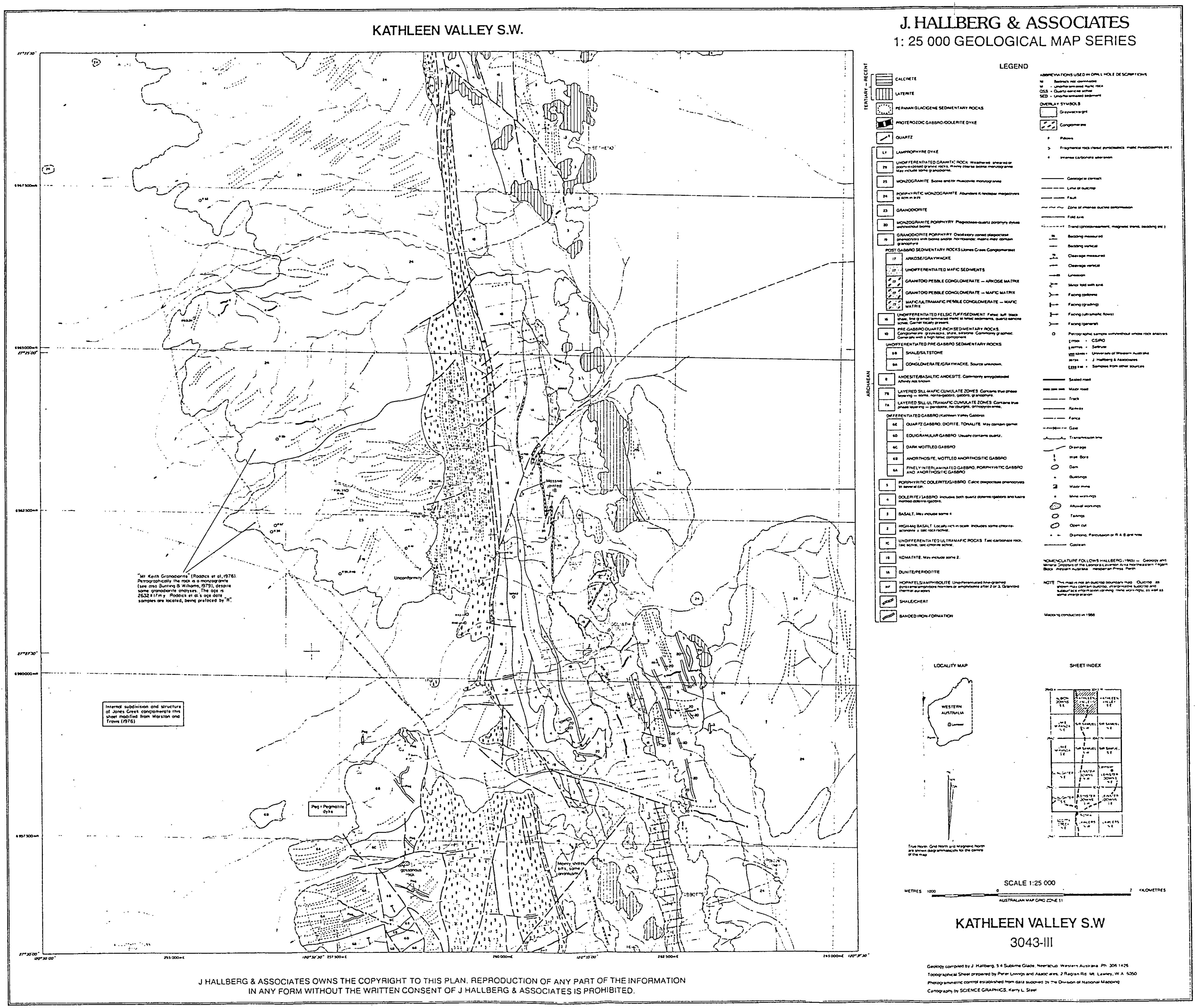

E36/136
M36/183
M36/183
M36/184
LEINSTER
VIOLET RANGE
ROAD
BELL VUE
MINE
THE
JONES
CREEK
WILUNA
E36/137
YAKABINDIE PROJECT
0 2 4 6
SCALE KILOMETRES
PLATE B2
Soil & Rock Engineering Pty. Ltd.

# APPENDIX C

# APPENDIX C1


HOUSES
AIRSTRIP
WILUNA - LEINSTER ROAD

# APPENDIX C2


KATHLEEN VALLEY S.W.
J. HALLBERG & ASSOCIATES
1: 25 000 GEOLOGICAL MAP SERIES
LEGEND
TERTIARY – RECENT
CALCRETE
LATERITE
PERMIAN GLACIGENE SEDIMENTARY ROCKS
PROTEROZOIC GABBRO/DOLERITE DYKE
QUARTZ
ARCHAEAN
LAMPROPHYRE DYKE
UNDIFFERENTIATED GRANITIC ROCK
MONZOGRANITE
PORPHYRITIC MONZOGRANITE
GRANODIORITE
MONZOGRANITE PORPHYRY
GRANODIORITE PORPHYRY
POST GABBRO SEDIMENTARY ROCKS (Jones Creek Conglomerate)
ARKOSE/GRAYWACKE
UNDIFFERENTIATED MAFIC SEDIMENTS
GRANITOID PEBBLE CONGLOMERATE — ARKOSE MATRIX
GRANITOID PEBBLE CONGLOMERATE — MAFIC MATRIX
MAFIC/ULTRAMAFIC PEBBLE CONGLOMERATE — MAFIC MATRIX
UNDIFFERENTIATED FELSIC TUFF/SEDIMENT
PRE-GABBRO QUARTZ-RICH SEDIMENTARY ROCKS.
UNDIFFERENTIATED PRE-GABBRO SEDIMENTARY ROCKS
SHALE/SILTSTONE
CONGLOMERATE/GRAYWACKE. Source unknown.
ANDESITE/BASALTIC ANDESITE. Commonly amygdaloidal
LAYERED SILL-MAFIC CUMULATE ZONES
LAYERED SILL-ULTRAMAFIC CUMULATE ZONES
DIFFERENTIATED GABBRO (Kathleen Valley Gabbro)
QUARTZ GABBRO, DIORITE, TONALITE
EQUIGRANULAR GABBRO
DARK MOTTLED GABBRO
ANORTHOSITE, MOTTLED ANORTHOSITIC GABBRO
FINELY INTERLAMINATED GABBRO, PORPHYRITIC GABBRO AND ANORTHOSITIC GABBRO
PORPHYRITIC DOLERITE/GABBRO
DOLERITE/GABBRO
BASALT. May include some 4
HIGH-Mg BASALT
UNDIFFERENTIATED ULTRAMAFIC ROCKS
KOMATIITE. May include some 2.
DUNITE/PERIDOTITE
HORNFELS/AMPHIBOLITE
SHALE/CHERT
BANDED IRON-FORMATION
ABBREVIATIONS USED IN DRILL HOLE DESCRIPTIONS
OVERLAY SYMBOLS
Graywacke grit
Conglomerate
Pillows
Geological contact
Limit of outcrop
Fault
Zone of intense ductile deformation
Fold axis
Bedding measured
Bedding vertical
Cleavage measured
Cleavage vertical
Lineation
Minor fold with axis
Facing (pillows)
Facing (grading)
Facing (ultramafic flows)
Facing (general)
CSIRO
Seltrust
University of Western Australia
J. Hallberg & Associates
Samples from other sources
Sealed road
Major road
Track
Railway
Fence
Gate
Transmission line
Drainage
Well Bore
Dam
Buildings
Major mine
Mine workings
Alluvial workings
Tailings
Open cut
Costean
Mapping conducted in 1986
LOCALITY MAP
WESTERN AUSTRALIA
SHEET INDEX
Unconformity
Peg = Pegmatite dyke
Internal subdivision and structure of Jones Creek conglomerate this sheet modified from Marston and Travis (1976)
SCALE 1:25 000
METRES
KILOMETRES
AUSTRALIAN MAP GRID ZONE 51
KATHLEEN VALLEY S.W
3043-III
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# APPENDIX C3

Rockwater
PROPRIETARY LIMITED
94 ROKEBY ROAD, SUBIACO, WESTERN AUSTRALIA 6008.
P.O. BOX 237, SUBIACO, WESTERN AUSTRALIA 6008.
TELEPHONE: (09) 382 4922
INTERNATIONAL: 619 382 4922
FACSIMILE: (09) 381 3264

SOIL AND ROCK ENGINEERING PTY LTD

# YAKABINDIE NICKEL PROJECT

# JONES CREEK FLOODS

MARCH 1990

142.1|90|1
R15 GW

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SOIL AND ROCK ENGINEERING PTY LTD

YAKABINDIE NICKEL PROJECT

JONES CREEK FLOODS

MARCH 1990

## 1. INTRODUCTION

Soil and Rock Engineering Pty Ltd have engaged Rockwater Pty Ltd to estimate flood flows in Jones Creek which drains the area of Dominion Mining's Yakabindie nickel project. This information is required for preparation of a document meeting the requirements of the Environmental Protection Authority's Consultative Environmental Review.

Yakabindie is located about 100 km south-east of Wiluna and 50 km north of Leinster, as shown in Figure 1.

## 2. RAINFALL

Average rainfall at Yakabindie since 1931 has been 207 mm/yr. Table 1 shows that, on average, most of the rain is in the first six months of the year.

TABLE 1
AVERAGE RAINFALL AT YAKABINDIE
(mm)

| J | F | M | A | M | J | J | A | S | O | N | D | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | 28 | 29 | 19 | 21 | 21 | 16 | 11 | 6 | 8 | 8 | 13 | 207 |

A design rainfall intensity diagram for Yakabindie was prepared by the Bureau of Meteorology using standard methods which are described in Australian Rainfall and Runoff (1987). This diagram is presented as Figure 2.

On 24 January 1990, 69 mm of rain was recorded at Yakabindie in a period of about 2 hrs, and Jones Creek was observed under flood conditions, by a Rockwater hydrogeologist on site. A photograph of the flood is shown as Figure 3. According to the Bureau of Meteorology, the highest daily rainfall since records began (in 1931) is 111 mm in March 1931.

According to Figure 2, the probability of receiving an average rainfall intensity of 34 mm/hr for 2 hours in this area is less than 1% (average recurrence interval of more than 100 yrs). The probability of receiving an average rainfall intensity of 4.6 mm/hr for 24 hrs (111 mm in a day) is slightly less than 5%.

## 3. SURFACE DRAINAGE

The site of the proposed Yakabindie mine is drained by Jones Creek and its tributaries. Streamflow is ephemeral in a reasonably dense network of streamlines. There are no flow measurement records for any streams in the vicinity of Yakabindie.

Figure 4 shows Jones Creek, major tributaries and the catchment boundary for streamflow past a point close to Six-Mile Well.

Table 2 lists characteristics of catchments defined by points slightly above and below the confluence of the western tributary with Jones Creek and of the western tributary, as estimated from the Sir Samuel sheet of the 1:250,000 map series and topographic maps of parts of the catchments, which were provided by Soil and Rock Engineering.

## 4. JANUARY 1990 FLOOD EVENT

Figure 5 shows cross sections of Jones Creek and the western tributary from elevations which are believed to be high water marks from the January 1990 flood event.

Maximum flows ($Q$ $m^3$/sec) were estimated from the cross-sectional area ($A_s m^2$), hydraulic radius ($R = A_s/P$ where $P$ is the wetted perimeter), the downstream slope of the stream beds ($S$ m/m) and the Manning roughness factor $n$, using the Manning formula for steady uniform flow:

$$Q = (1/n)\ A_s\ R^{2/3}\ S^{1/2}. \qquad (1)$$

TABLE 2
CHARACTERISTICS OF CATCHMENTS

| Catchment | Area $A_c$ ($km^2$) | Stream Length L (km) | Average Stream Slope (m/km) |
|---|---|---|---|
| Jones Creek[1] | 31.9 | 7.5 | 4.0 |
| Jones Creek[2] | 43 | 7.8 | 4.0 |
| Western Tributary | 4.8 | 2.5 | 12.4 |

1 Above confluence with Western Tributary
2 Calculated with Equation 1 and assuming n = 0.045.

The value n = 0.045 was used on advice from the Main Roads Department of W.A. Table 3 presents the values of other terms used, and the calculated flow rates.

TABLE 3
FLOW CALCULATIONS
(STORM IN JANUARY 1990)

| Catchment | Cross-Section $A_s$($m^2$) | Wetted Perimeter P (m) | Hydraulic Radius R (m) | Stream Slope S(m/m) | Flow Rate[2] Q ($m^3$/s) |
|---|---|---|---|---|---|
| Jones Creek[1] | 144 | 107 | 1.35 | 0.0013 | 140 |
| Western Tributary | 64 | 44 | 1.45 | 0.006 | 140 |

1 Above confluence with Western Tributary
2 Calculated with Equation 1 and assuming n = 0.045.

According to Australian Rainfall and Runoff (1987), the value of the Manning Roughness Factor (n) for these streams should lie in the range of 0.035 to 0.100. If the lowest value was appropriate, the calculated flow rate in each stream would be increased by nearly 30%. If the highest value was appropriate, the calculated flow rates would be reduced by 55%.

## 5. FLOOD FORECASTS

Flood flows in Jones Creek, both above and below the confluence with the western tributary, and in the Western Tributary alone, were estimated using the Rational Method formula (ARR, 1987):

$$Q_Y = 0.278\ C_Y \times I_{t_c}Y \times A_c \qquad (2)$$

where $Q_Y$ ($m^3/s$) is the peak flow rate;

$C_Y$ (dimensionless) is the runoff coefficient for an Average Recurrence Interval (ARI) of Y yrs;

$A_c$($km^2$) is catchment area; and

$I_{t_c}\ Y$ (mm/hr) is average rainfall intensity for design duration of $t_c$ hours and ARI of Y years.

The time of concentration ($t_c$ mins) was computed using the Bransby Williams formula (ARR 1987):

$$t_c = 58L/A_c^{0.1} \times S_e^{\ 0.2} \qquad (3)$$

where L (km) is main-stream length to the catchment divide and;

$S_e$ (m/km) is the equal-area slope of the main-stream projected to the catchment divide.

For each stream, the average slope was used as an approximation to $S_e$, since topographic maps of the whole of the catchments were not available.

There are no gauging stations in the vicinity of Yakabindie, and consequently values of the runoff coefficient $C_Y$ for this region have not been determined. On the basis of data from one catchment in the Eastern Goldfields, ARR (1987) recommends use of the formula:

$$C_{10} = 0.346 \times L^{-0.42}.$$

For this catchment, with an area of 59 $km^2$, the frequency factor (ratio of peak flow rate for an average recurrence interval of 50 years to that for 10 years) is

$$Q_{50}/Q_{10} = 1.62. \qquad (4)$$

Table 4 presents the results of calculations of the 50-year recurrence interval flood flows for the three catchments, using Equations (2), (3) and (4), characteristics of the catchments from Table 2, and the design rainfall intensity diagram (Figure 2).

TABLE 4
FLOOD CALCULATIONS

| Catchment | $t_c$ (min) | $I_{t_c}$ 10 (mm/hr) | $C_{10}$ | $Q_{10}$ ($m^3/s$) | $Q_{50}$ ($m^3/s$) |
|---|---|---|---|---|---|
| Jones Creek[1] | 233 | 12 | 0.15 | 16 | 26 |
| Jones Creek[2] | 235 | 12 | 0.15 | 21 | 34 |
| Western Tributory | 75 | 24 | 0.24 | 8 | 12 |

1 Above confluence with Western Tributary.
2 Below confluence with Western Tributary.

## 6. COMPARISON OF FORECASTS WITH JANUARY 1990 FLOOD

There is a large difference between the calculated 50-year floods and the flows estimated from observations of the flood in January 1990. Part of the difference is due to the exceptional intensity of rainfall in January 1990 (average recurrence interval more than 100 yrs). Other possible factors are the assumed value of the Manning Roughness Factor, and estimates of the stream slope and runoff coefficient.

It is considered that the estimated flows in the January 1990 event are conservative approximations to the 50-year flood events in Jones Creek near Six-Mile Well, and the western tributary which joins Jones Creek a short distance further downstream.

## 7. WATER QUALITY

There are no known records of streamwater quality at Yakabindie. Streamflow during the January 1990 flood was described as carrying a moderate suspended sediment load.

It can be assumed that the water is fresh, as the catchment contains no recognisable saline ground.

## 8. CONCLUSIONS

Average rainfall at Yakabindie is 207 mm/yr, and streamlines are normally dry.

In January 1990, a total of 69 mm of rain was recorded at Yakabindie in about 2 hours. On the basis of the design rainfall intensity diagram for the site, this event had an average recurrence interval of more than 100 years (probability of occurrence in any year, less than 1%).

Streamflows in the January 1990 flood are estimated to have reached 140 $m^3/s$ in both Jones Creek near Six-Mile Well, and in the western tributary which joins Jones Creek a short distance further downstream. These flows are much greater than the 50-year (average recurrence interval) floods estimated by conventional means.

The January 1990 flood flows are considered to provide a conservative estimate to the 50-year flood flows in these streams.

There are no records of the quality of water in Jones Creek.

DATED: 19 MARCH 1990

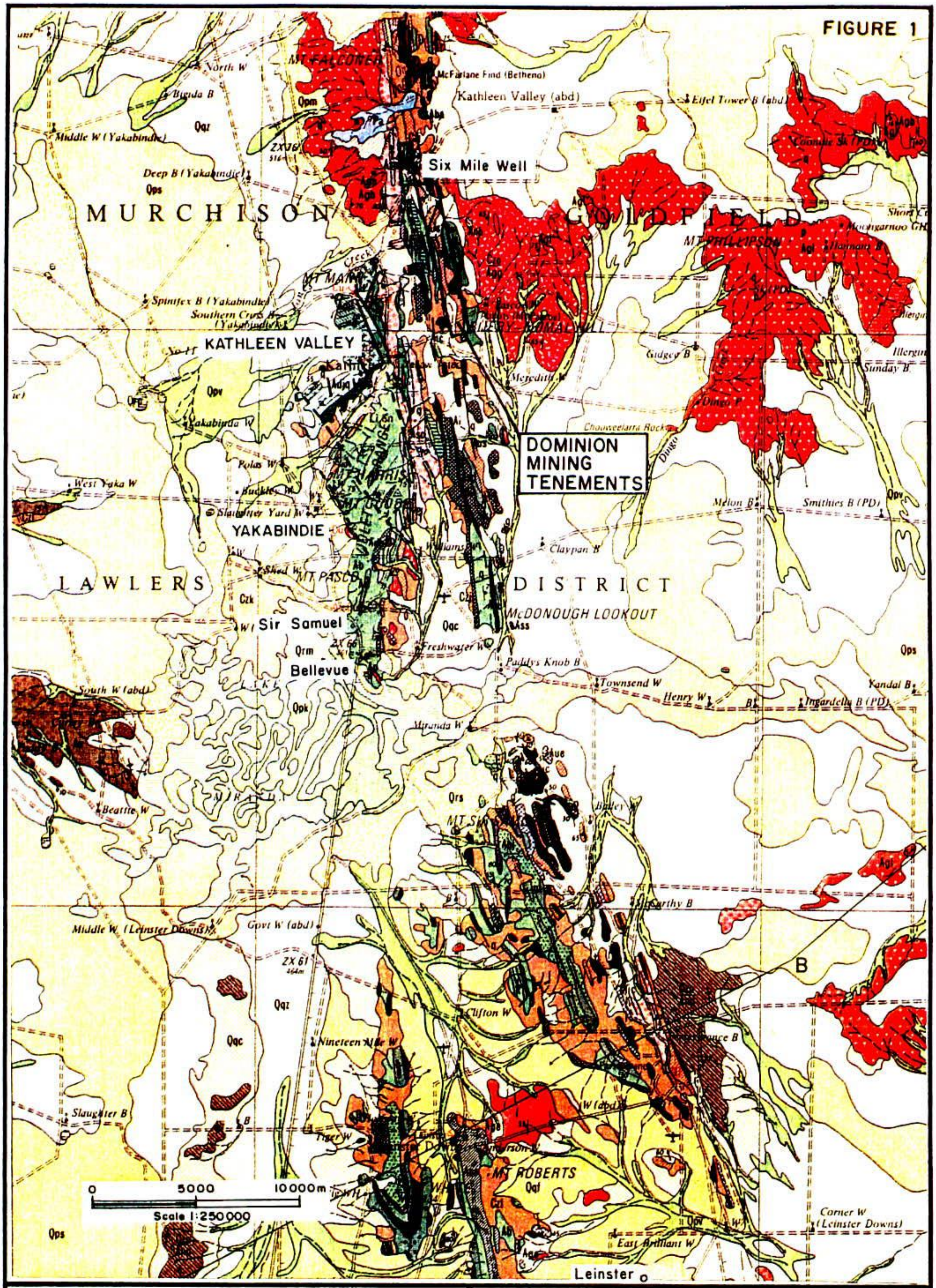
ROCKWATER PTY LTD

for

A. J. PECK
PRINCIPAL HYDROLOGIST

## REFERENCE

Australian Rainfall and Runoff (1987). A Guide to Flood Estimation, Volume 1. The Institution of Engineers, Australia, Canberra.




Client : DOMINION MINING N.L.

Project : YAKABINDIE GROUNDWATER ASSESSMENT

Date : March 1990 Drg. No. 142·1/90/1-1

GEOLOGICAL & LOCALITY MAP

ROCKWATER PTY LTD

FIGURE 2

# DESIGN RAINFALL INTENSITY DIAGRAM

LOCATION 27.425 S 120.575 E * NEAR. YAKABINDIE

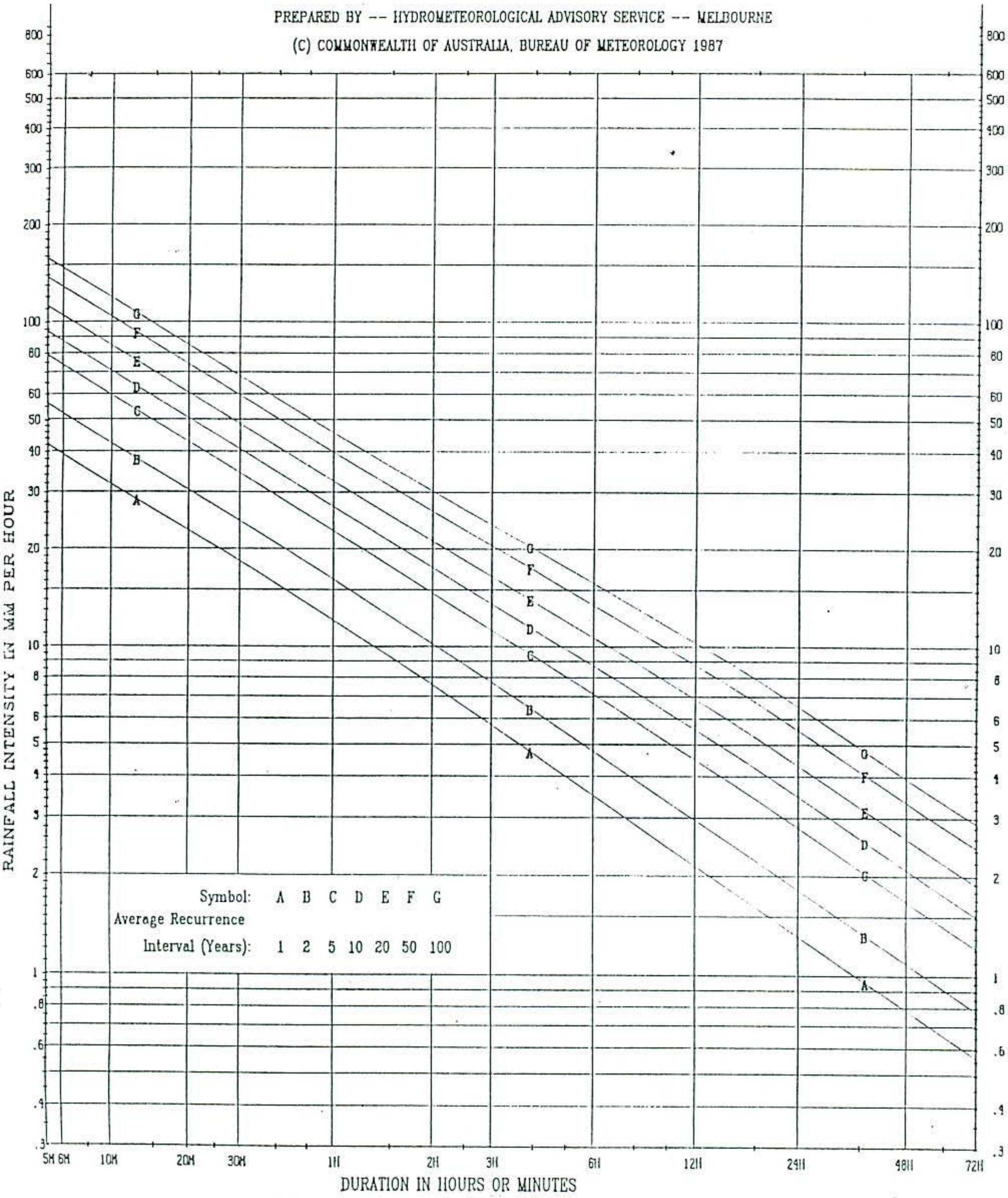
* ENSURE THE COORDINATES ARE THOSE REQUIRED
SINCE DATA IS BASED ON THESE AND NOT THE LOCATION NAME.

ISSUED 27TH FEBRUARY 1990 REF. -FN3226

(RAW DATA 16.28, 2.95, 0.77, 39.75, 8.80, 2.41, 0.040, 590)

PREPARED BY -- HYDROMETEOROLOGICAL ADVISORY SERVICE -- MELBOURNE






Client : SOIL & ROCK ENGINEERING PTY. LTD.

Project : YAKABINDIE ENVIRONMENTAL STUDY

Date : March 1990 Drg. No. 142·1/90/1-2

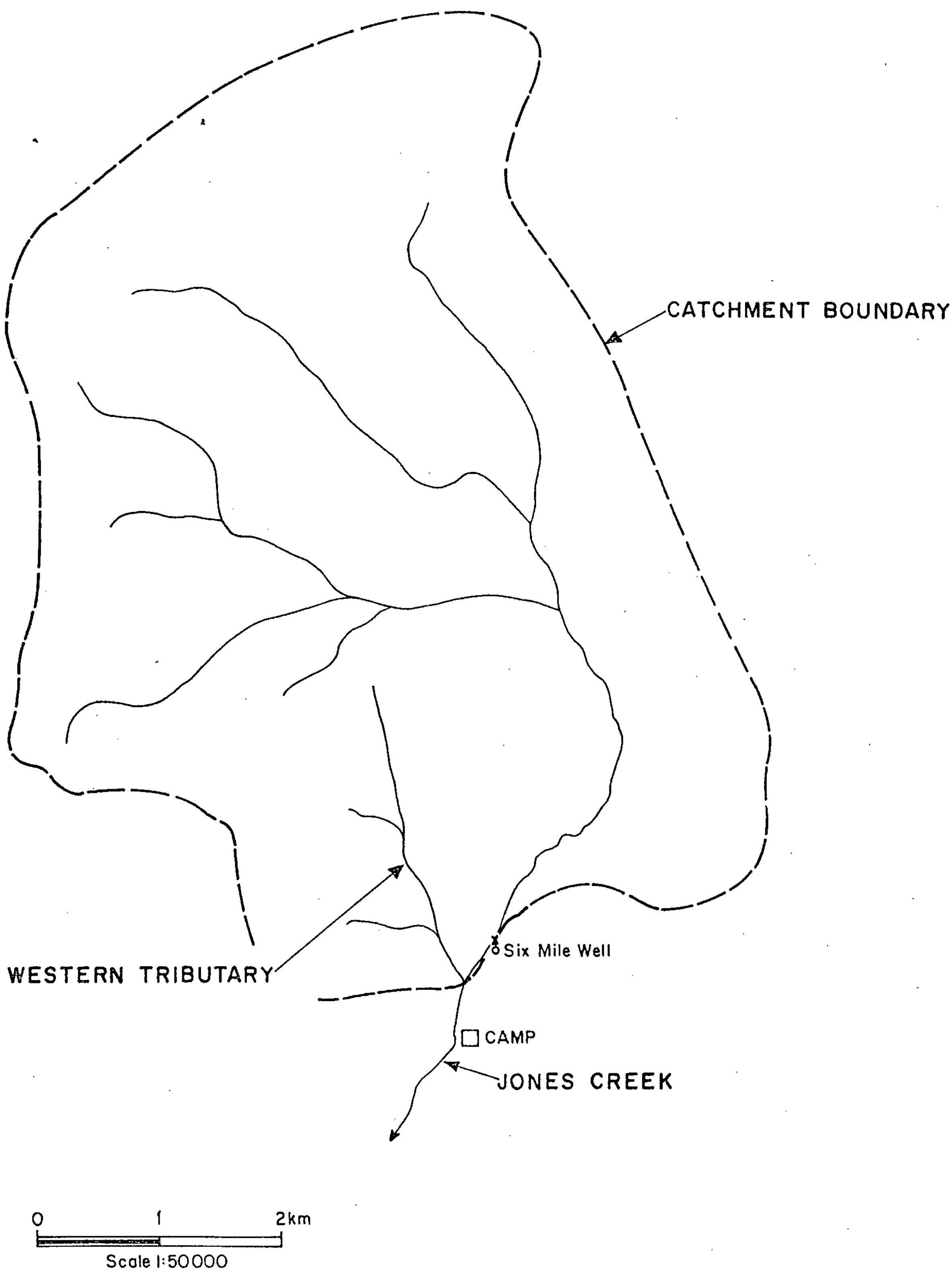
## DESIGN RAINFALL INTENSITY DIAGRAM

FIGURE 3

PHOTOGRAPH OF JONES CREEK AT SIX MILE PROSPECT,
YAKABINDIE, IN FLOOD ON 23 JANUARY 1990

Client: DOMINION MINING
Project: YAKABINDIE GROUNDWATER ASSESSMENT
Date: MARCH 1990 Drg. No. 142.1/90/1-3

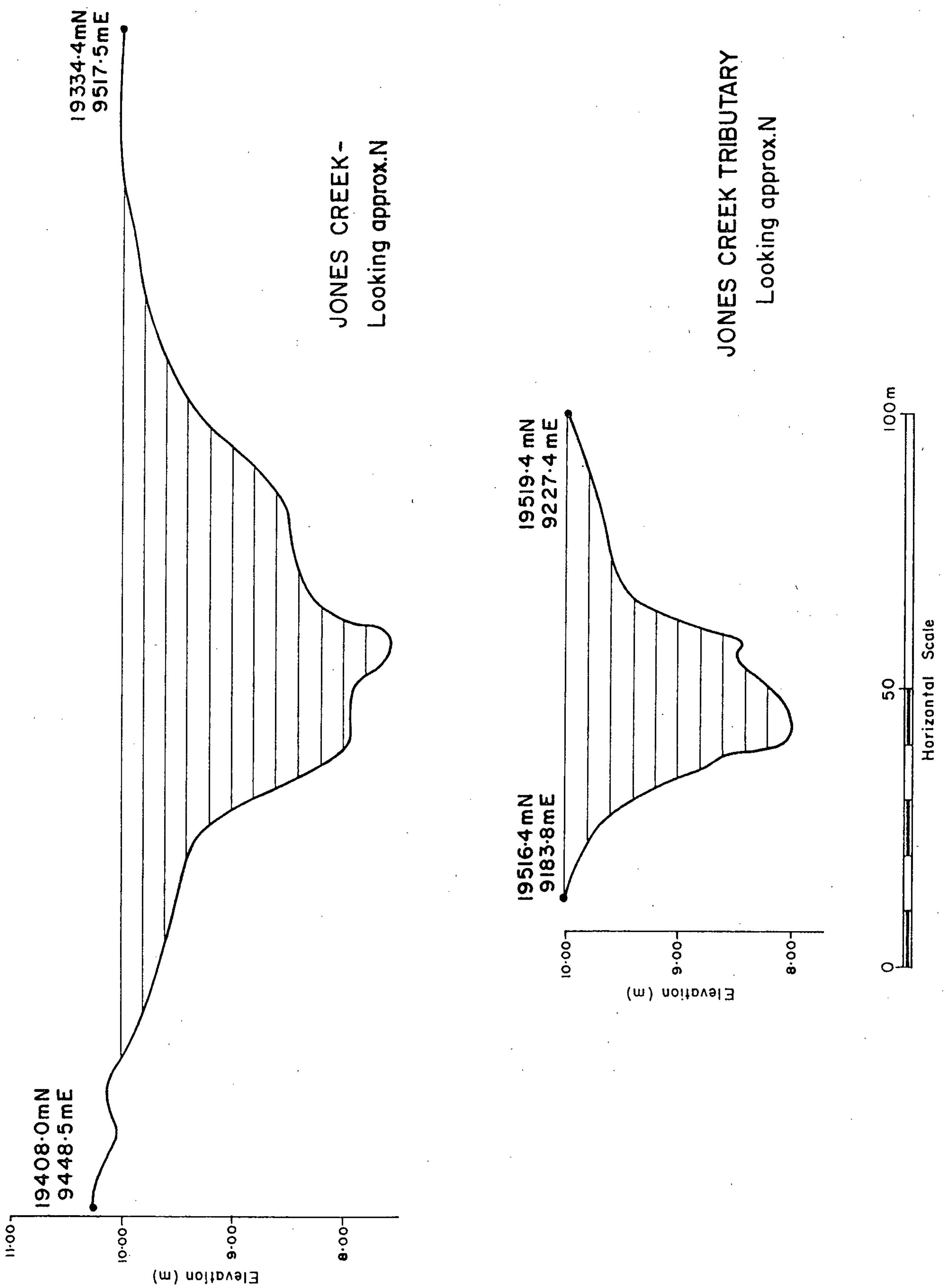
FIGURE 4




| | |
|---|---|
| Client : SOIL & ROCK ENGINEERING PTY. LTD.<br>Project : YAKABINDIE ENVIRONMENTAL STUDY<br>Date : March 1990 Drg. No. 142·1/90/1–4 | JONES CREEK<br>CATCHMENTS & STREAMLINES |

ROCKWATER PTY LTD

FIGURE 5




| | |
|---|---|
| Client : SOIL & ROCK ENGINEERING PTY. LTD.<br>Project : YAKABINDIE ENVIRONMENTAL STUDY<br>Date : March 1990    Drg. No. 142·1/90/1-5 | CROSS SECTIONS OF CREEK BEDS |

ROCKWATER PTY LTD

Rockwater
PROPRIETARY LIMITED
94 ROKEBY ROAD, SUBIACO, WESTERN AUSTRALIA 6008.
P.O. BOX 237, SUBIACO, WESTERN AUSTRALIA 6008.
TELEPHONE: (09) 382 4922
INTERNATIONAL: 619 382 4922
FACSIMILE: (09) 381 3264

DOMINION MINING NL

SOIL AND ROCK ENGINEERING

# GROUNDWATER ENVIRONMENTAL ASSESSMENT
# YAKABINDIE PROJECT

MARCH 1990

142.1/90/2
R16 GW

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DOMINION MINING NL
SOIL AND ROCK ENGINEERING

GROUNDWATER ENVIRONMENTAL ASSESSMENT
YAKABINDIE PROJECT

MARCH 1990

# 1. INTRODUCTION

Process water supplies for the Yakabindie Project are being developed from groundwater sources in an alluvial basin located 12 to 30 kilometres south-west of the mine site at Six Mile Well. Fresh water supplies for domestic use and ore-concentrate washing will be taken from the same basin, or closer sources if they can be located. The rates of supply required for the several uses are given in Section 1.1, below.

The evaluation of the groundwater resources is partly complete. Stage I comprised the drilling of 34 test holes and the construction and test-pumping of five production bores on groundwater exploration Lease E36/136. Further stages have been recommended, to extend the area and detail of the investigation, and to test for fresh groundwater.

This Environmental Assessment has the purpose of describing the groundwater regime, outlining the proposed utilisation scheme, and estimating environmental effects notably water-level reduction, that are expected to arise from the planned extraction of groundwater.

A Geological Locality Map is presented as Figure 1, and a Topographic Locality Plan is presented as Figure 2.

## 1.1 PROJECT WATER REQUIREMENTS

### 1.1.1 Process Water - Saline

The requirements for low-quality process water are 10,800 cu m/d (4 x $10^6$ cu m/yr) to support a projected throughput of 6 x $10^6$ mtpa. Salinities of about 20,000 mg/1 TDS are understood to be suitable. Water of higher salinity will probably be usable, subject to the results of metallurgical test work.

1.1.2 Process Water - Fresh

›r final washing of the ore concentrate, a fresh-water supply of 270 cu m/d ($0.1 \times 10^6$ cu m/yr) is required. Such water needs to have low chloride content.

1.1.3 Domestic Water - Fresh

To support a camp of 200 - 220 people and 15 households, a domestic fresh-water supply of 130 cu m/d ($0.05 \times 10^6$ cu m/yr) is required. Such water needs to have a salinity below 1,000 mg/1 TDS, or at worst 1500 mg/1.

2. EXISTING GROUNDWATER CONDITIONS

The region has two types of groundwater domains: bedrock outcrop areas and alluvial basins. Whereas the mine is located in a belt of mafic/ultramafic bedrock, the main groundwater exploration area lies in a broad, shallow basin. : is shown in Figure 1.

2.1 BASINS

The basins in the Yakabindie area contain sedimentary deposits - alluvium, calcrete, and eolian sands - to depths of up to 120 metres, generally overlying granitic bedrock. Groundwater occurs in sandy alluvium, calcrete, and weathered granite underlying the sedimentary strata. Aquifer intervals are commonly separated by clayey alluvium of low permeability.

A programme of exploration drilling and test-pumping has identified two moderately-productive aquifers on the lease. The major aquifer lies within a palaeochannel of sand trending south-south-westwards from Dingo Creek to Townsend Well and may extend to the eastern end of Lake Miranda. A second aquifer of shallow calcrete underlies the east-west drainage through Townsend Well, Henry Well and Ingardella Bore.

Groundwater salinities range from fresh to saline. Values of salinity from stock bores/wells and some groundwater exploration bores are shown in Figure 2. It is seen that salinities are low in the higher parts of the catchments, and high in the lower parts - reaching hypersaline in the sediments beneath Lake Miranda (which is ephemeral, saline).

Groundwater is presently used for stock watering. Several bores and wells tap both the shallow calcrete in the east-west drainage and alluvium/weathered bedrock elsewhere in the basin. The waters are suitable for stock, ie. less than about 8,000 mg/1. It is noted that the pastoralist's wells/bores in the east-west drainage supply stock-quality water because they tap only the top of the aquifer; there is saltier water at greater depths. Bores drilled in the east-west drainage as part of the present investigation extended deeper into the aquifer and yielded higher salinity water than the stock bores.
ıere is one major groundwater supply developed in the vicinity, for the Bellevue

Mine. The borefield produces about ?1,000 cu m/d (0.36 x $10^6$ cu m/yr) and is located in alluvium, seven kilometres west of the western boundary of Lease 6/136.

The borefields for the Mount Keith nickel project are located several tens of kilometres north of the present test area, from which they are separated by impermeable bedrock highs. Their locations are shown in Figure 2.

### 2.2 BEDROCK

Bedrock contains modest supplies of groundwater locally, in fracture zones that have adequate water storage capacity below the water table.

Mafic bedrock yields groundwater to Six Mile Well and bores/wells near Yakabindie Homestead. There is known to be a significant quantity of groundwater in mafic/ultramafic rocks at the Six Mile Prospect orebody, contained in fractured rock; this source has not yet been evaluated in detail. On the whole, there has en little development of mafic-bedrock groundwater for stock water supplies.

Granite bedrock such as that occurring east of the Prospect and north of the groundwater lease apparently yields water to one or two bores. This rock type is generally low-producing, and has essentially no significance in the present context. Any permeable weathered granite encountered beneath the alluvial basin will be evaluated in conjunction with the sedimentary aquifers.

In this area the bedrock groundwater is fresh to slightly saline. The occurrences of fresh groundwater in bedrock, such as near Yakabindie Homestead, are attributed to favourable local recharge conditions, elevated position, and moderately high permeability.

## 3. PROPOSED BOREFIELD DEVELOPMENT

A borefield to provide the saline process water supply of 10,800 cu m/d (4 x $10^6$ cu m/yr) is proposed to be constructed on Groundwater Exploration Lease E36/136 plus Area 2, which is an extension to the south-west (Fig. 2). A licence is presently being sought for the additional area.

The preliminary design of the borefield is based on a drilling and test-pumping programme followed by hydrogeological assessment and mathematical modelling of the aquifer system. As the investigation programme covered only Area 1, the treatment of Area 2 has required extrapolation of hydrogeological information. Accordingly, the final details of the borefield layout await the results of field investigations in the extended area.

For planning purposes the borefield is designated to comprise 22 bores producing at an average of 490 cu m/d. The layout will be approximately as shown in Figure although the pattern shown is somewhat stylised to conform with the computer model grid. Additional to the salinity process-water borefield, two bores are proposed to be drilled for the fresh-water supply. Potential sites, not yet decided, are: (1) along the eastern margin of the greenstone belt south of Six Mile Well, and (2) along Dingo Creek to the north-east of sites drilled to date.

## 4. EFFECTS OF BOREFIELD OPERATION

### 4.1 WATER LEVELS

The water-level drawdown resulting from borefield operation has been modelled, where possible using aquifer parameters calculated from pumping tests in the present aquifer system.

Simulation was effected with the program MODFLOW (McDonald and Harbaugh, 1984).

The grid size was 1 km x 1 km and the area covered was 15 km x 18 km.

Twenty two bores in Areas 1 and 2 (Fig. 3) were assigned the average pumping rate of 490 cu m/d, giving a total production of 10,800 cu m/d. A pumping period of two years was adopted, to indicate the long-term effects. Beyond that time, the system is expected to reach more or less steady state, by the adjustment of recharge and evapotranspiration rates. Annual recharge (to the aquifer system) was assigned the value 18 mm per year over the borefield area; this is a reasonably conservative value considering the average annual rainfall of 207 mm and the fact that much of the area is low-lying and carries ponded surface water after rainy periods. Significant recharge was indicated by rises in groundwater level of about 0.5 m, following heavy rainfall in January - February 1990.

Contours of model-calculated water-table drawdown are presented in Figure 3. They show the following features.

(1) Generally, the drawdowns in the area containing the borefield are between 2 m and 6 m. The largest drawdown is 7m, in one of the cells containing a production bore.

(2) Because the productive aquifer is an alluvial channel deposit surrounded by material of low permeability, the drawdown will extend very little distance from the channel itself.

(3) The existing bores/wells that might be affected by drawdown are listed below, with estimate of drawdown values.

| | |
|---|---|
| Townsend Well | 1.9 m |
| Bellevue Borefield | 0.02 m |
| Paddy's Bore | 1.6 m |

| | |
|---|---|
| Miranda Well | 0.04 m |
| Henry Well | 0 |
| Ingardella Bore | 0 |

The values are approximate, and will be modified by seasonal effects, especially rainfall. They indicate that only Townsend Well and Paddy's Knob bore are likely to be affected by significant drawdown. The productivity of these water sources should be little affected by drawdown of this scale.

### 4.2 GROUNDWATER QUALITY

As described in Section 2.1, the stock wells in the east-west drainage draw from a thin layer of brackish groundwater overlying saline groundwater. It is possible, but not expected, that pumping from the Yakabindie Project Borefield will cause a depletion of the freshwater at Miranda Paddy's Knob, Townsend, and Henry wells. These water points will need to be sampled regularly during operation of the borefield, to check for any such salinity increase.

The water produced from Area 1 of the Yakabindie Project borefield is expected to have a salinity of about 20,000 mg/1 TDS. That from Area 2 will be more saline, probably in the range 20,000 to 80,000 mg/1. Because water might be drawn from aquifers beneath Lake Miranda, there is a possibility that salinities may rise in the long term. Any such effects will need to be monitored.

### 4.3 OTHER BOREFIELDS

The closest major borefield supplying the Bellevue Mine, is 4 km from the nearest bore proposed for the Yakabindie Project. It is in a separate alluvial channel to the latter, although the aquifers are likely to be connected hydraulically. Simulation has indicated that there will be negligible drawdown interference (0.02 m) caused by the proposed pumping. This prediction would be firmed-up after the testing of Area 2, and checked by monitoring during borefield eration.

The largest user of groundwater in the area is expected to be the Mount Keith Project, whose demand is said to be up to 17 x $10^6$ cu m/yr. Three borefields have been proposed (Fig. 2), the closest two being 12 km to the north and 17 km to the north-west of the Yakabindie lease area. In addition to lying at large distances, the Mount Keith borefields are separated from the present borefield by bedrock ranges and surface-water divides. There is no possibility of drawdown interference.

## 5. MINE DEWATERING

The mine at Six Mile Prospect is designed to be open-cut, and extend to 300 m depth. There is local groundwater contained in fractured mafic and ultramafic ›ck, at least in the upper levels to about 80 m depth.

Dewatering operations will be needed to control groundwater for mine workability and pit-wall stability. They will entail either borehole or in-pit pumping (or both) depending on the aquifer geometry and the scale of water inflows.

The lowering of water levels at the mine will create a local cone of depression in water levels in the adjacent bedrock. This is not seen to be a significant environmental issue because:

(1) local aquifers are relatively small and low-yielding, being restricted to shear zones within the crystalline bedrock

(2) the bedrock has low bulk permeability, therefore the cone of depression will be steep-sided and localised. Unless a major permeable shear zone is discovered in the vicinity of the mine, it is not likely that drawdown effects would extend beyond one or two kilometres along strike, and to much smaller distances across strike.

(3) the only well that will be affected is Six Mile Well, which is expected to become redundant because of the mining operations.

## 6. ENVIRONMENTAL MANAGEMENT

The environmental management procedures recommended herein are designed to:

(1) measure the rates of groundwater extraction
(2) evaluate the extent and depth of drawdowns in and around the borefield
(3) monitor the quality of groundwater produced from the production bores and stock bores/wells in the vicinity.

These procedures will allow identification of any impact on local water resources with respect to other users and effects on vegetation. Remedial measures would be taken to correct any significant adverse effects. These would include the provision of alternate water supplies to maintain stock watering points.

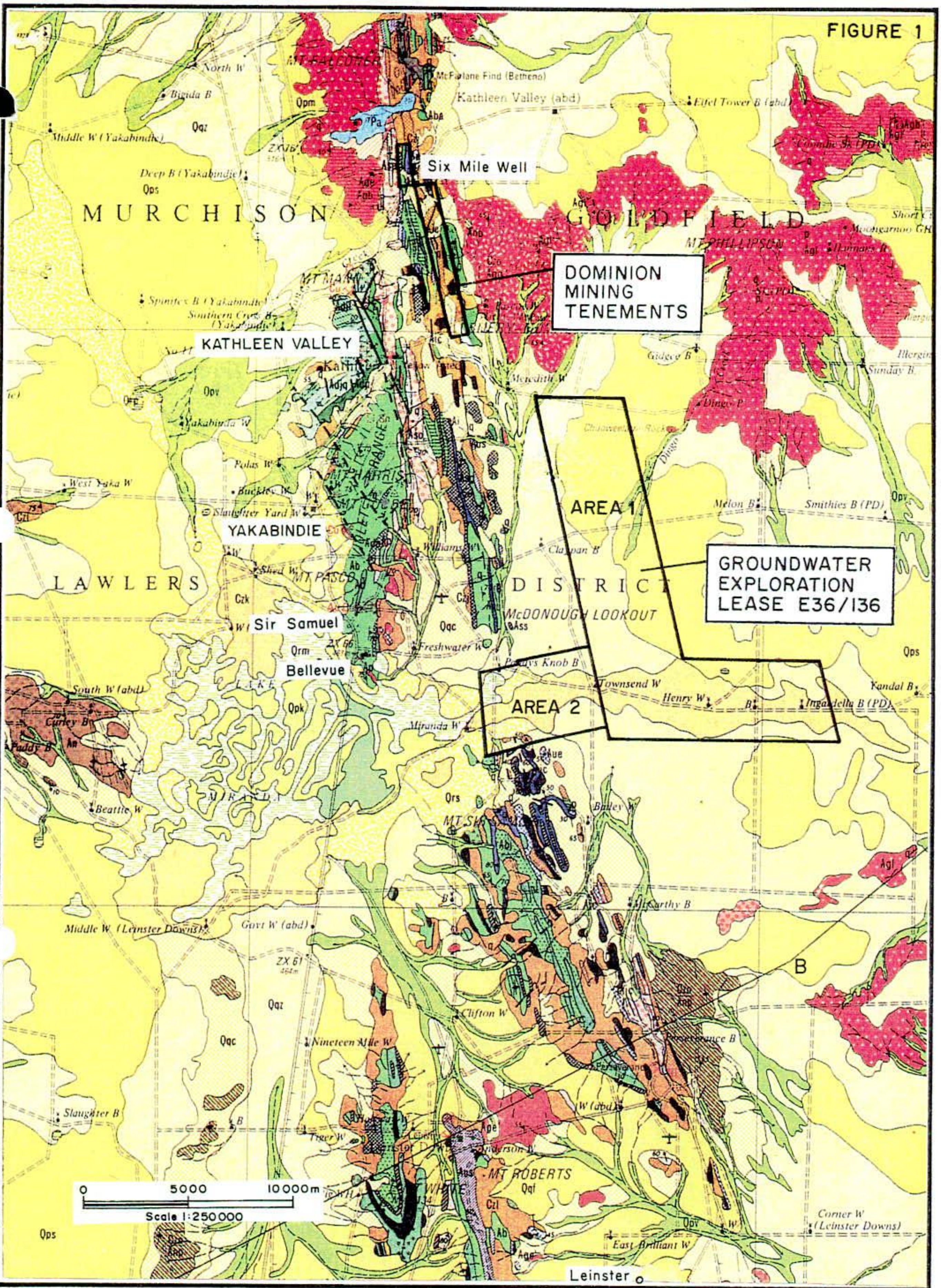
DATED: 29 MARCH 1990

ROCKWATER PTY LTD

J. R. PASSMORE
PRINCIPAL HYDROGEOLOGIST

## REFERENCE

McDonald M.G. and Harbaugh, A.W., 1984, A modular three-dimensional finite-difference groundwater flow model. USGS, National Center, Reston, Virginia.




Client : DOMINION MINING N.L.

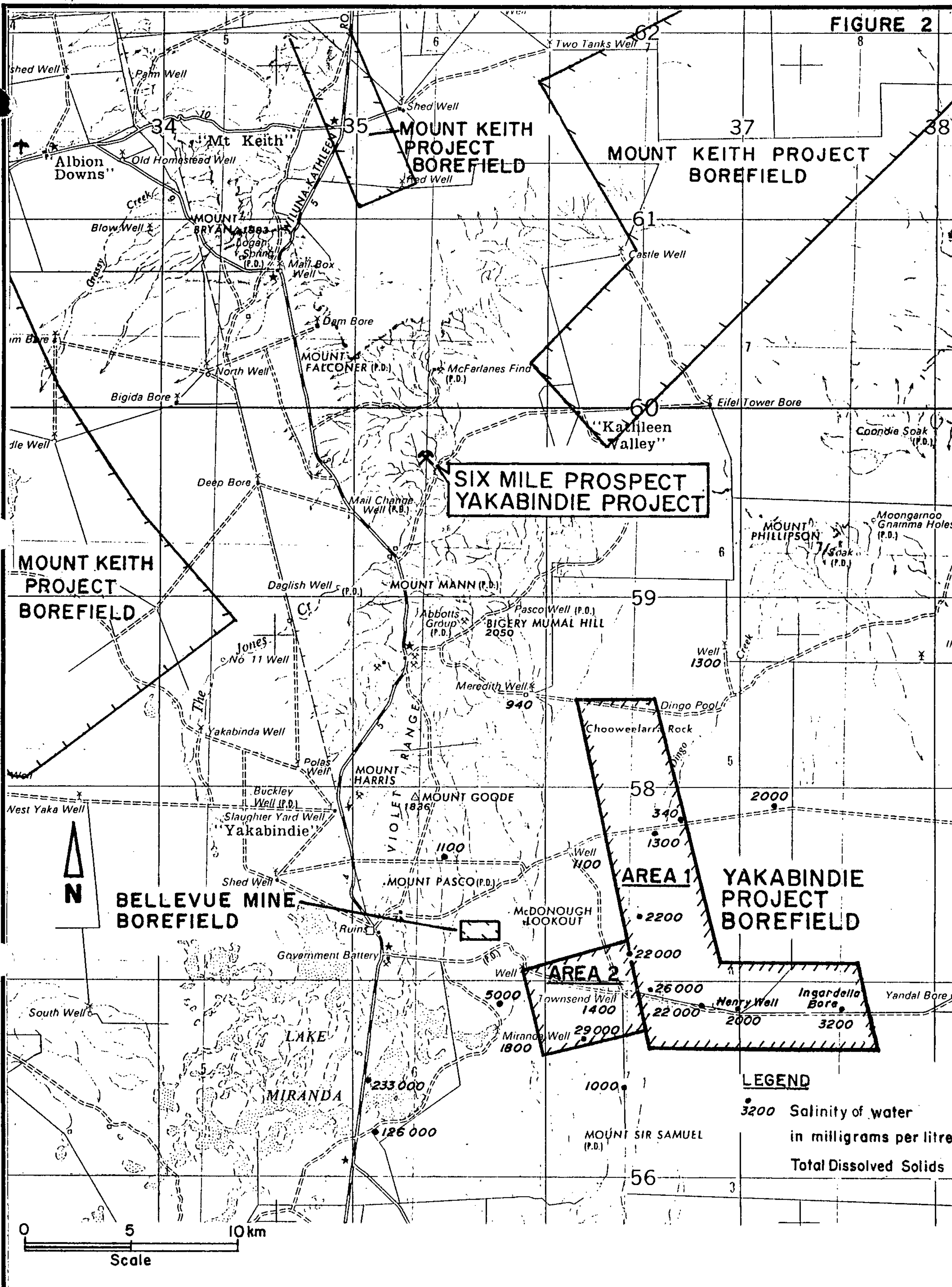
Project : YAKABINDIE ENVIRONMENTAL STUDY

Date : March 1990 Drg. No. 142·1/90/2-1

# GEOLOGICAL & LOCALITY MAP

ROCKWATER PTY LTD

FIGURE 2




| | |
|---|---|
| Client : DOMINION MINING N.L.<br>Project : YAKABINDIE ENVIRONMENTAL STUDY<br>Date : March 1990 Drg. No. 142·1/90/2-2 | TOPOGRAPHIC LOCALITY MAP |

ROCKWATER PTY LTD

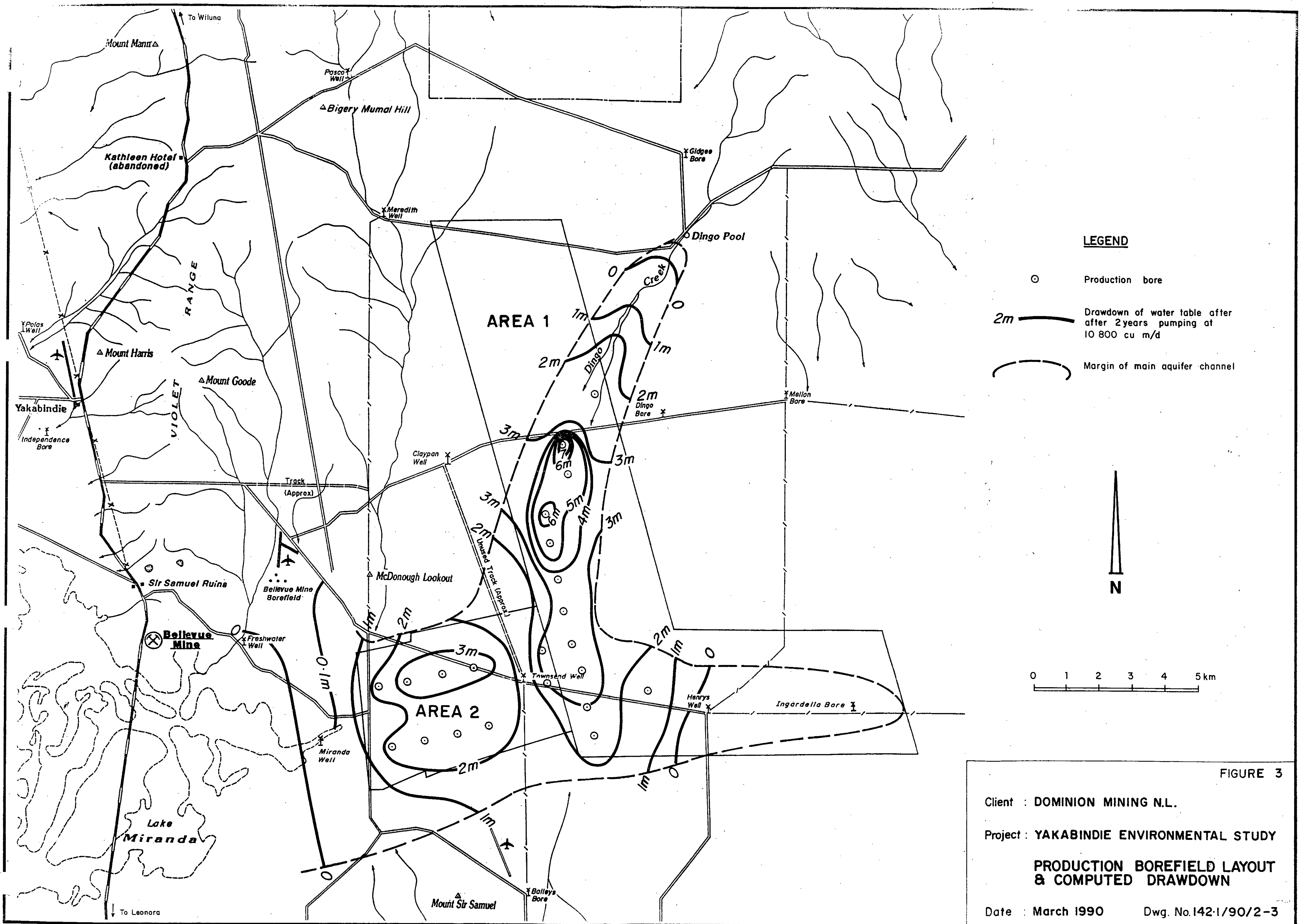



FIGURE 3

Client : DOMINION MINING N.L.

Project : YAKABINDIE ENVIRONMENTAL STUDY

**PRODUCTION BOREFIELD LAYOUT & COMPUTED DRAWDOWN**

Date : March 1990 Dwg. No. 142·1/90/2-3

ROCKWATER PTY LTD

# APPENDIX C4

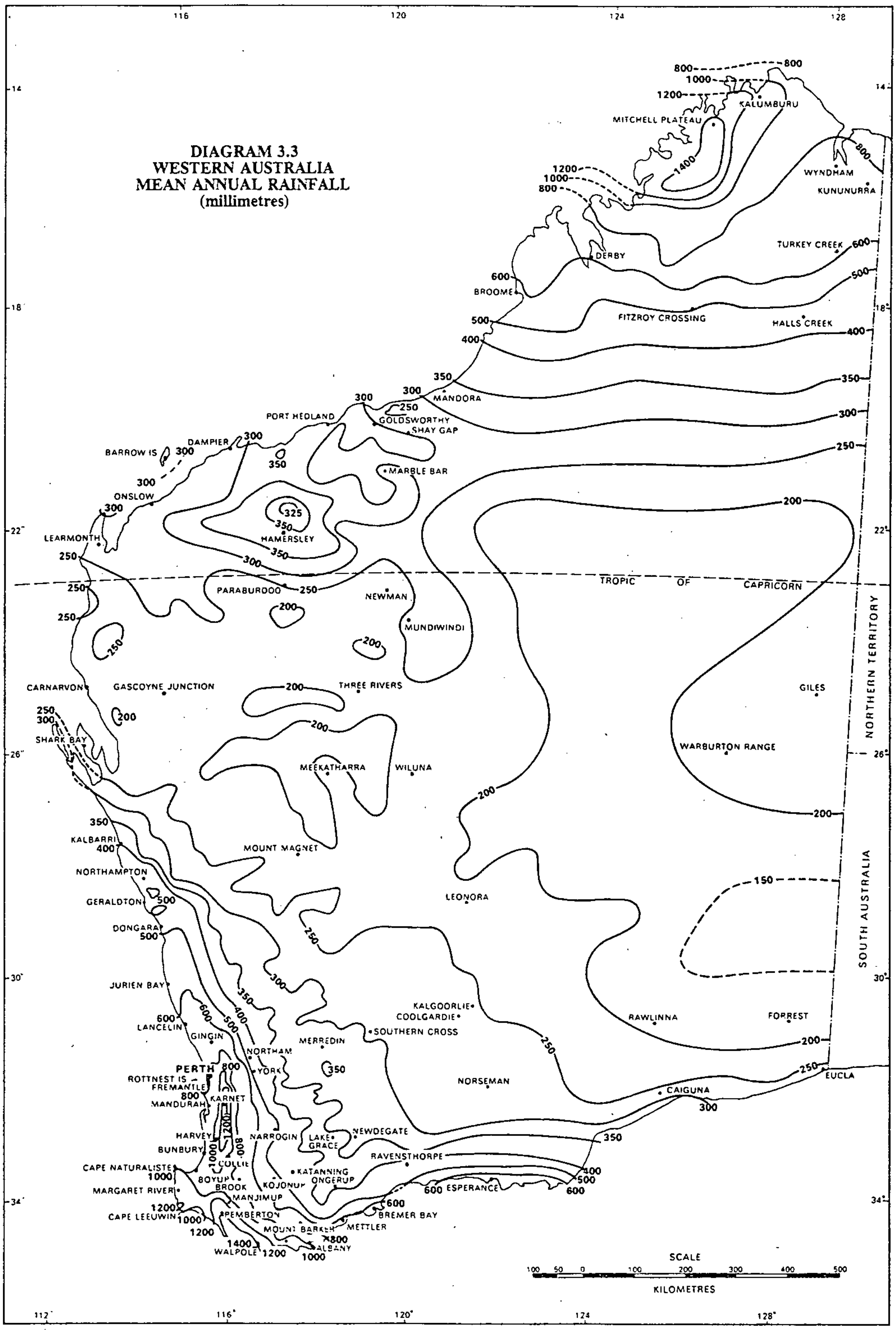



DIAGRAM 3.3
WESTERN AUSTRALIA
MEAN ANNUAL RAINFALL
(millimetres)

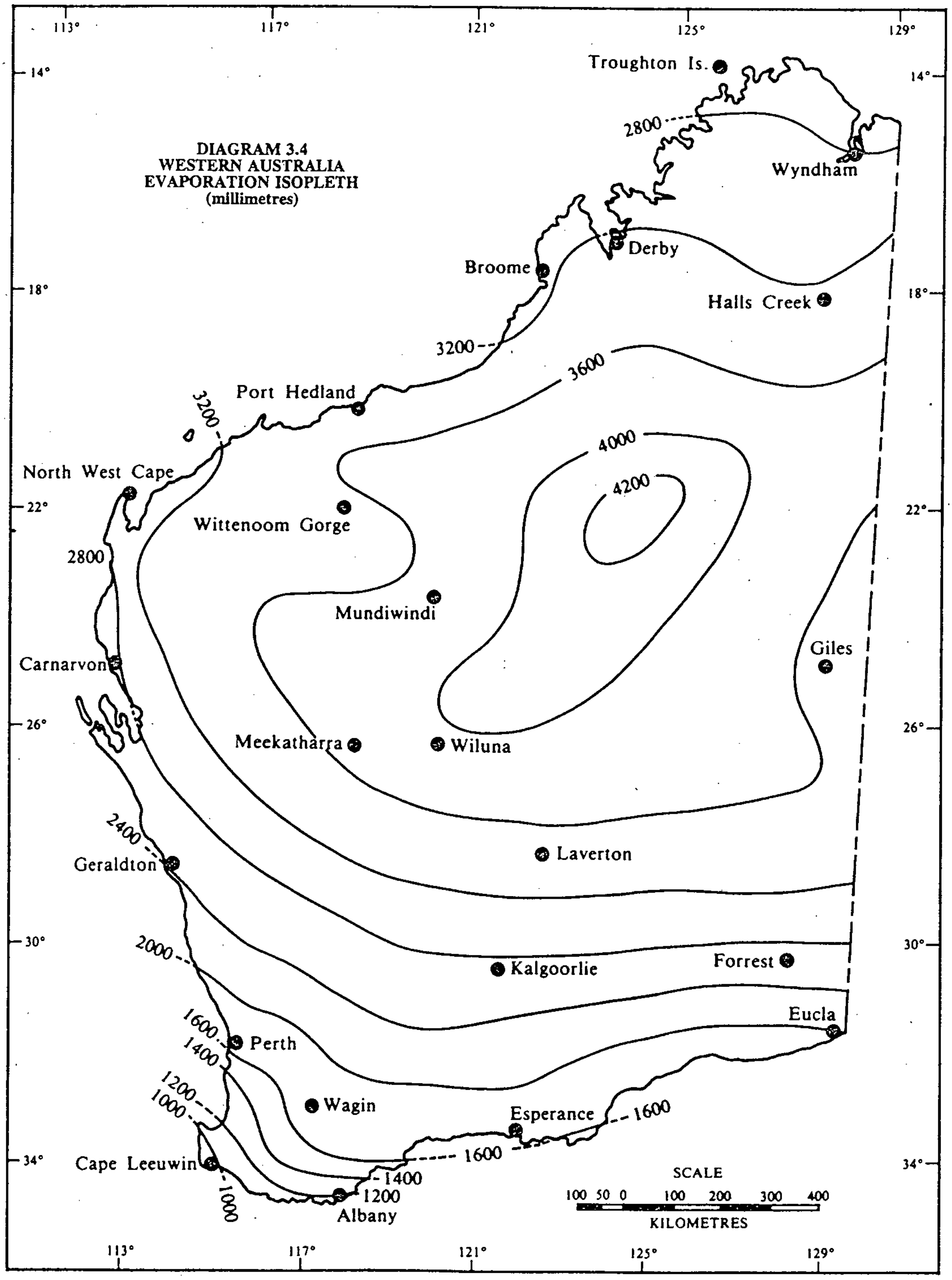
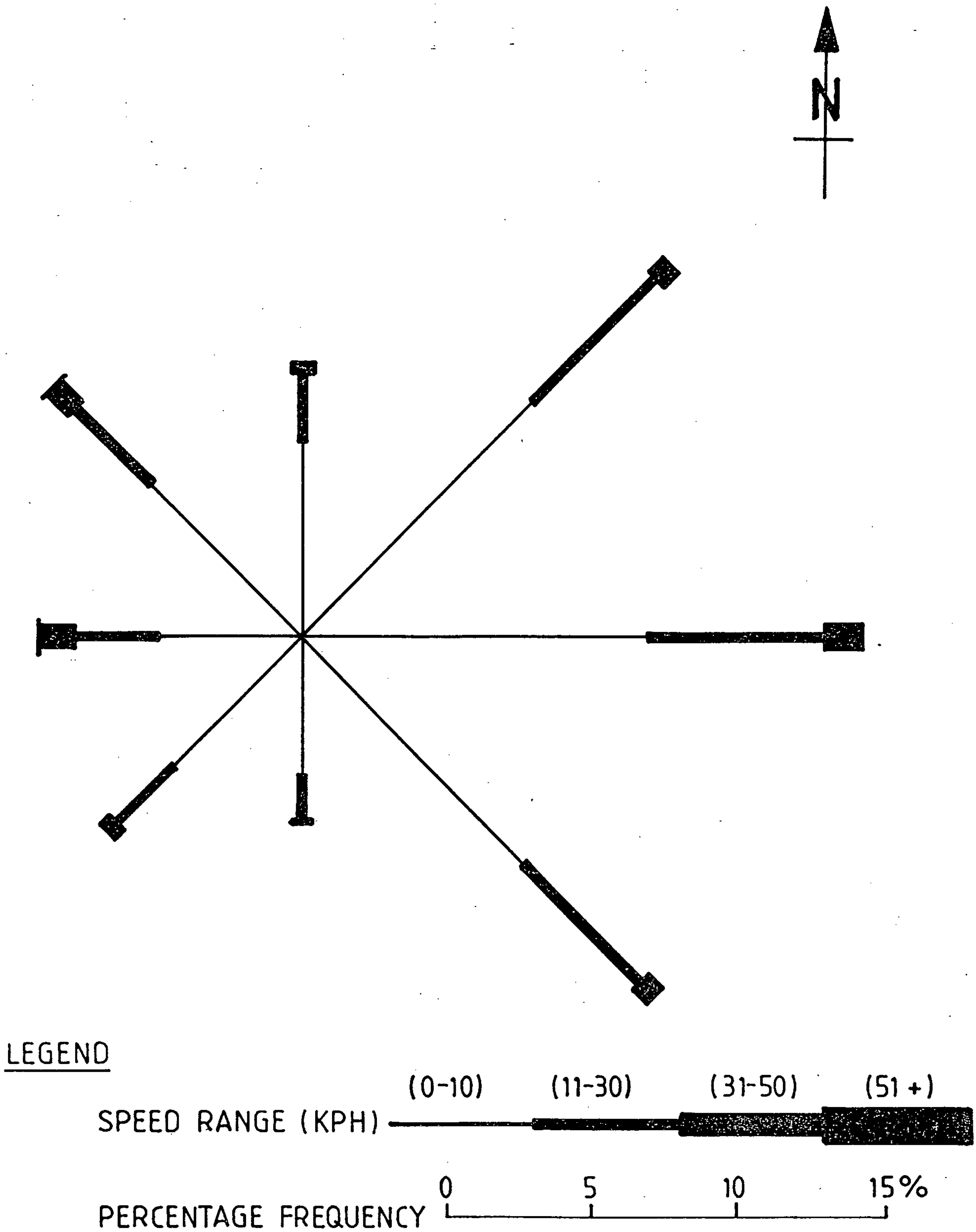


DIAGRAM 3.4
WESTERN AUSTRALIA
EVAPORATION ISOPLETH
(millimetres)
113°
117°
121°
125°
129°
14°
18°
22°
26°
30°
34°
Troughton Is.
Wyndham
Derby
Broome
Halls Creek
Port Hedland
North West Cape
Wittenoom Gorge
Mundiwindi
Giles
Carnarvon
Meekatharra
Wiluna
Laverton
Geraldton
Kalgoorlie
Forrest
Eucla
Perth
Wagin
Esperance
Cape Leeuwin
Albany
2800
3200
3600
4000
4200
2400
2000
1600
1400
1200
1000
SCALE
100 50 0 100 200 300 400
KILOMETRES




YAKABINDIE WIND ROSE

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 32 YEARS OF RECORDS

FIRST YEAR : 1957 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 0.83 %

STATION : 012046 LEONORA (LEONORA POST OFFICE) 28 53 S, 121 19 E 376.0 M ELEV

JANUARY 0900 HOURS LST

SPEED (KM/HR)

CALM 4

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 1 | 1 | 1 | * | | * | | 3 |
| NE | 6 | 5 | 5 | 1 | 1 | | | 18 |
| E | 9 | 11 | 10 | 3 | 3 | 1 | | 37 |
| SE | 7 | 8 | 6 | 2 | 1 | * | | 25 |
| S | 1 | 1 | 1 | * | * | | | 4 |
| SW | 2 | 1 | * | * | * | | | 4 |
| W | * | * | 1 | * | | | | 2 |
| NW | 1 | 1 | 1 | * | * | | | 3 |
| ALL | 28 | 30 | 25 | 7 | 5 | 2 | | |

NO. OF OBS. 990

FEBRUARY 0900 HOURS LST

SPEED (KM/HR)

CALM 5

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 1 | 1 | 1 | * | | | | 3 |
| NE | 6 | 5 | 4 | 1 | 1 | | | 17 |
| E | 10 | 11 | 12 | 3 | 3 | 1 | | 39 |
| SE | 8 | 8 | 7 | 2 | 1 | * | | 26 |
| S | 1 | 1 | 1 | * | | | | 3 |
| SW | 1 | 1 | * | | * | * | | 2 |
| W | 1 | 1 | * | | | * | | 2 |
| NW | 1 | 1 | * | * | * | * | | 3 |
| ALL | 29 | 28 | 26 | 7 | 5 | 1 | | |

NO. OF OBS. 902

MARCH 0900 HOURS LST

SPEED (KM/HR)

CALM 4

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | 1 | * | * | | | 4 |
| NE | 7 | 6 | 4 | 1 | 1 | * | | 18 |
| E | 10 | 11 | 9 | 4 | 4 | 1 | | 38 |
| SE | 8 | 8 | 4 | 2 | 1 | * | * | 23 |
| S | 1 | 1 | 1 | * | * | | | 3 |
| SW | 1 | 1 | 1 | * | * | * | | 3 |
| W | * | 1 | 1 | * | | | | 2 |
| NW | 2 | 1 | 1 | * | * | | | 4 |
| ALL | 31 | 29 | 22 | 7 | 6 | 1 | * | |

NO. OF OBS. 985

APRIL 0900 HOURS LST

SPEED (KM/HR)

CALM 6

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 2 | 2 | * | * | | | 6 |
| NE | 9 | 7 | 3 | 1 | * | | | 20 |
| E | 10 | 8 | 7 | 3 | 2 | * | | 30 |
| SE | 7 | 6 | 4 | 1 | * | | | 19 |
| S | 2 | 2 | 1 | | | | | 4 |
| SW | 4 | 2 | 1 | * | * | | | 7 |
| W | 1 | 1 | 1 | * | * | * | * | 4 |
| NW | 2 | 2 | 1 | * | * | | | 6 |
| ALL | 36 | 29 | 20 | 5 | 3 | * | * | |

NO. OF OBS. 957

JANUARY 1500 HOURS LST

SPEED (KM/HR)

CALM 9

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | 1 | * | * | * | * | 4 |
| NE | 6 | 3 | 1 | * | | * | | 9 |
| E | 8 | 7 | 7 | 1 | 1 | | | 24 |
| SE | 11 | 7 | 4 | 2 | 1 | | | 25 |
| S | 2 | 2 | 1 | * | | | | 5 |
| SW | 3 | 1 | 1 | 1 | * | * | | 7 |
| W | 2 | 2 | 2 | 1 | 1 | * | | 9 |
| NW | 3 | 2 | 2 | 1 | * | * | * | 8 |
| ALL | 38 | 24 | 19 | 6 | 3 | 1 | * | |

NO. OF OBS. 988

FEBRUARY 1500 HOURS LST

SPEED (KM/HR)

CALM 7

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | * | * | * | * | | 4 |
| NE | 4 | 2 | 2 | * | * | | | 9 |
| E | 11 | 8 | 5 | 2 | 1 | * | | 26 |
| SE | 12 | 10 | 4 | 1 | 1 | * | | 29 |
| S | 2 | 1 | 1 | | * | | | 4 |
| SW | 3 | 2 | 1 | * | 1 | * | | 7 |
| W | 2 | 1 | 2 | 1 | 1 | * | * | 7 |
| NW | 2 | 2 | 2 | * | * | 1 | | 7 |
| ALL | 38 | 27 | 18 | 5 | 4 | 1 | * | |

NO. OF OBS. 896

MARCH 1500 HOURS LST

SPEED (KM/HR)

CALM 7

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 1 | 1 | 1 | * | * | * | | 3 |
| NE | 5 | 3 | 1 | * | * | * | | 10 |
| E | 9 | 8 | 6 | 2 | 1 | * | | 25 |
| SE | 10 | 8 | 4 | 1 | 1 | | | 24 |
| S | 3 | 2 | 1 | * | * | | | 6 |
| SW | 4 | 1 | * | * | * | * | | 6 |
| W | 3 | 2 | 2 | 1 | 1 | * | | 9 |
| NW | 4 | 3 | 1 | 1 | 1 | * | * | 10 |
| ALL | 38 | 29 | 16 | 6 | 3 | 1 | * | |

NO. OF OBS. 984

APRIL 1500 HOURS LST

SPEED (KM/HR)

CALM 6

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 1 | * | * | * | | | 5 |
| NE | 8 | 4 | 1 | * | * | | | 14 |
| E | 9 | 6 | 4 | 1 | * | | | 21 |
| SE | 8 | 5 | 2 | * | * | | | 16 |
| S | 2 | 1 | 1 | * | * | | | 5 |
| SW | 4 | 1 | 2 | 1 | * | * | | 8 |
| W | 3 | 3 | 3 | 1 | 1 | * | | 12 |
| NW | 4 | 3 | 3 | 1 | 1 | * | * | 13 |
| ALL | 41 | 25 | 17 | 5 | 4 | 1 | * | |

NO. OF OBS. 942

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 32 YEARS OF RECORDS

FIRST YEAR : 1957 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 0.83 %

STATION : 012046 LEONORA (LEONORA POST OFFICE) 28 53 S, 121 19 E 376.0 M ELEV

MAY 0900 HOURS LST

SPEED (KM/HR)

CALM: 12

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 2 | 1 | 1 | * | | | 7 |
| NE | 6 | 5 | 3 | 1 | 1 | | | 15 |
| E | 11 | 5 | 5 | 1 | 1 | * | | 23 |
| SE | 8 | 4 | 2 | * | | | | 14 |
| S | 2 | 1 | * | * | | | | 3 |
| SW | 4 | 2 | 1 | * | | | | 7 |
| W | 4 | 2 | 2 | * | 1 | 1 | | 9 |
| NW | 4 | 2 | 2 | 1 | 1 | * | * | 10 |
| ALL | 43 | 22 | 16 | 4 | 4 | 1 | * | |

NO. OF OBS. 986

JUNE 0900 HOURS LST

SPEED (KM/HR)

CALM: 14

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 1 | 2 | 1 | * | * | * | 7 |
| NE | 9 | 3 | 2 | 1 | * | * | * | 15 |
| E | 8 | 3 | 3 | 1 | * | * | | 15 |
| SE | 9 | 1 | 1 | * | * | | | 12 |
| S | 2 | * | * | | * | | | 3 |
| SW | 3 | 1 | 1 | * | * | | | 5 |
| W | 5 | 3 | 2 | 1 | 1 | 1 | * | 13 |
| NW | 6 | 4 | 2 | 2 | 2 | * | * | 16 |
| ALL | 46 | 17 | 12 | 5 | 4 | 1 | * | |

NO. OF OBS. 955

JULY 0900 HOURS LST

SPEED (KM/HR)

CALM: 15

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 2 | 1 | 1 | 1 | * | | 7 |
| NE | 5 | 4 | 2 | 1 | * | * | * | 12 |
| E | 9 | 4 | 2 | * | * | | | 15 |
| SE | 6 | 3 | 1 | * | * | | | 10 |
| S | 2 | 1 | 1 | * | * | | | 4 |
| SW | 3 | 2 | 1 | 1 | * | * | | 7 |
| W | 5 | 3 | 2 | 1 | 1 | 1 | | 14 |
| NW | 6 | 3 | 3 | 1 | 1 | 1 | * | 15 |
| ALL | 41 | 21 | 13 | 5 | 4 | 2 | * | |

NO. OF OBS. 984

AUGUST 0900 HOURS LST

SPEED (KM/HR)

CALM: 14

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 1 | 1 | 1 | * | * | * | 6 |
| NE | 5 | 4 | 3 | 1 | 1 | * | * | 15 |
| E | 7 | 4 | 3 | 1 | 1 | * | | 16 |
| SE | 6 | 4 | 1 | * | * | | | 12 |
| S | 2 | 1 | 1 | * | * | | | 4 |
| SW | 4 | 3 | 2 | 1 | * | * | | 10 |
| W | 3 | 3 | 2 | 1 | 1 | * | * | 11 |
| NW | 5 | 3 | 2 | 1 | 1 | 1 | * | 12 |
| ALL | 35 | 23 | 16 | 6 | 4 | 2 | * | |

NO. OF OBS. 992

MAY 1500 HOURS LST

SPEED (KM/HR)

CALM: 9

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 2 | 1 | * | * | * | | 6 |
| NE | 6 | 4 | 1 | * | | | | 12 |
| E | 7 | 5 | 3 | 1 | * | | | 16 |
| SE | 7 | 4 | 1 | * | * | | | 13 |
| S | 2 | 1 | 1 | * | | | | 4 |
| SW | 3 | 3 | 1 | 1 | * | | | 8 |
| W | 4 | 4 | 3 | 1 | 1 | 1 | * | 15 |
| NW | 5 | 4 | 3 | 2 | 2 | * | * | 16 |
| ALL | 38 | 28 | 15 | 5 | 3 | 2 | 1 | |

NO. OF OBS. 948

JUNE 1500 HOURS LST

SPEED (KM/HR)

CALM: 7

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 1 | 1 | 1 | * | * | * | 7 |
| NE | 9 | 3 | 2 | * | * | | | 14 |
| E | 6 | 3 | 2 | * | 1 | | | 11 |
| SE | 6 | 2 | 1 | * | | | | 9 |
| S | 1 | 1 | * | * | * | | | 2 |
| SW | 4 | 3 | 2 | * | * | * | | 9 |
| W | 4 | 5 | 3 | 3 | 2 | 1 | * | 18 |
| NW | 7 | 5 | 4 | 2 | 3 | 1 | 1 | 23 |
| ALL | 40 | 23 | 14 | 6 | 6 | 3 | 1 | |

NO. OF OBS. 950

JULY 1500 HOURS LST

SPEED (KM/HR)

CALM: 9

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 2 | 1 | 1 | * | * | | 8 |
| NE | 5 | 3 | 2 | * | * | | | 10 |
| E | 5 | 3 | 2 | * | * | * | | 11 |
| SE | 5 | 3 | 1 | * | | | | 10 |
| S | 2 | 2 | * | * | | | | 4 |
| SW | 5 | 3 | 2 | 1 | 1 | 1 | | 11 |
| W | 5 | 3 | 3 | 2 | 2 | 2 | 1 | 17 |
| NW | 7 | 4 | 4 | 2 | 2 | 1 | * | 20 |
| ALL | 37 | 23 | 14 | 7 | 5 | 4 | 1 | |

NO. OF OBS. 976

AUGUST 1500 HOURS LST

SPEED (KM/HR)

CALM: 8

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 1 | 2 | * | 1 | * | * | 6 |
| NE | 4 | 2 | 1 | * | * | | | 8 |
| E | 5 | 3 | 2 | * | * | * | | 11 |
| SE | 6 | 3 | 1 | * | * | * | | 10 |
| S | 2 | 1 | 1 | 1 | * | | | 4 |
| SW | 3 | 5 | 2 | 1 | * | * | * | 12 |
| W | 4 | 5 | 5 | 3 | 1 | 2 | 1 | 20 |
| NW | 5 | 4 | 4 | 3 | 2 | 1 | 1 | 19 |
| ALL | 32 | 23 | 18 | 8 | 5 | 4 | 1 | |

NO. OF OBS. 988

* OCCURRED BUT LESS THAN 0.5 PERCENT

PRODUCED BY M.I.S.S. 29/ 3/89

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 32 YEARS OF RECORDS

FIRST YEAR : 1957 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 0.83 %

STATION : 012046 LEONORA (LEONORA POST OFFICE) 28 53 S. 121 19 E 376.0 M ELEV

SEPTEMBER 0900 HOURS LST

SPEED (KM/HR)

CALM 9

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | 2 | 1 | * | * | * | 6 |
| NE | 4 | 6 | 3 | 1 | * | | | 15 |
| E | 6 | 5 | 5 | 2 | 1 | 1 | | 20 |
| SE | 7 | 4 | 3 | 1 | * | * | * | 16 |
| S | 2 | 2 | 1 | * | 1 | * | | 6 |
| SW | 3 | 3 | 2 | 1 | * | * | | 9 |
| W | 2 | 2 | 2 | 2 | 1 | 1 | * | 10 |
| NW | 3 | 2 | 2 | 1 | * | * | * | 9 |
| ALL | 29 | 25 | 20 | 9 | 4 | 2 | 1 | |

NO. OF OBS. 959

OCTOBER 0900 HOURS LST

SPEED (KM/HR)

CALM 5

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 1 | 1 | 2 | * | * | | | 4 |
| NE | 4 | 7 | 4 | 1 | 1 | * | | 18 |
| E | 5 | 5 | 7 | 2 | 1 | 1 | | 21 |
| SE | 6 | 6 | 6 | 2 | * | * | | 20 |
| S | 2 | 2 | 2 | * | * | | | 6 |
| SW | 3 | 2 | 3 | 1 | 1 | * | | 11 |
| W | 2 | 1 | 3 | 1 | 1 | * | * | 8 |
| NW | 1 | 2 | 1 | 1 | 1 | * | * | 6 |
| ALL | 25 | 27 | 27 | 9 | 5 | 2 | 1 | |

NO. OF OBS. 990

NOVEMBER 0900 HOURS LST

SPEED (KM/HR)

CALM 4

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | 1 | 1 | 1 | | | 6 |
| NE | 5 | 4 | 6 | 1 | 1 | * | | 17 |
| E | 5 | 7 | 9 | 2 | 3 | 1 | * | 27 |
| SE | 6 | 7 | 5 | 2 | 1 | * | | 22 |
| S | 2 | 1 | 1 | * | * | | | 4 |
| SW | 3 | 3 | 2 | 1 | * | * | | 9 |
| W | 3 | 2 | 1 | * | 1 | * | | 7 |
| NW | 1 | 1 | 1 | 1 | * | * | | 5 |
| ALL | 27 | 25 | 28 | 8 | 6 | 2 | * | |

NO. OF OBS. 958

DECEMBER 0900 HOURS LST

SPEED (KM/HR)

CALM 4

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | 1 | * | * | | | 4 |
| NE | 5 | 7 | 6 | 1 | 1 | * | | 20 |
| E | 8 | 7 | 10 | 3 | 3 | * | | 31 |
| SE | 7 | 8 | 6 | 1 | * | | | 22 |
| S | 2 | 2 | 1 | * | | * | | 5 |
| SW | 3 | 1 | 1 | 1 | * | | | 6 |
| W | 1 | 1 | * | * | * | | | 3 |
| NW | 2 | 1 | 2 | * | * | * | | 5 |
| ALL | 30 | 28 | 27 | 6 | 5 | 1 | | |

NO. OF OBS. 988

SEPTEMBER 1500 HOURS LST

SPEED (KM/HR)

CALM 9

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | 1 | * | | | | 4 |
| NE | 4 | 2 | 2 | * | * | | | 9 |
| E | 5 | 4 | 2 | * | * | * | | 12 |
| SE | 5 | 4 | 2 | * | * | | | 12 |
| S | 2 | 1 | 1 | * | * | | | 4 |
| SW | 5 | 4 | 2 | 1 | 1 | 1 | * | 13 |
| W | 4 | 3 | 5 | 3 | 2 | 1 | 1 | 19 |
| NW | 5 | 5 | 4 | 3 | 1 | 1 | * | 19 |
| ALL | 31 | 24 | 18 | 8 | 6 | 3 | 1 | |

NO. OF OBS. 952

OCTOBER 1500 HOURS LST

SPEED (KM/HR)

CALM 6

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 2 | 1 | 1 | * | * | | | 4 |
| NE | 3 | 3 | 2 | * | * | * | | 9 |
| E | 4 | 4 | 2 | * | 1 | | | 12 |
| SE | 6 | 5 | 2 | 1 | * | | | 15 |
| S | 2 | 2 | 1 | 1 | * | | | 6 |
| SW | 4 | 3 | 4 | 2 | 1 | * | | 15 |
| W | 3 | 3 | 4 | 2 | 2 | 1 | 1 | 15 |
| NW | 3 | 5 | 5 | 3 | 2 | 1 | 1 | 19 |
| ALL | 28 | 25 | 21 | 9 | 6 | 3 | 2 | |

NO. OF OBS. 980

NOVEMBER 1500 HOURS LST

SPEED (KM/HR)

CALM 7

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 1 | 1 | 1 | * | * | * | | 3 |
| NE | 4 | 2 | 1 | 1 | * | | | 8 |
| E | 4 | 4 | 4 | 1 | 1 | * | | 14 |
| SE | 7 | 6 | 4 | 1 | 1 | | | 18 |
| S | 2 | 2 | 1 | * | * | | * | 5 |
| SW | 5 | 3 | 2 | 1 | 1 | * | * | 12 |
| W | 3 | 4 | 4 | 3 | 2 | 1 | * | 16 |
| NW | 4 | 5 | 3 | 2 | 1 | * | | 16 |
| ALL | 29 | 27 | 20 | 9 | 6 | 2 | * | |

NO. OF OBS. 953

DECEMBER 1500 HOURS LST

SPEED (KM/HR)

CALM 6

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 1 | 1 | 1 | * | * | | | 3 |
| NE | 4 | 4 | 2 | * | | | | 10 |
| E | 6 | 6 | 6 | 1 | 1 | * | | 19 |
| SE | 10 | 6 | 3 | * | * | | | 20 |
| S | 3 | 1 | 1 | * | * | * | | 6 |
| SW | 5 | 2 | 3 | * | * | * | * | 10 |
| W | 3 | 4 | 3 | 2 | 1 | 1 | | 14 |
| NW | 3 | 4 | 2 | 1 | 1 | * | * | 11 |
| ALL | 35 | 29 | 20 | 6 | 3 | 1 | * | |

NO. OF OBS. 980

* OCCURRED BUT LESS THAN 0.5 PERCENT

PRODUCED BY M.I.S.S. 29/ 3/89

# BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 32 YEARS OF RECORDS

FIRST YEAR : 1957    LAST YEAR : 1988    NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 9.96 %

STATION : 013012 WILUNA (WILUNA POST OFFICE)    26 35 S, 120 13 E    521.0 M.ELEV

### JANUARY 0900 HOURS LST

SPEED (KM/HR)

CALM: *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 5 | 3 | 3 | 1 | * | | * | 12 |
| NE | 6 | 9 | 9 | 7 | 3 | 1 | | 35 |
| E | 2 | 6 | 5 | 4 | 2 | 1 | | 20 |
| SE | 3 | 5 | 3 | 4 | 2 | 1 | | 18 |
| S | 3 | 2 | 2 | * | | * | | 6 |
| SW | 2 | 1 | 1 | * | | | | 4 |
| W | 1 | 1 | * | | | | | 2 |
| NW | 1 | 1 | 1 | * | * | | | 3 |
| ALL | 24 | 27 | 23 | 16 | 7 | 2 | * | |

NO. OF OBS. 851

### FEBRUARY 0900 HOURS LST

SPEED (KM/HR)

CALM: 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 5 | 3 | 1 | 1 | * | | | 10 |
| NE | 8 | 9 | 11 | 5 | 1 | * | | 33 |
| E | 4 | 6 | 10 | 5 | 1 | 1 | * | 26 |
| SE | 3 | 4 | 6 | 3 | 2 | * | * | 18 |
| S | 2 | 1 | 1 | 1 | | | | 5 |
| SW | 1 | * | * | * | | | | 2 |
| W | 1 | * | | | | | | 1 |
| NW | 2 | 1 | 1 | * | * | | * | 4 |
| ALL | 26 | 23 | 30 | 14 | 4 | 1 | * | |

NO. OF OBS. 835

### MARCH 0900 HOURS LST

SPEED (KM/HR)

CALM: 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 7 | 3 | 2 | 1 | * | * | | 14 |
| NE | 8 | 9 | 11 | 5 | 1 | | | 33 |
| E | 6 | 7 | 6 | 3 | 1 | * | | 23 |
| SE | 4 | 4 | 5 | 2 | 1 | * | * | 17 |
| S | 3 | 1 | 1 | 1 | * | | | 5 |
| SW | 2 | 1 | * | | * | | | 2 |
| W | 1 | * | | | | | | 1 |
| NW | 2 | 1 | 1 | * | * | | | 4 |
| ALL | 32 | 25 | 25 | 12 | 4 | 1 | * | |

NO. OF OBS. 879

### APRIL 0900 HOURS LST

SPEED (KM/HR)

CALM: 2

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 10 | 3 | 4 | 1 | * | | | 18 |
| NE | 11 | 6 | 8 | 5 | 1 | * | | 31 |
| E | 5 | 4 | 4 | 3 | 1 | * | | 16 |
| SE | 4 | 3 | 4 | 2 | 1 | * | | 15 |
| S | 4 | 1 | * | * | | * | | 5 |
| SW | 1 | 1 | 1 | * | * | * | | 4 |
| W | 1 | * | * | * | | | | 2 |
| NW | 4 | 2 | 1 | 1 | | | | 7 |
| ALL | 40 | 21 | 22 | 12 | 3 | 1 | | |

NO. OF OBS. 825

### JANUARY 1500 HOURS LST

SPEED (KM/HR)

CALM: *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 3 | 1 | 1 | * | * | | 9 |
| NE | 5 | 5 | 2 | 2 | 1 | * | | 15 |
| E | 4 | 5 | 3 | 3 | 2 | | | 17 |
| SE | 4 | 7 | 5 | 5 | 1 | * | | 23 |
| S | 4 | 4 | 2 | 1 | * | * | | 11 |
| SW | 4 | 3 | 2 | 1 | * | | | 10 |
| W | 1 | 1 | 1 | * | * | | | 4 |
| NW | 4 | 3 | 2 | 1 | 1 | * | | 11 |
| ALL | 30 | 31 | 18 | 14 | 6 | 1 | | |

NO. OF OBS. 833

### FEBRUARY 1500 HOURS LST

SPEED (KM/HR)

CALM: 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 5 | 2 | 1 | * | * | * | * | 9 |
| NE | 6 | 6 | 3 | 1 | * | * | | 17 |
| E | 5 | 6 | 5 | 3 | 1 | * | * | 20 |
| SE | 6 | 8 | 8 | 3 | 2 | * | * | 27 |
| S | 5 | 2 | 1 | * | * | | | 9 |
| SW | 2 | 2 | 1 | * | * | | | 6 |
| W | 2 | 1 | 1 | 1 | * | * | | 4 |
| NW | 4 | 2 | 2 | * | | | | 8 |
| ALL | 34 | 28 | 22 | 9 | 3 | 1 | * | |

NO. OF OBS. 827

### MARCH 1500 HOURS LST

SPEED (KM/HR)

CALM: 3

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 6 | 3 | 1 | 1 | | | | 10 |
| NE | 6 | 4 | 4 | 1 | | | | 15 |
| E | 7 | 5 | 5 | 2 | 1 | * | | 20 |
| SE | 6 | 7 | 6 | 2 | 1 | * | | 22 |
| S | 4 | 2 | 2 | 1 | * | | | 9 |
| SW | 3 | 2 | 1 | 1 | | | | 7 |
| W | 1 | 2 | 1 | * | * | | | 4 |
| NW | 5 | 3 | 2 | 1 | * | | | 10 |
| ALL | 38 | 27 | 22 | 8 | 2 | * | | |

NO. OF OBS. 864

### APRIL 1500 HOURS LST

SPEED (KM/HR)

CALM: 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 8 | 3 | 1 | 1 | * | * | | 13 |
| NE | 8 | 3 | 4 | 1 | | * | | 16 |
| E | 6 | 3 | 4 | 2 | 1 | | | 16 |
| SE | 5 | 4 | 5 | 1 | 1 | | | 16 |
| S | 5 | 2 | 1 | * | * | * | | 8 |
| SW | 4 | 3 | 2 | 1 | | * | | 10 |
| W | 1 | 2 | 1 | 1 | * | * | | 5 |
| NW | 6 | 3 | 4 | 1 | * | * | | 15 |
| ALL | 42 | 24 | 22 | 7 | 2 | 1 | | |

NO. OF OBS. 816

* OCCURRED BUT LESS THAN 0.5 PERCENT

PRODUCED BY M.I.S.S. 29/ 3/89

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 32 YEARS OF RECORDS

FIRST YEAR : 1957 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 9.96 %

STATION : 013012 WILUNA (WILUNA POST OFFICE) 26 35 S, 120 13 E 521.0 M ELEV

MAY 0900 HOURS LST

SPEED (KM/HR) — CALM 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 9 | 4 | 3 | 1 | * | * | * | 18 |
| NE | 9 | 8 | 7 | 3 | 1 | * | | 28 |
| E | 7 | 3 | 3 | 1 | * | | | 14 |
| SE | 6 | 3 | 3 | 1 | * | * | | 12 |
| S | 3 | 1 | 1 | * | * | | | 5 |
| SW | 4 | 1 | 1 | * | | | * | 6 |
| W | 3 | 1 | * | * | * | * | * | 4 |
| NW | 6 | 2 | 2 | 1 | 1 | | | 11 |
| ALL | 46 | 22 | 19 | 8 | 3 | * | * | |

NO. OF OBS. 915

JUNE 0900 HOURS LST

SPEED (KM/HR) — CALM 2

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 11 | 3 | 2 | 1 | * | * | | 18 |
| NE | 10 | 6 | 5 | 1 | 1 | * | * | 23 |
| E | 5 | 3 | 1 | * | 1 | | | 10 |
| SE | 6 | 3 | 2 | 1 | | | | 12 |
| S | 4 | 1 | * | * | | | | 6 |
| SW | 4 | 2 | 1 | 1 | * | * | | 7 |
| W | 4 | 1 | 1 | * | * | * | | 7 |
| NW | 8 | 2 | 2 | 1 | * | | | 14 |
| ALL | 51 | 22 | 16 | 6 | 3 | * | * | |

NO. OF OBS. 902

JULY 0900 HOURS LST

SPEED (KM/HR) — CALM 2

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 8 | 3 | 3 | 2 | 1 | * | * | 15 |
| NE | 9 | 4 | 4 | 3 | 1 | * | | 20 |
| E | 7 | 3 | 2 | 1 | * | | | 12 |
| SE | 8 | 3 | 2 | 1 | | * | | 15 |
| S | 4 | 1 | 1 | * | * | * | | 6 |
| SW | 5 | 3 | 1 | 1 | 1 | | | 10 |
| W | 3 | 2 | 1 | * | * | * | | 7 |
| NW | 7 | 3 | 1 | 1 | 1 | | * | 12 |
| ALL | 50 | 21 | 15 | 8 | 3 | 1 | * | |

NO. OF OBS. 914

AUGUST 0900 HOURS LST

SPEED (KM/HR) — CALM 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 7 | 4 | 2 | 1 | 1 | | | 15 |
| NE | 6 | 7 | 5 | 3 | 1 | * | | [illegible] |
| E | 3 | 4 | 3 | 2 | 1 | | | 13 |
| SE | 5 | 6 | 4 | 2 | 1 | * | | 17 |
| S | 3 | 1 | 2 | 1 | * | | | 7 |
| SW | 3 | 2 | 2 | 1 | * | * | | 9 |
| W | 3 | 2 | 1 | * | * | * | | 6 |
| NW | 4 | 2 | 1 | 1 | 1 | * | | 9 |
| ALL | 35 | 27 | 20 | 11 | 5 | 1 | | |

NO. OF OBS. 945

MAY 1500 HOURS LST

SPEED (KM/HR) — CALM *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 7 | 3 | 2 | 1 | * | | * | 13 |
| NE | 7 | 3 | 3 | 1 | * | | | 15 |
| E | 7 | 4 | 4 | 1 | * | * | | 17 |
| SE | 6 | 4 | 2 | 1 | * | * | | 13 |
| S | 4 | 2 | 1 | * | * | | | 7 |
| SW | 3 | 4 | 2 | 1 | * | * | | 10 |
| W | 2 | 2 | 2 | 1 | * | * | | 7 |
| NW | 7 | 3 | 3 | 1 | 1 | | * | 16 |
| ALL | 42 | 26 | 21 | 8 | 3 | 1 | * | |

NO. OF OBS. 905

JUNE 1500 HOURS LST

SPEED (KM/HR) — CALM 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 8 | 3 | 2 | 1 | * | | | 14 |
| NE | 8 | 4 | 4 | 2 | 1 | | | 17 |
| E | 5 | 3 | 2 | 1 | * | * | | 11 |
| SE | 4 | 3 | 4 | 1 | * | * | | 12 |
| S | 4 | 2 | 1 | * | * | | | 6 |
| SW | 3 | 3 | 3 | 1 | 1 | * | | 11 |
| W | 3 | 2 | 2 | 2 | * | * | | 10 |
| NW | 6 | 4 | 3 | 3 | 1 | * | * | 17 |
| ALL | 41 | 23 | 21 | 9 | 3 | 1 | * | |

NO. OF OBS. 889

JULY 1500 HOURS LST

SPEED (KM/HR) — CALM 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 6 | 3 | 3 | 1 | 1 | * | | 13 |
| NE | 6 | 4 | 3 | 1 | * | * | | 15 |
| E | 5 | 2 | 3 | 1 | * | * | | 11 |
| SE | 5 | 4 | 3 | 2 | * | * | | 14 |
| S | 5 | 2 | 1 | * | | | | 8 |
| SW | 5 | 3 | 3 | 2 | 1 | | | 15 |
| W | 2 | 3 | 2 | * | 1 | 1 | * | 9 |
| NW | 7 | 3 | 3 | 1 | 1 | 1 | | 15 |
| ALL | 41 | 25 | 20 | 8 | 4 | 2 | * | |

NO. OF OBS. 898

AUGUST 1500 HOURS LST

SPEED (KM/HR) — CALM *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 3 | 1 | 1 | * | * | | 9 |
| NE | 5 | 3 | 3 | 1 | * | | | 13 |
| E | 3 | 3 | 2 | 2 | 1 | | | 10 |
| SE | 6 | 5 | 4 | 2 | * | * | | 16 |
| S | 3 | 2 | 1 | 1 | * | | | 6 |
| SW | 4 | 4 | 4 | 2 | 1 | * | | 16 |
| W | 3 | 3 | 3 | 1 | 1 | 1 | * | 13 |
| NW | 5 | 3 | 4 | 2 | 1 | * | * | 16 |
| ALL | 33 | 26 | 22 | 12 | 5 | 2 | * | |

NO. OF OBS. 930

* OCCURRED BUT LESS THAN 0.5 PERCENT

PRODUCED BY M.I.S.S. 29/ 3/89

* OCCURRED BUT LESS THAN 0.5 PERCENT

PRODUCED BY M.I.S.S. 29/ 3/89

H 04

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 32 YEARS OF RECORDS

FIRST YEAR : 1957 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 9.96 %

STATION : 013012 WILUNA (WILUNA POST OFFICE) 26 35 S, 120 13 E 521.0 M ELEV

SEPTEMBER 0900 HOURS LST

SPEED (KM/HR)

CALM: *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 3 | 2 | 1 | 1 | | | 10 |
| NE | 5 | 5 | 7 | 4 | 2 | 1 | | 24 |
| E | 4 | 4 | 4 | 2 | 1 | * | | 16 |
| SE | 5 | 4 | 6 | 3 | 1 | * | * | 20 |
| S | 4 | 3 | 2 | 1 | * | | * | 9 |
| SW | 3 | 3 | 3 | 2 | 1 | * | | 11 |
| W | 2 | * | * | * | * | * | * | 4 |
| NW | 3 | 1 | 1 | 1 | 1 | * | | 6 |
| ALL | 29 | 23 | 25 | 14 | 7 | 2 | * | |

NO. OF OBS. 880

OCTOBER 0900 HOURS LST

SPEED (KM/HR)

CALM: 1

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 2 | 3 | 1 | * | * | * | 11 |
| NE | 4 | 6 | 7 | 4 | 2 | 1 | * | 25 |
| E | 4 | 5 | 5 | 2 | 1 | * | | 17 |
| SE | 4 | 4 | 6 | 2 | 1 | * | | 18 |
| S | 3 | 3 | 2 | 1 | * | | | 9 |
| SW | 3 | 2 | 3 | 2 | * | | | 10 |
| W | 1 | 1 | 1 | * | * | | | 4 |
| NW | 2 | 1 | 1 | 1 | * | * | | 6 |
| ALL | 26 | 25 | 27 | 13 | 6 | 2 | * | |

NO. OF OBS. 936

NOVEMBER 0900 HOURS LST

SPEED (KM/HR)

CALM: *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 3 | 3 | 1 | 1 | * | * | 11 |
| NE | 4 | 6 | 7 | 5 | 4 | 1 | * | 28 |
| E | 3 | 3 | 4 | 3 | 2 | * | * | 15 |
| SE | 4 | 6 | 5 | 3 | 1 | * | | 19 |
| S | 1 | 3 | 2 | 1 | * | | | 7 |
| SW | 3 | 3 | 2 | 1 | * | 1 | | 10 |
| W | 1 | 1 | 1 | | | * | | 4 |
| NW | 2 | 1 | 1 | * | * | * | | 5 |
| ALL | 23 | 26 | 24 | 14 | 9 | 3 | * | |

NO. OF OBS. 857

DECEMBER 0900 HOURS LST

SPEED (KM/HR)

CALM: *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 3 | 3 | 1 | 1 | * | | 12 |
| NE | 4 | 8 | 10 | 5 | 2 | 1 | | 31 |
| E | 2 | 4 | 5 | 4 | 1 | * | | 18 |
| SE | 4 | 5 | 5 | 4 | 2 | * | | 20 |
| S | 2 | 2 | 2 | 1 | * | | * | 8 |
| SW | 2 | 3 | 1 | * | * | | | 5 |
| W | 1 | 1 | * | * | | | | 2 |
| NW | 2 | 2 | 1 | * | * | * | | 5 |
| ALL | 21 | 28 | 26 | 17 | 6 | 1 | * | |

NO. OF OBS. 872

SEPTEMBER 1500 HOURS LST

SPEED (KM/HR)

CALM:

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 2 | 2 | 1 | * | * | * | 9 |
| NE | 3 | 3 | 2 | 1 | * | * | | 10 |
| E | 3 | 3 | 1 | 2 | 1 | * | | 10 |
| SE | 5 | 4 | 4 | 2 | 1 | 1 | | 16 |
| S | 3 | 2 | 2 | 1 | * | * | | 8 |
| SW | 3 | 4 | 4 | 2 | 2 | 1 | | 15 |
| W | 3 | 3 | 3 | 3 | 2 | * | * | 14 |
| NW | 5 | 4 | 4 | 2 | 1 | 1 | 1 | 17 |
| ALL | 29 | 24 | 22 | 13 | 7 | 3 | 1 | |

NO. OF OBS. 862

OCTOBER 1500 HOURS LST

SPEED (KM/HR)

CALM: *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 1 | 1 | 1 | * | * | | 7 |
| NE | 4 | 2 | 1 | 1 | * | * | * | 10 |
| E | 4 | 4 | 2 | 1 | * | * | | 11 |
| SE | 3 | 4 | 3 | 2 | 1 | * | | 12 |
| S | 5 | 3 | 2 | * | * | | | 10 |
| SW | 4 | 6 | 5 | 2 | 1 | 1 | | 19 |
| W | 2 | 3 | 4 | 2 | 1 | 1 | * | 13 |
| NW | 4 | 4 | 4 | 3 | 2 | 1 | * | 18 |
| ALL | 31 | 26 | 21 | 13 | 6 | 3 | * | |

NO. OF OBS. 923

NOVEMBER 1500 HOURS LST

SPEED (KM/HR)

CALM: *

| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 3 | 2 | 2 | 1 | 1 | | | 9 |
| NE | 3 | 3 | 2 | 2 | 1 | * | * | 11 |
| E | 3 | 3 | 2 | 2 | 1 | * | * | 11 |
| SE | 3 | 5 | 4 | 2 | 1 | * | * | 14 |
| S | 3 | 2 | 2 | 1 | * | * | | 8 |
| SW | 4 | 6 | 3 | 2 | 1 | * | * | 18 |
| W | 2 | 3 | 3 | 1 | 2 | * | * | 13 |
| NW | 5 | 3 | 4 | 2 | 1 | * | * | 16 |
| ALL | 27 | 28 | 23 | 12 | 7 | 2 | 1 | |

NO. OF OBS. 843

DECEMBER 1500 HOURS LST

SPEED (KM/HR)

CALM: *

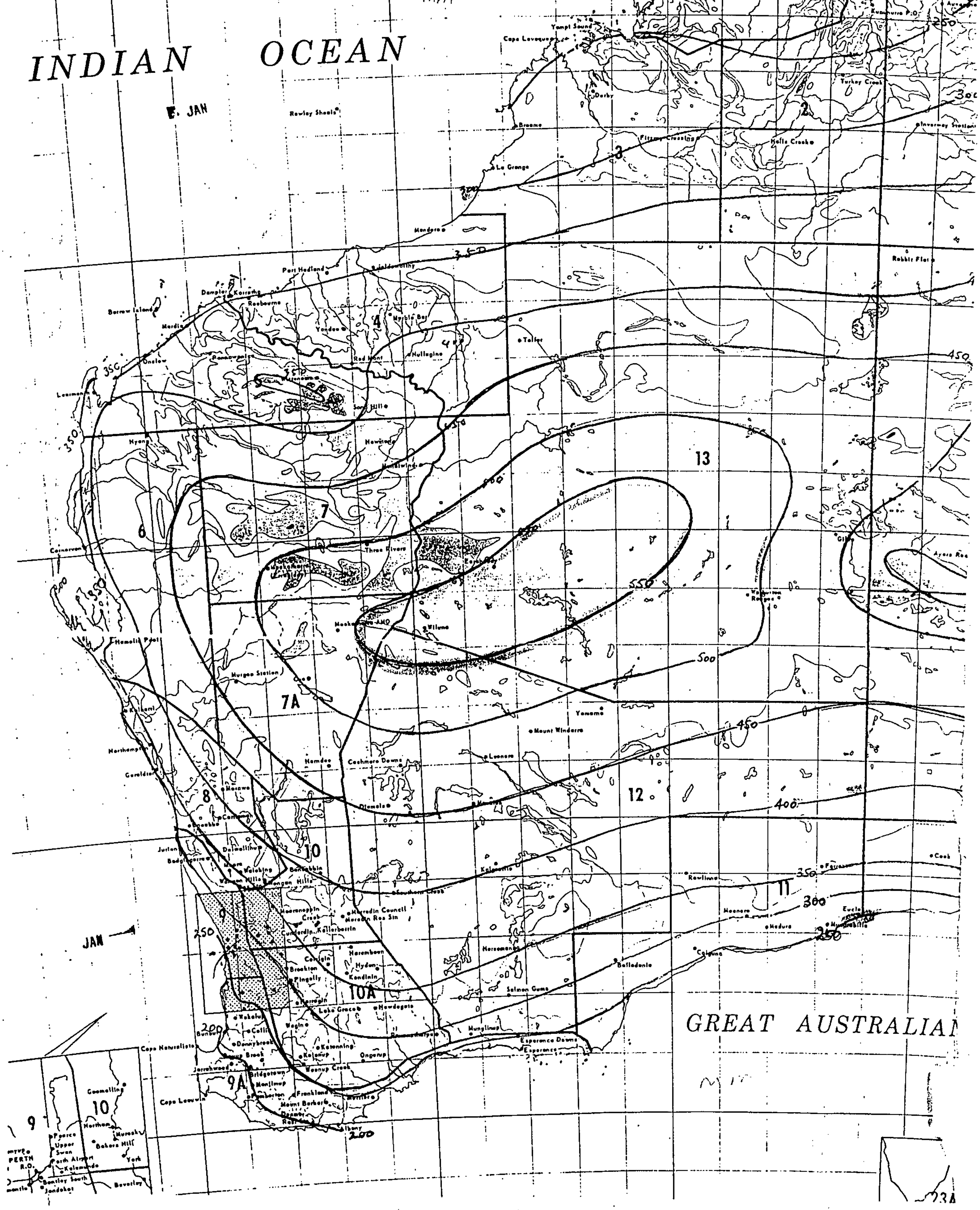
| DIRN | 1 TO 5 | 6 TO 10 | 11 TO 20 | 21 TO 30 | 31 TO 40 | 41 TO 50 | 51 & UP | ALL |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 3 | 2 | 1 | * | | * | 10 |
| NE | 3 | 4 | 3 | 1 | * | | | 11 |
| E | 4 | 4 | 3 | 2 | * | | | 13 |
| SE | 3 | 5 | 6 | 3 | 1 | * | * | 18 |
| S | 5 | 4 | 3 | * | * | * | | 13 |
| SW | 2 | 5 | 3 | 1 | * | * | | 12 |
| W | 2 | 3 | 2 | 1 | * | * | | 9 |
| NW | 4 | 5 | 3 | 1 | * | | | 14 |
| ALL | 27 | 33 | 25 | 10 | 3 | 1 | * | |

NO. OF OBS. 846

* OCCURRED BUT LESS THAN 0.5 PERCENT

PRODUCED BY M.I.S.S. 29/ 3/89

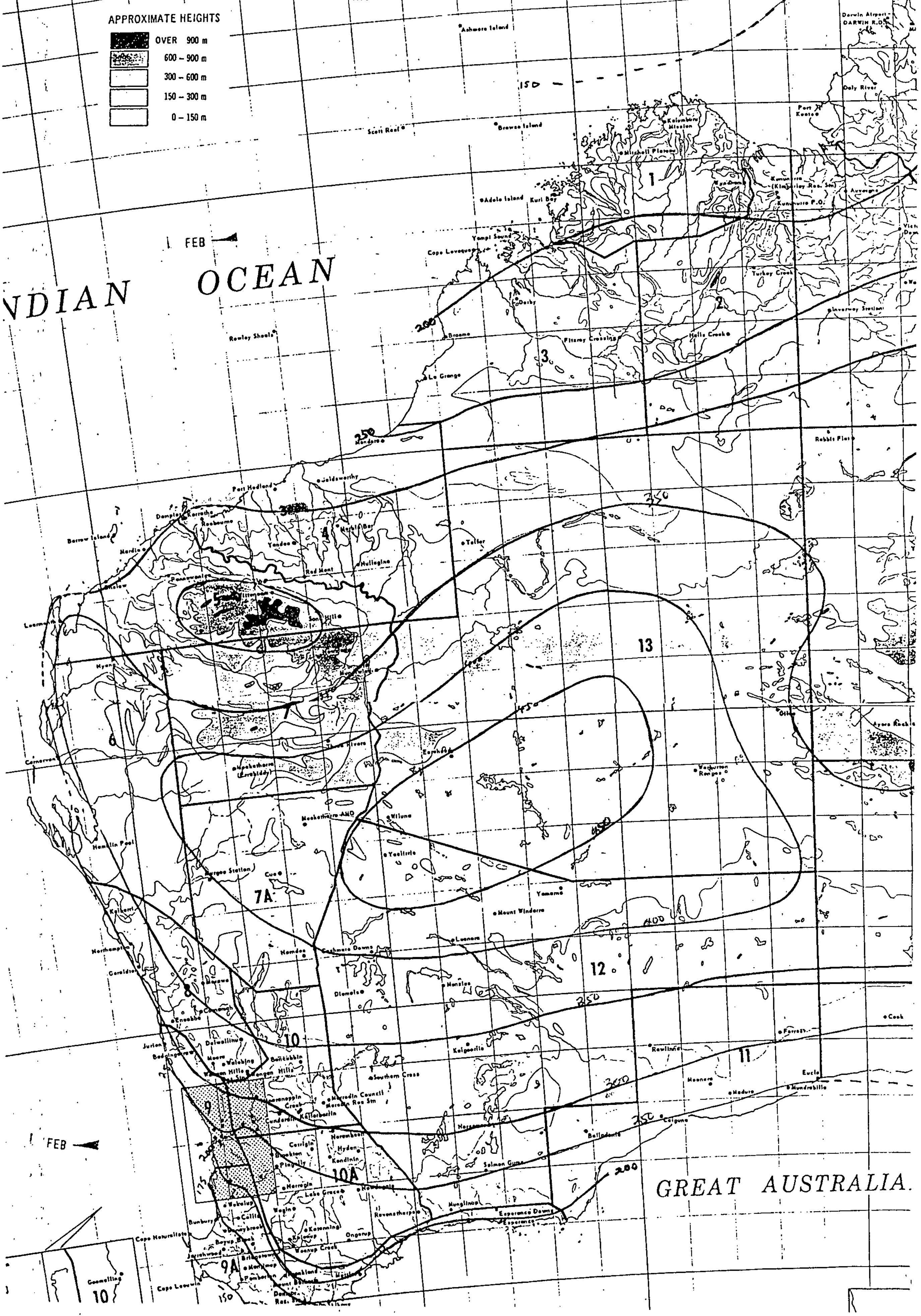
AVERAGE MONTHLY EVAPORATION - JANUARY in mm



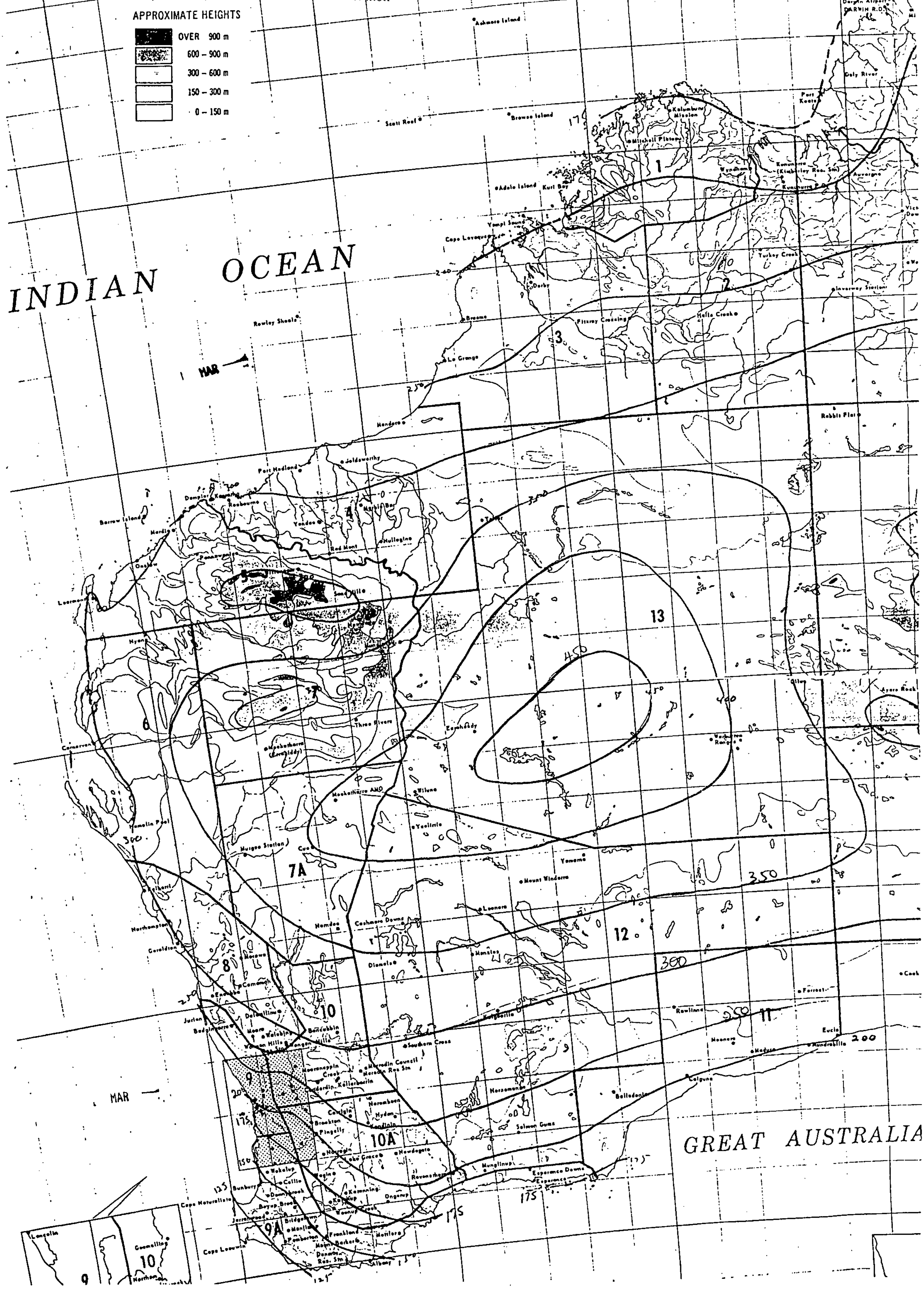

EVAPORATION JAN mm

ISOPLETH.

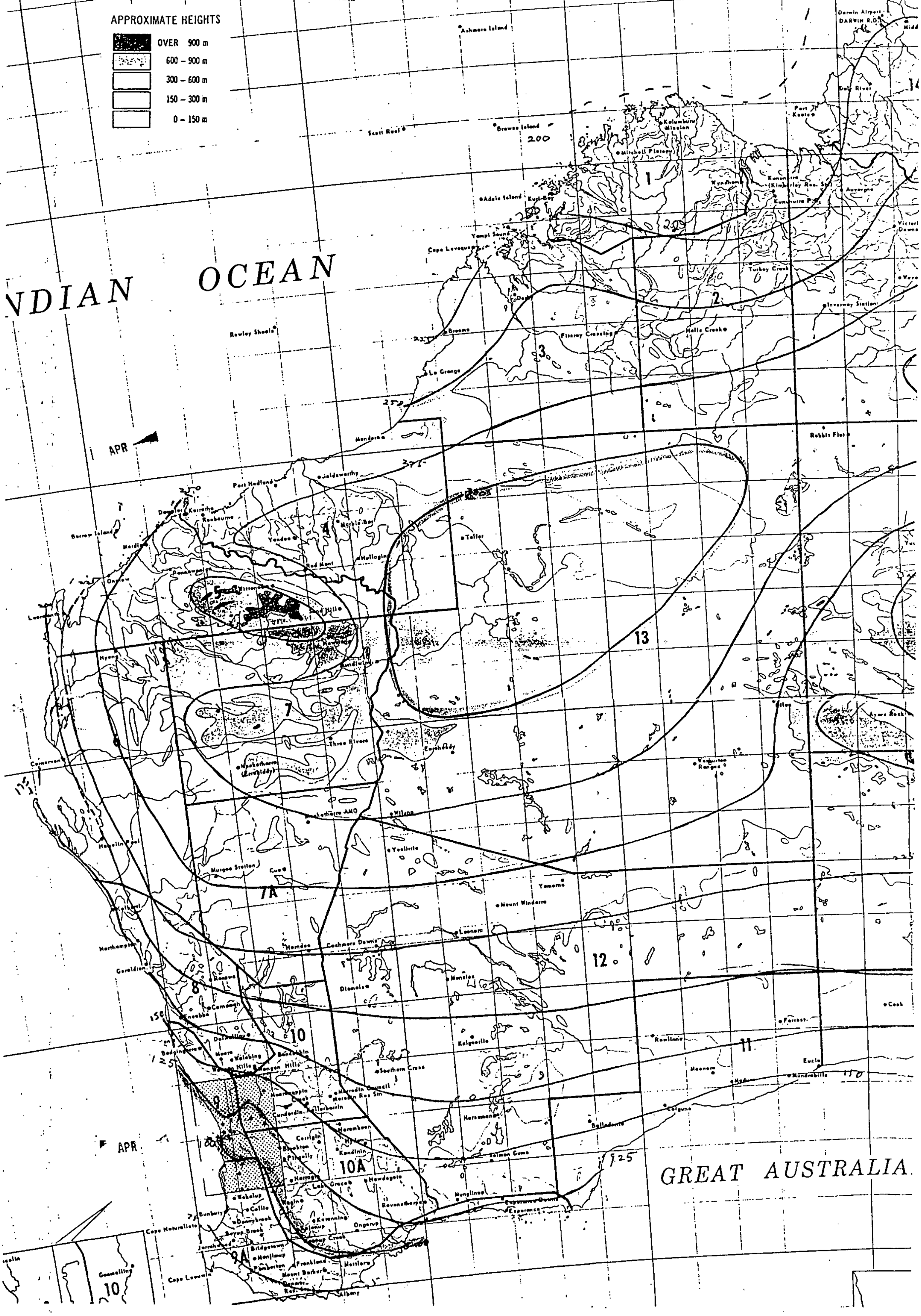
AVERAGE MONTHLY EVAPORATION - FEBRUARY

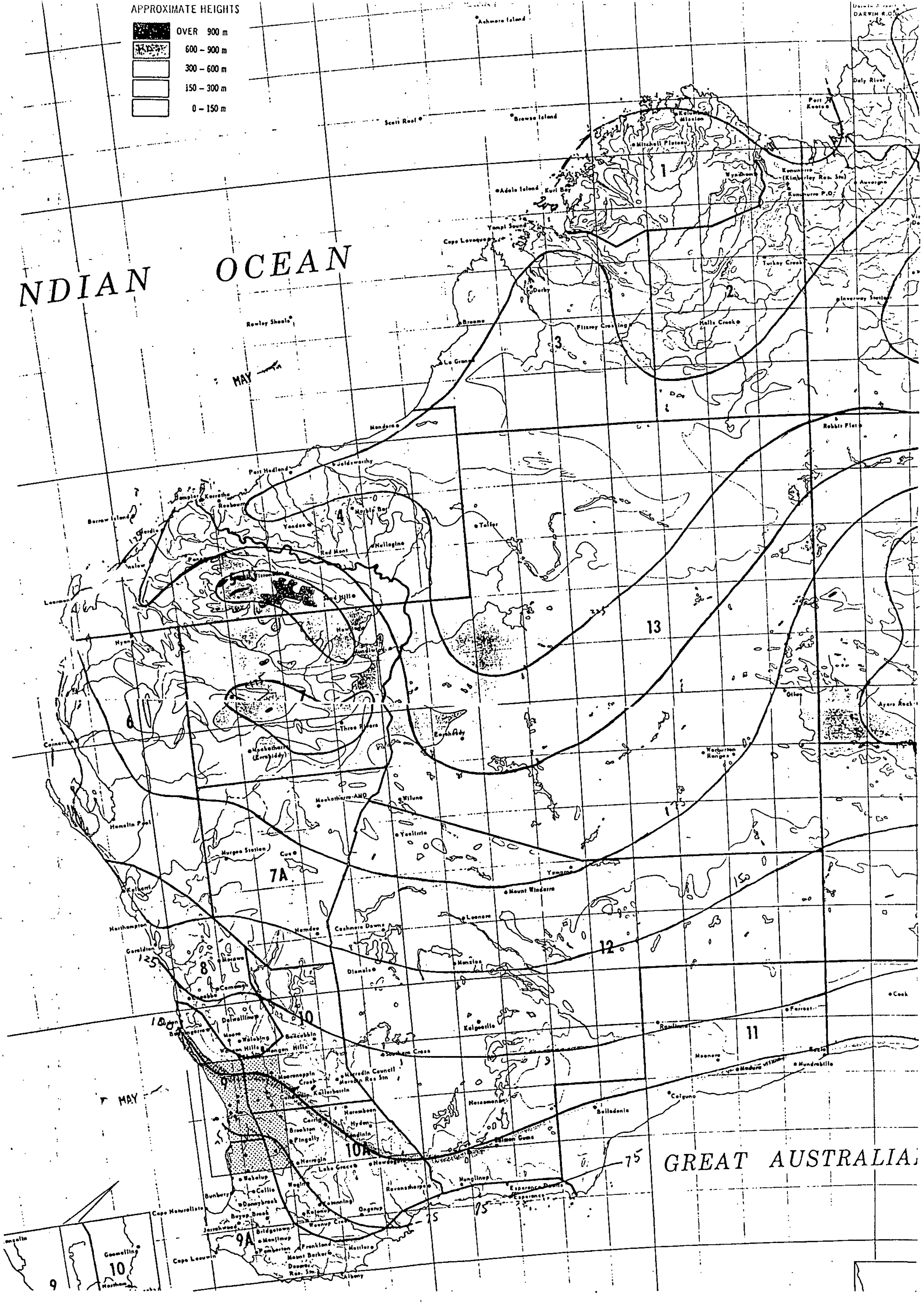


AVERAGE MONTHLY EVAPORATION - MARCH



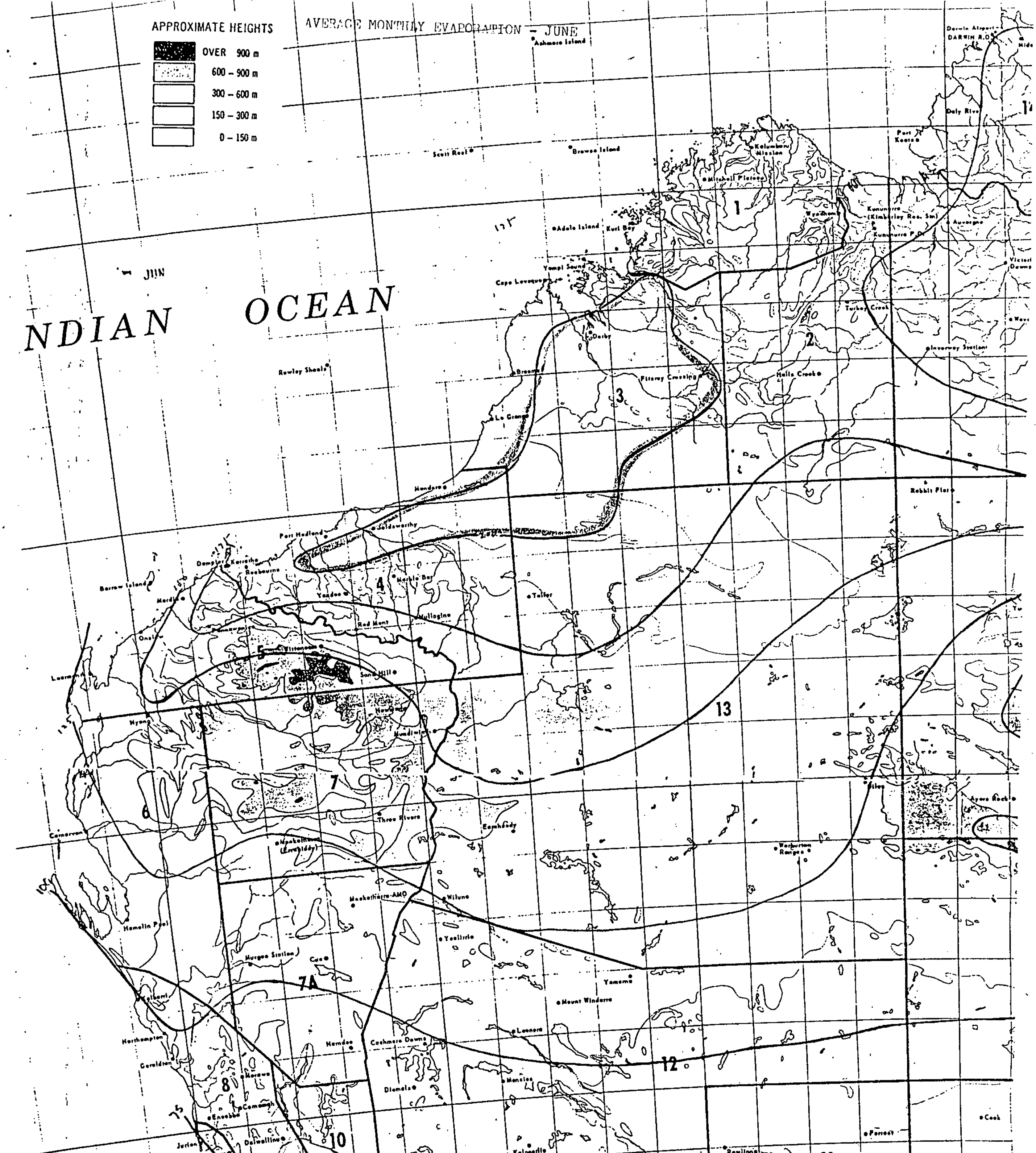
AVERAGE MONTHLY EVAPORATION - APRIL



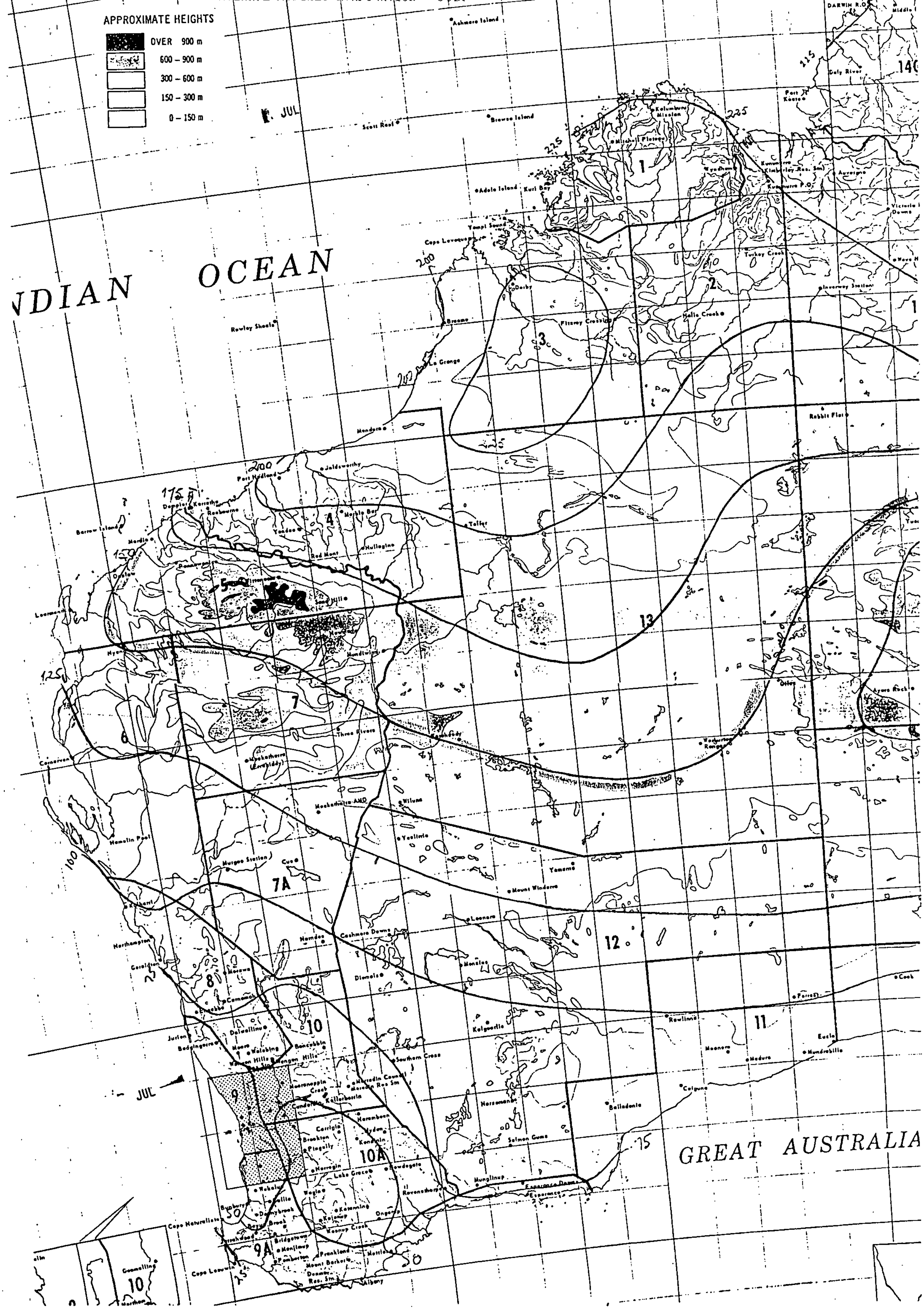


APPROXIMATE HEIGHTS
OVER 900 m
600 – 900 m
300 – 600 m
150 – 300 m
0 – 150 m
INDIAN OCEAN
GREAT AUSTRALIA
MAY
MAY
1
2
3
4
6
7
7A
8
9
9A
10
10A
11
12
13
75
125
150
175

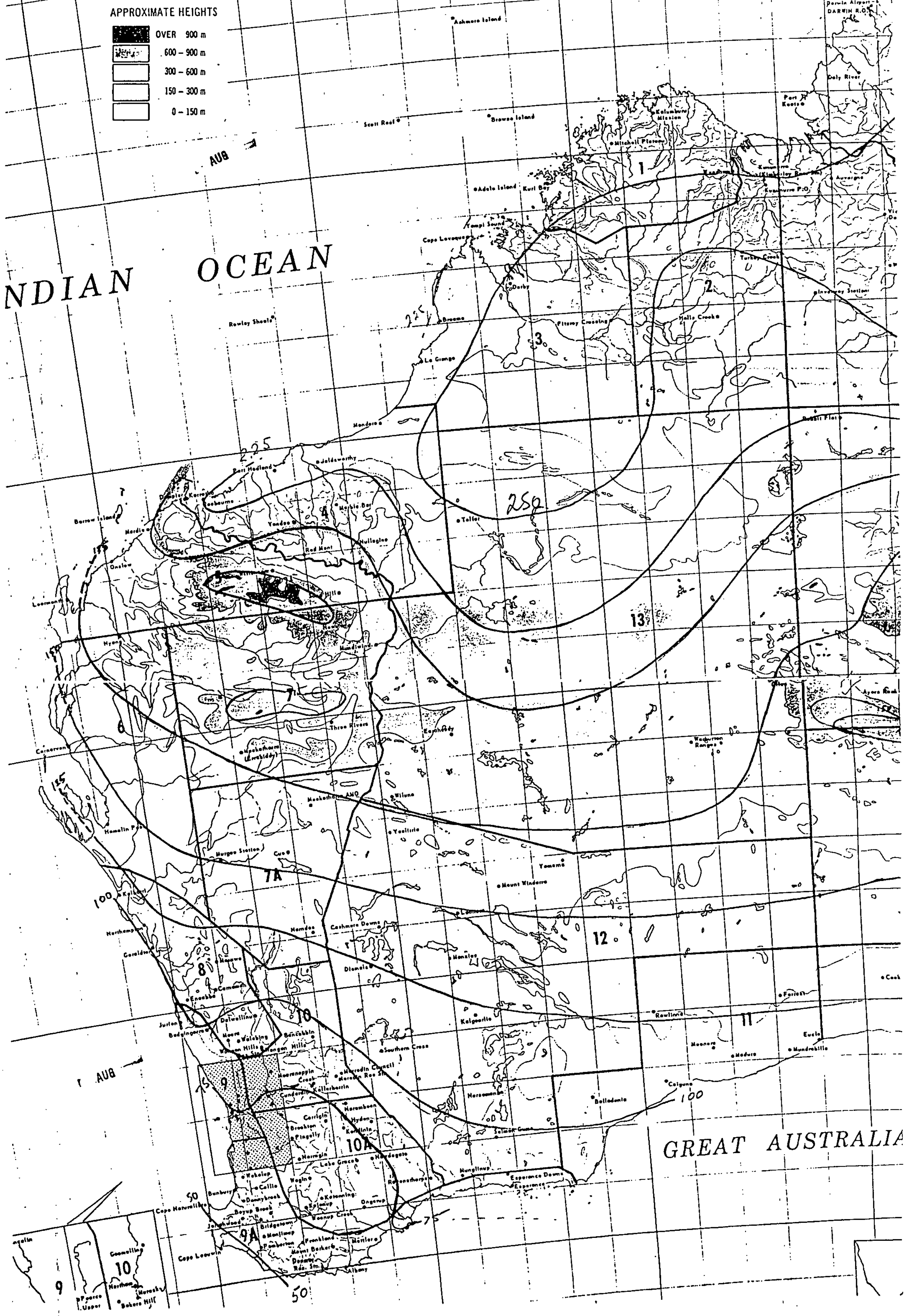
AVERAGE MONTHLY EVAPORATION - JUNE



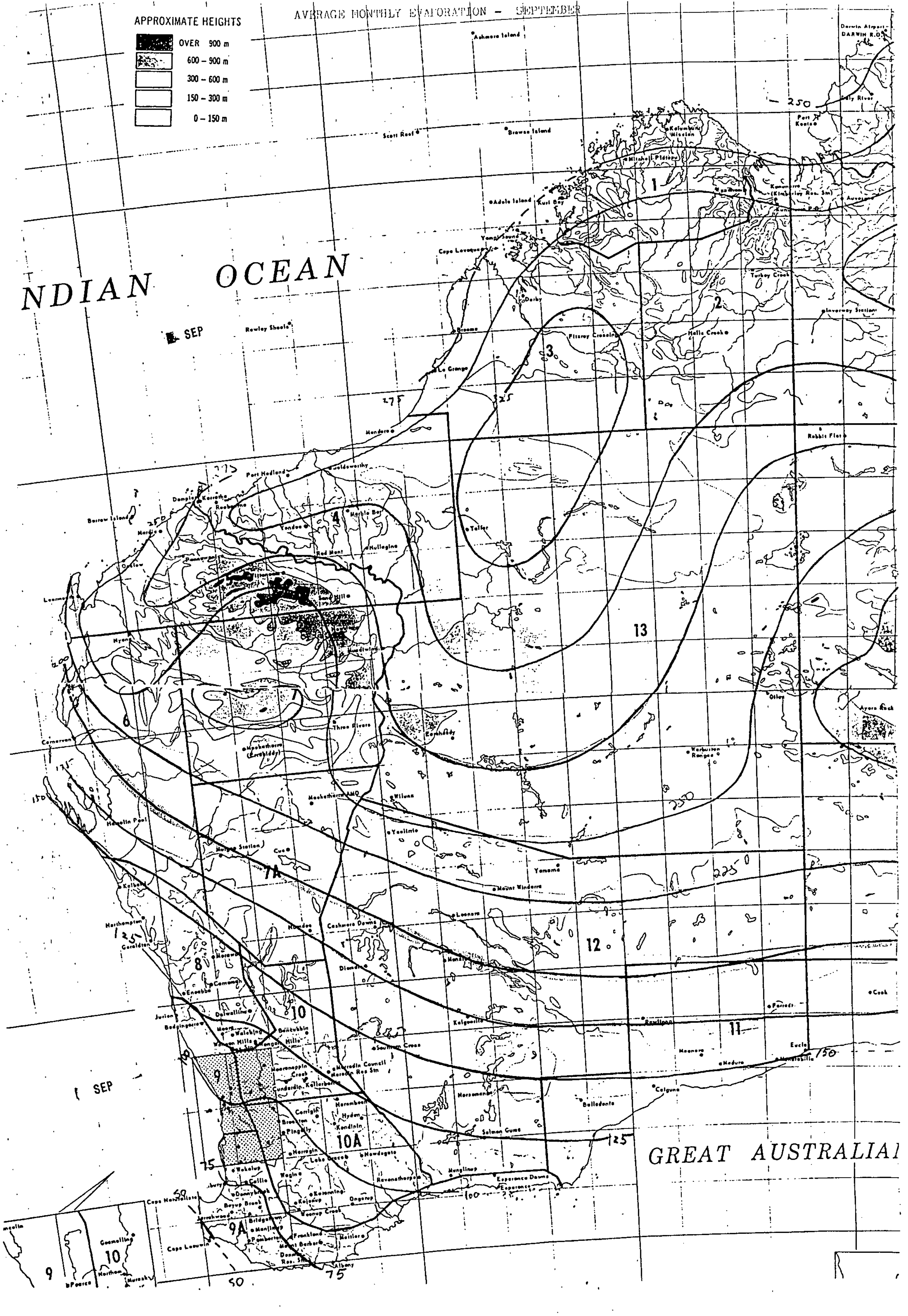
AVERAGE MONTHLY EVAPORATION - JULY



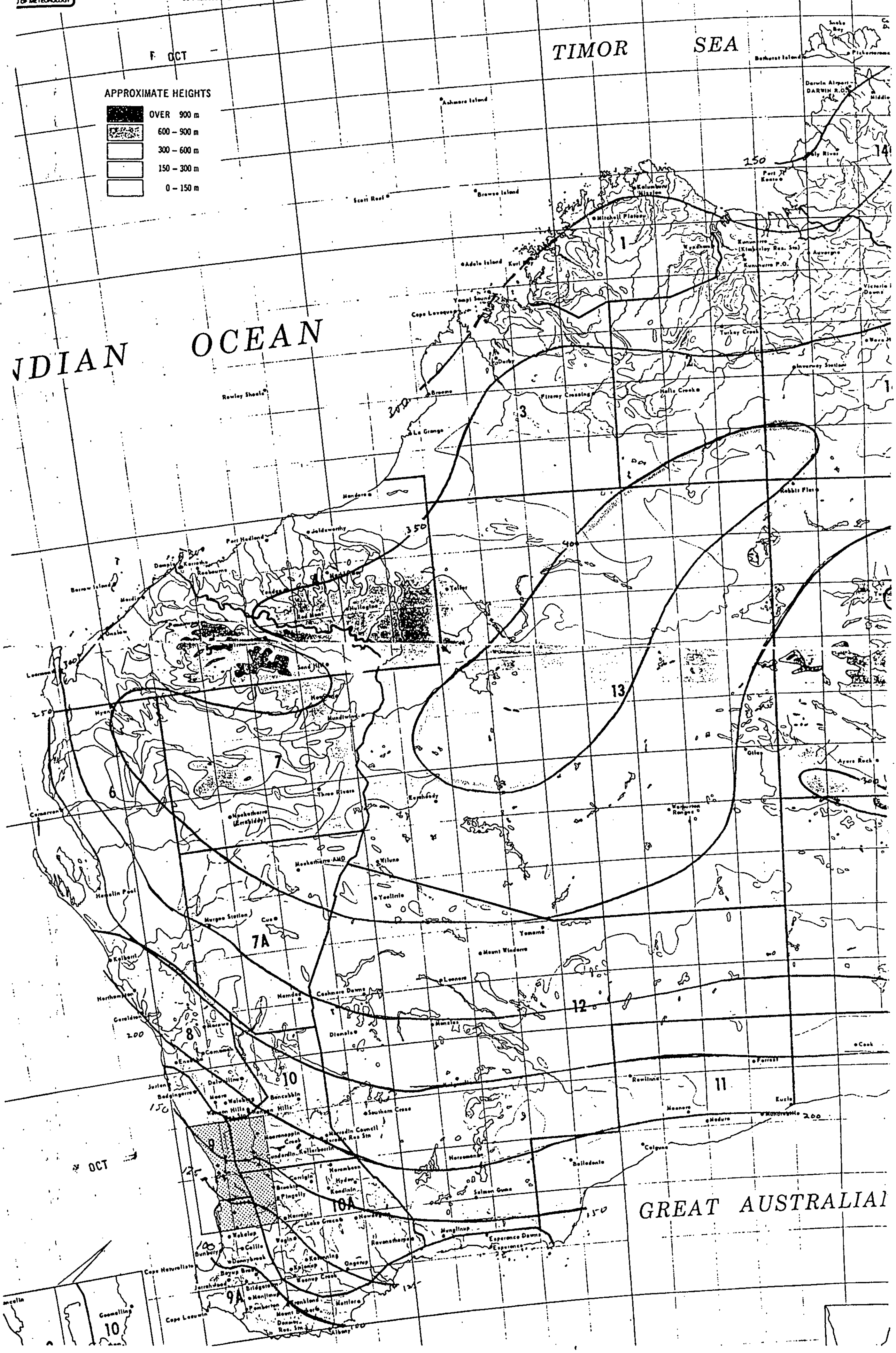
AVERAGE MONTHLY EVAPORATION - AUGUST



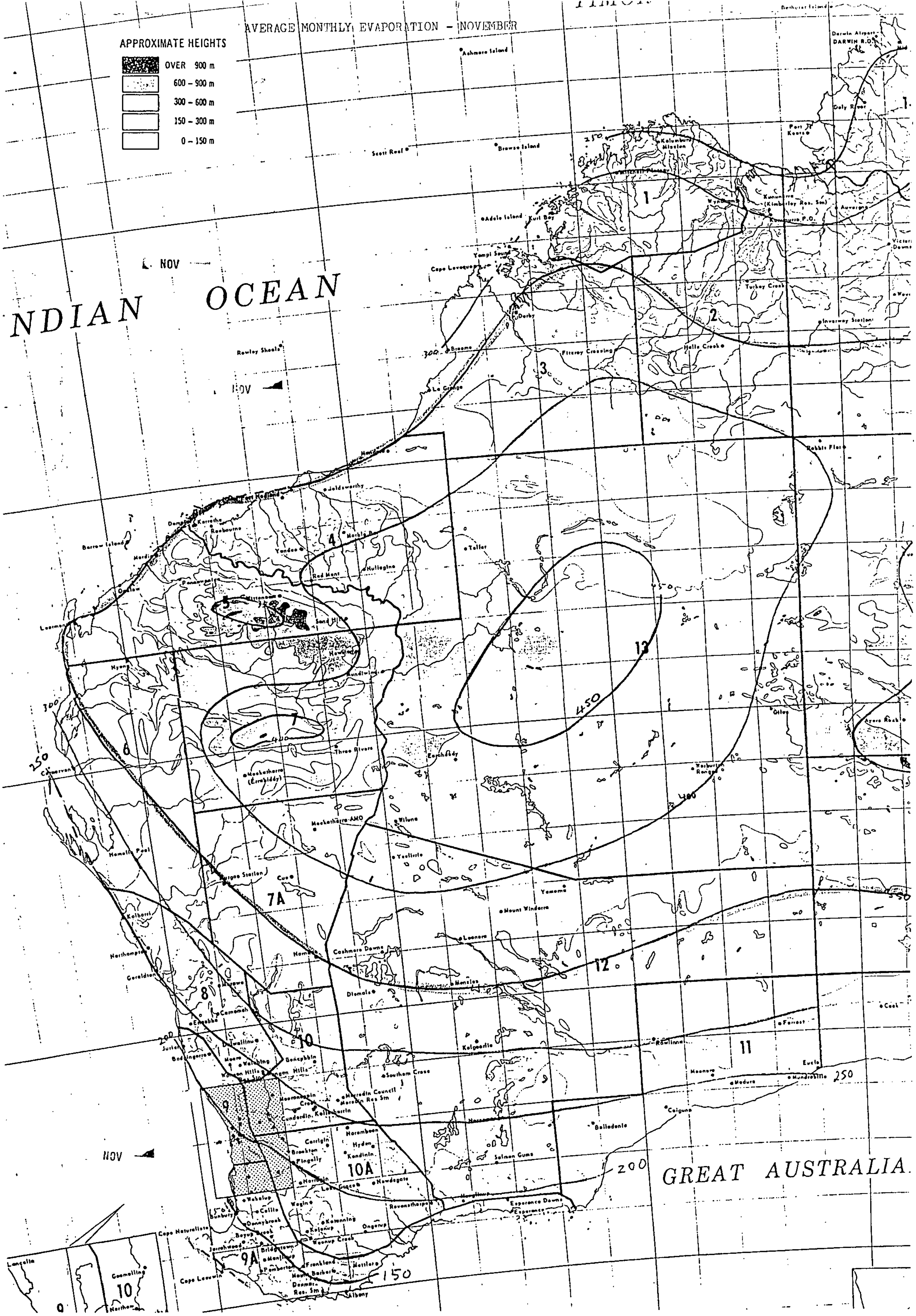
AVERAGE MONTHLY EVAPORATION - SEPTEMBER



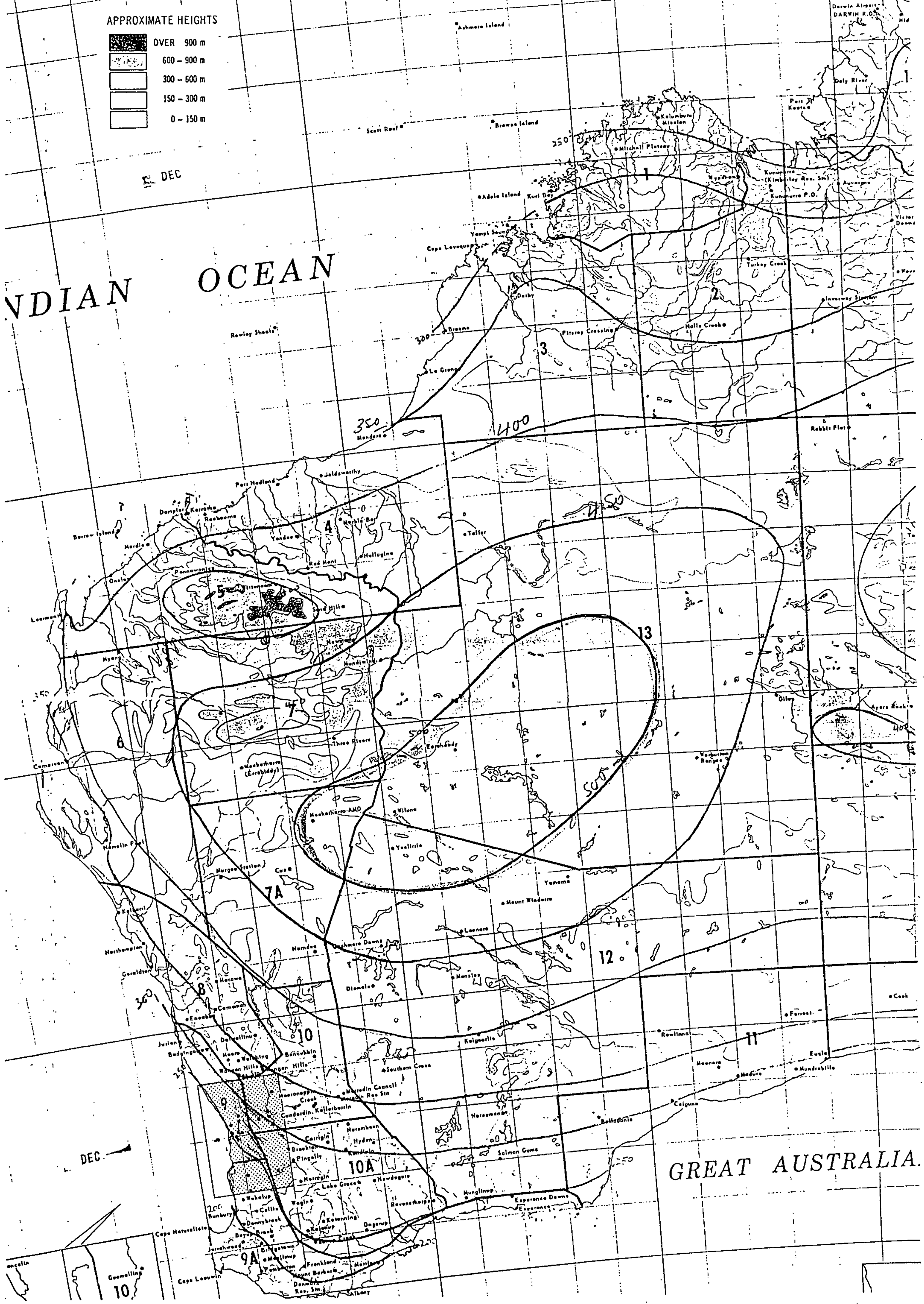
AVERAGE MONTHLY EVAPORATION - OCTOBER

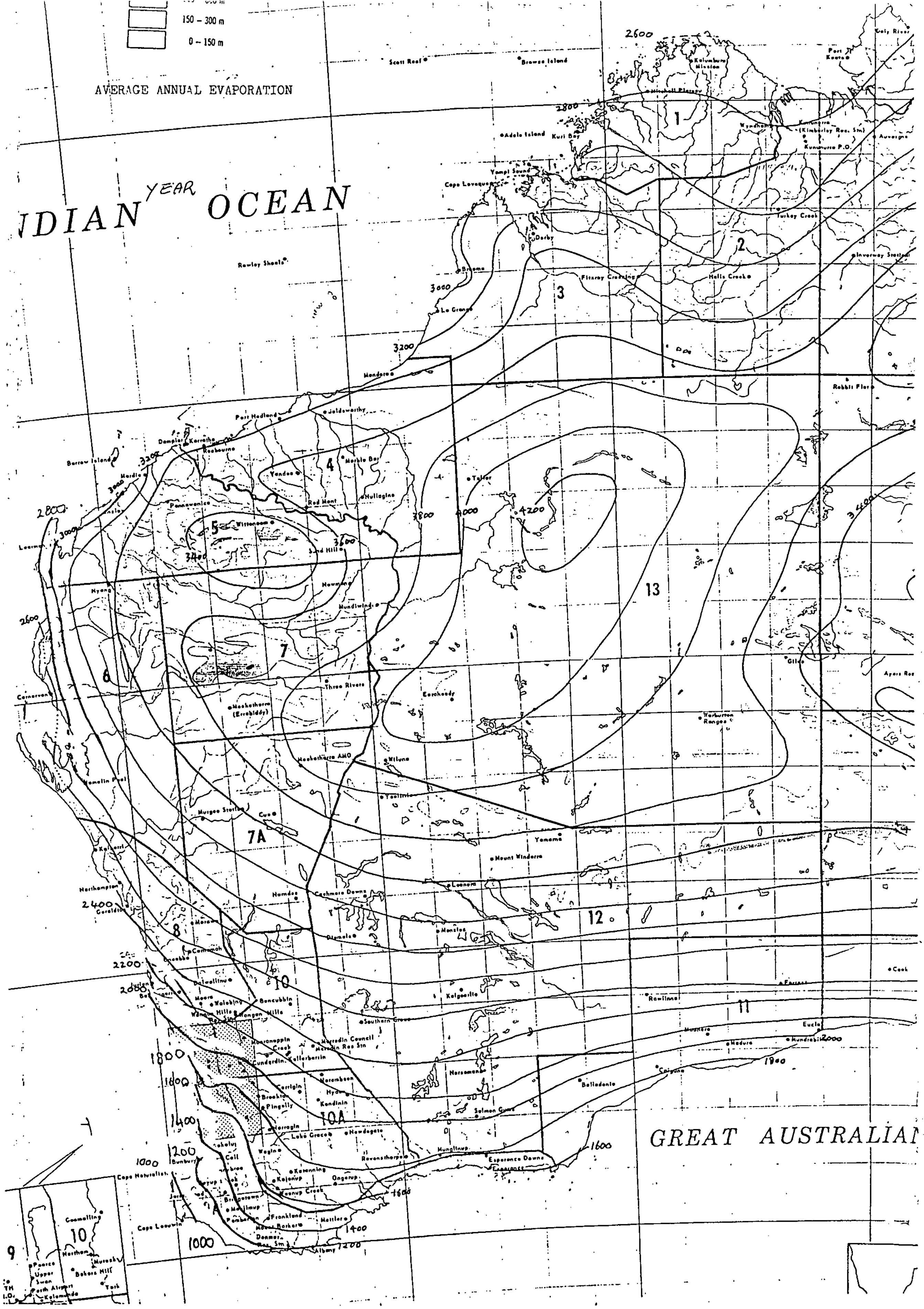


AVERAGE MONTHLY EVAPORATION - NOVEMBER



AVERAGE MONTHLY EVAPORATION - DECEMBER




150 – 300 m
0 – 150 m
AVERAGE ANNUAL EVAPORATION
INDIAN OCEAN
YEAR
GREAT AUSTRALIAN
Rowley Shoals
Scott Reef
Browse Island
Adele Island
Port Hedland
Dampier
Karratha
Roebourne
Barrow Island
Onslow
Carnarvon
Hamelin Pool
Kalbarri
Northampton
Geraldton
Cape Naturaliste
Cape Leeuwin
Bunbury
Albany
Esperance Downs
Kalgoorlie
Southern Cross
Rawlinna
Eucla
Giles
Wittenoom
Newman
Marble Bar
Nullagine
Meekatharra
Three Rivers
Wiluna
Yeelirrie
Leonora
Cue
Mount Magnet
Yamarna
Mount Windarra
Menzies
Laverton
Derby
Broome
La Grange
Fitzroy Crossing
Halls Creek
Wyndham
Kununurra P.O.
Turkey Creek
Balladonia
Norseman
Salmon Gums
Merredin
Narrogin
Katanning
Wagin
Collie
Pemberton
Bridgetown
Manjimup
Frankland
1
2
3
4
5
6
7
7A
8
9
10
10A
11
12
13
2600
2800
3000
3200
3400
3600
3800
4000
4200
2400
2200
2000
1800
1600
1400
1200
1000

Our ref: 2488/E/00/CL/st
C2488A/CHA



PROJECT YAKABINDIE NICKEL PROJECT - FEASIBILITY STUDY

SUBJECT: WEATHER RECORDS, LEONORA (LEONORA POST OFFICE) COMMENCED 1898 WESTERN AUSTRALIA

Number 012046 Latitude 28 Deg 53 Min S Longitude 121 Deg 19 Min E Elevation 376.0 M

| | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **9am Mean Temperatures (C) and Mean Relative Humidity (%)** | | | | | | | | | | | | | **32 Years of Record** |
| Dry Bulb | 27.7 | 26.0 | 24.1 | 20.4 | 15.2 | 11.7 | 10.5 | 12.7 | 16.7 | 20.8 | 23.9 | 26.5 | 19.7 |
| Wet Bulb | 17.4 | 17.6 | 16.5 | 14.2 | 11.1 | 9.0 | 7.7 | 8.9 | 11.0 | 13.0 | 14.8 | 16.5 | 13.1 |
| Dew Point | 9 | 11 | 11 | 9 | 7 | 6 | 4 | 5 | 5 | 7 | 7 | 8 | 7 |
| Humidity | 32 | 40 | 43 | 47 | 58 | 68 | 66 | 58 | 46 | 36 | 33 | 32 | 47 |
| **3pm Mean Temperatures (C) and Mean Relative Humidity (%)** | | | | | | | | | | | | | **32 Years of Record** |
| Dry Bulb | 36.0 | 34.0 | 31.8 | 27.2 | 21.8 | 18.5 | 17.6 | 19.6 | 23.7 | 27.9 | 31.1 | 34.1 | 26.9 |
| Wet Bulb | 19.9 | 20.0 | 18.9 | 16.5 | 13.6 | 11.9 | 11.0 | 11.7 | 13.5 | 15.2 | 16.9 | 18.7 | 15.7 |
| Dew Point | 8 | 10 | 9 | 8 | 6 | 5 | 4 | 3 | 3 | 3 | 4 | 6 | 6 |
| Humidity | 18 | 23 | 25 | 29 | 35 | 41 | 40 | 33 | 26 | 19 | 18 | 18 | 27 |
| **Daily Maximum Temperature (C)** | | | | | | | | | | | | | **32 Years of Record** |
| Mean | 37.2 | 35.2 | 32.8 | 28.2 | 22.8 | 19.2 | 18.4 | 20.4 | 24.6 | 28.9 | 32.3 | 35.4 | 28.0 |
| 86 Percentile | 42.2 | 40.7 | 38.4 | 33.8 | 27.8 | 22.8 | 22.2 | 24.8 | 30.0 | 34.9 | 37.8 | 40.2 | |
| 14 Percentile | 32.0 | 29.4 | 26.7 | 22.2 | 18.3 | 15.8 | 15.1 | 16.2 | 19.5 | 23.3 | 27.0 | 30.6 | |
| **Daily Minimum Temperature (C)** | | | | | | | | | | | | | **32 Years of Record** |
| Mean | 21.8 | 20.8 | 18.7 | 14.9 | 10.1 | 7.6 | 6.0 | 7.0 | 9.9 | 13.7 | 17.2 | 20.2 | 14.0 |
| 86 Percentile | 25.6 | 24.9 | 22.7 | 19.2 | 14.4 | 11.4 | 9.8 | 10.8 | 13.5 | 17.8 | 21.5 | 24.0 | |
| 14 Percentile | 18.0 | 16.7 | 15.0 | 10.4 | 6.0 | 3.9 | 2.5 | 3.3 | 6.1 | 9.5 | 13.4 | 16.2 | |
| **Rainfall (mm)** | | | | | | | | | | | | | **91 Years of Record** |
| Mean | 23 | 25 | 28 | 20 | 25 | 25 | 18 | 16 | 10 | 7 | 11 | 15 | 223 |
| Median | 10 | 11 | 11 | 8 | 19 | 20 | 16 | 11 | 4 | 4 | 6 | 7 | 211 |
| **Raindays (No.)** | | | | | | | | | | | | | **91 Years of Record** |
| Mean | 3 | 3 | 4 | 3 | 4 | 5 | 5 | 4 | 2 | 2 | 3 | 3 | 41 |

PROJECT YAKABINDIE NICKEL PROJECT - FEASIBILITY STUDY

SUBJECT: WEATHER RECORDS, WILUNA (WILUNA POST OFFICE) COMMENCED 1898 WESTERN AUSTRALIA

| Number 013012 | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude 26 Deg 35 Min S; Longitude 120 Deg 13 Min E; Elevation 521.0 M | | | | | | | | | | | | | |
| **9am Mean Temperatures (C) and Mean Relative Humidity (%)** — 30 Years of Record | | | | | | | | | | | | | |
| Dry Bulb | 30.2 | 28.0 | 25.9 | 21.6 | 16.1 | 12.6 | 11.5 | 13.7 | 17.8 | 22.4 | 26.2 | 29.0 | 21.3 |
| Wet Bulb | 18.5 | 18.6 | 17.3 | 14.8 | 11.1 | 9.5 | 8.0 | 9.0 | 10.9 | 13.1 | 15.4 | 17.2 | 13.6 |
| Dew Point | 10 | 12 | 11 | 9 | 6 | 6 | 4 | 4 | 3 | 4 | 6 | 8 | 7 |
| Humidity | 28 | 37 | 39 | 45 | 51 | 65 | 59 | 50 | 38 | 29 | 27 | 26 | 41 |
| **3pm Mean Temperatures (C) and Mean Relative Humidity (%)** — 30 Years of Record | | | | | | | | | | | | | |
| Dry Bulb | 37.0 | 34.9 | 33.3 | 28.7 | 23.1 | 19.5 | 18.8 | 21.1 | 25.5 | 29.5 | 32.9 | 35.5 | 28.3 |
| Wet Bulb | 20.3 | 20.4 | 19.4 | 17.2 | 13.8 | 12.3 | 11.3 | 12.1 | 13.6 | 15.3 | 17.3 | 18.9 | 16.0 |
| Dew Point | 8 | 10 | 9 | 8 | 5 | 5 | 3 | 2 | 1 | 1 | 3 | 5 | 5 |
| Humidity | 17 | 23 | 23 | 27 | 31 | 39 | 35 | 29 | 20 | 16 | 15 | 15 | 24 |
| **Daily Maximum Temperature (C)** — 31 Years of Record | | | | | | | | | | | | | |
| Mean | 38.3 | 36.1 | 34.4 | 29.4 | 23.9 | 20.4 | 19.5 | 21.8 | 26.2 | 30.5 | 34.0 | 36.9 | 29.3 |
| 86 Percentile | 42.2 | 41.0 | 38.9 | 34.5 | 28.4 | 23.9 | 23.3 | 26.5 | 31.2 | 35.7 | 38.4 | 40.5 | |
| 14 Percentile | 34.4 | 31.6 | 29.4 | 23.9 | 19.4 | 16.7 | 15.8 | 17.6 | 21.4 | 25.0 | 29.4 | 33.2 | |
| **Daily Minimum Temperature (C)** — 31 Years of Record | | | | | | | | | | | | | |
| Mean | 23.5 | 22.2 | 19.9 | 15.6 | 10.1 | 7.5 | 5.9 | 7.0 | 10.2 | 14.2 | 18.0 | 21.4 | 14.6 |
| 86 Percentile | 26.7 | 25.6 | 23.6 | 19.5 | 14.8 | 12.0 | 10.5 | 11.1 | 14.1 | 18.5 | 22.2 | 25.0 | |
| 14 Percentile | 20.0 | 18.9 | 16.0 | 11.1 | 5.6 | 3.3 | 1.7 | 3.0 | 6.2 | 10.0 | 13.9 | 18.0 | |
| **Rainfall (mm)** — 90 Years of Record | | | | | | | | | | | | | |
| Mean | 34 | 33 | 36 | 25 | 26 | 24 | 15 | 10 | 4 | 7 | 9 | 19 | 242 |
| Median | 17 | 15 | 13 | 11 | 16 | 13 | 9 | 4 | 1 | 1 | 3 | 8 | 206 |
| **Raindays (No.)** — 90 Years of Record | | | | | | | | | | | | | |
| Mean | 4 | 4 | 4 | 3 | 4 | 5 | 4 | 3 | 2 | 2 | 2 | 3 | 40 |

# APPENDIX C5

DOMINION MINING LIMITED

# YAKABINDIE NICKEL MINE PROJECT

# CONSULTATIVE ENVIRONMENTAL REVIEW: FLORA AND FAUNA SURVEY

MARCH 1990

Prepared by

*ecologia* ECOLOGICAL CONSULTANTS

CONTENTS

TABLES



FIGURES



PLATES

## SUMMARY

The project area encompasses landforms and vegetation associations which are widely distributed in the Northern Goldfields region. The area is characterised by the north-south greenstone belt, the granite hill complex to the west and The Jones Creek drainage system. Vegetation is largely *Acacia* and chenopod woodlands and shrublands dominated by Mulga *Acacia aneura.* Historical land use practices have resulted in a severe environmental impact with almost complete degradation of the understorey. However, the extremely limited representation within conservation areas in the region of the project area, landform habitats is significant.

Previous biological knowledge of the region is limited to broad-scale vegetation mapping (Beard,1976; Carnahan,1976), the Biological Surveys Committee survey (McKenzie *et al,* in press) and a long term systematic account of the birds of Wanjarri Station (Moriarty,1972). In addition some opportunistic collecting has been carried out by CALM officers and amateur naturalists. In all cases, virtually no details specific to the project area were available.

An intensive field survey of the project area was carried out by ***ecologia*** Ecological Consultants in early February 1990. The principle aim was to document the existing biota, delineate the main ecological units, map the area and integrate previously published and unpublished information.

Based on the BSC Goldfields habitat landform classification system five landform habitat units and sub-units occur in the project area. Physiography is weakly correlated to underlying rock type.Seventy one vascular plant species were collected from the area. No "Declared Rare Flora" were present, although three species of uncertain status may require further investigation or special protection within specific localities. Faunal habitats are closely aligned with landform vegetation associations. The project area may support 101 bird, 15 native and 7 introduced mammal, 48 reptile and 7 amphibian species. Evidence of three species gazetted as "rare or other wise in need of special protection" is present. They are the Lesser stick Nest Rat (extinct), Peregrine Falcon and Alexandra Parrot. None of the proposed developments will adversely affect these species.

The adjacent Wanjarri Nature Reserve is of major significance, being the only conservation area within the Northern Goldfields Region. The region is ecologically diverse, encompassing biotic assemblages which do not occur elsewhere and is an overlap zone between arid northern and mesic southern elements of both flora and fauna. Recognition of the biological importance of Wanjarri led to the EPA and State Cabinet endorsement of the area as a Class A Nature Reserve in 1975. The close proximity of the proposed developments to the reserve is a major consideration in any perceived environmental impacts and subsequent management recommendations.

The principle environmental impacts arising from the proposed project will be the loss of vegetated area, reduction in area of breakaway habitat and the impositions on the Jones Creek drainage system. The area loss from the developments (990 ha) is insignificant in comparison to the ecological landform units represented. The impact on the fauna is generally secondary. There will be major local impacts initially with destruction of habitat and relocation of mobile species into adjacent habitats. Impacts can be minimised by staging clearing, limiting clearing to absolute essential minimum, fencing off dangerous areas and limiting road and track development.

The only factors which have the potential to impact the biota of Wanjarri Nature Reserve are dust, erosional runoff from the eastern waste dump and increased visitation by the public. The subsequent localised mortality of adjacent vegetation within the reserve resulting from excessive dust and erosion can be minimised by appropriate management methods. Employee education programmes and liaison with CALM will reduce the potential for adverse impacts associated with any increased visitation to the reserve. No other environmental impacts are perceived to impinge upon the integrity of the reserve.

# 1. INTRODUCTION

The Yakabindie Nickel Mine proposed by Dominion Mining Ltd. is located at Six Mile Well (27°25' S,120°35'E) adjacent to the south-western corner of Wanjarri Nature Reserve #A 30897 in the Northern Goldfields, 65 km north of Leinster, Western Australia (Fig. 1.). The proposed development includes an open-cut pit mine, tailings dam, plant, waste dumps, air strip and camp site covering 5,000 ha (Fig. 2.) within 11 mining tenements P36/973, P36/976, P36/978, M36/57, E36/137, P36/632-633, P36/856-857, P36/906-907. In accordance with Environmental Protection Authority requirements the project feasibility study will be formally assessed at the level of Consultative Environmental Review. The guidelines for the CER require the documentation of the existing biota of the project area, an assessment of the potential impacts with recommendations for management and rehabilitation. To fulfil these objectives ***ecologia*** Ecological Consultants carried out a biological survey of the project area in February 1990. The survey provides baseline information on the flora and vertebrate fauna of the project area. Additionally this report, which documents the survey undertaken, will detail;

A) An inventory of;

Flora

-vegetation associations/communities.
-species lists including declared rare flora.

Fauna

-vertebrate species list including recent published and unpublished records.
-valuable faunal habitats and critical resources.
-records of species which might be expected to occur but whose presence is as yet unrecorded.

B) A review of;

Flora

-biologically significant species including declared rare flora
-environmental impacts and recommendations for species and or associations requiring special management.

Fauna

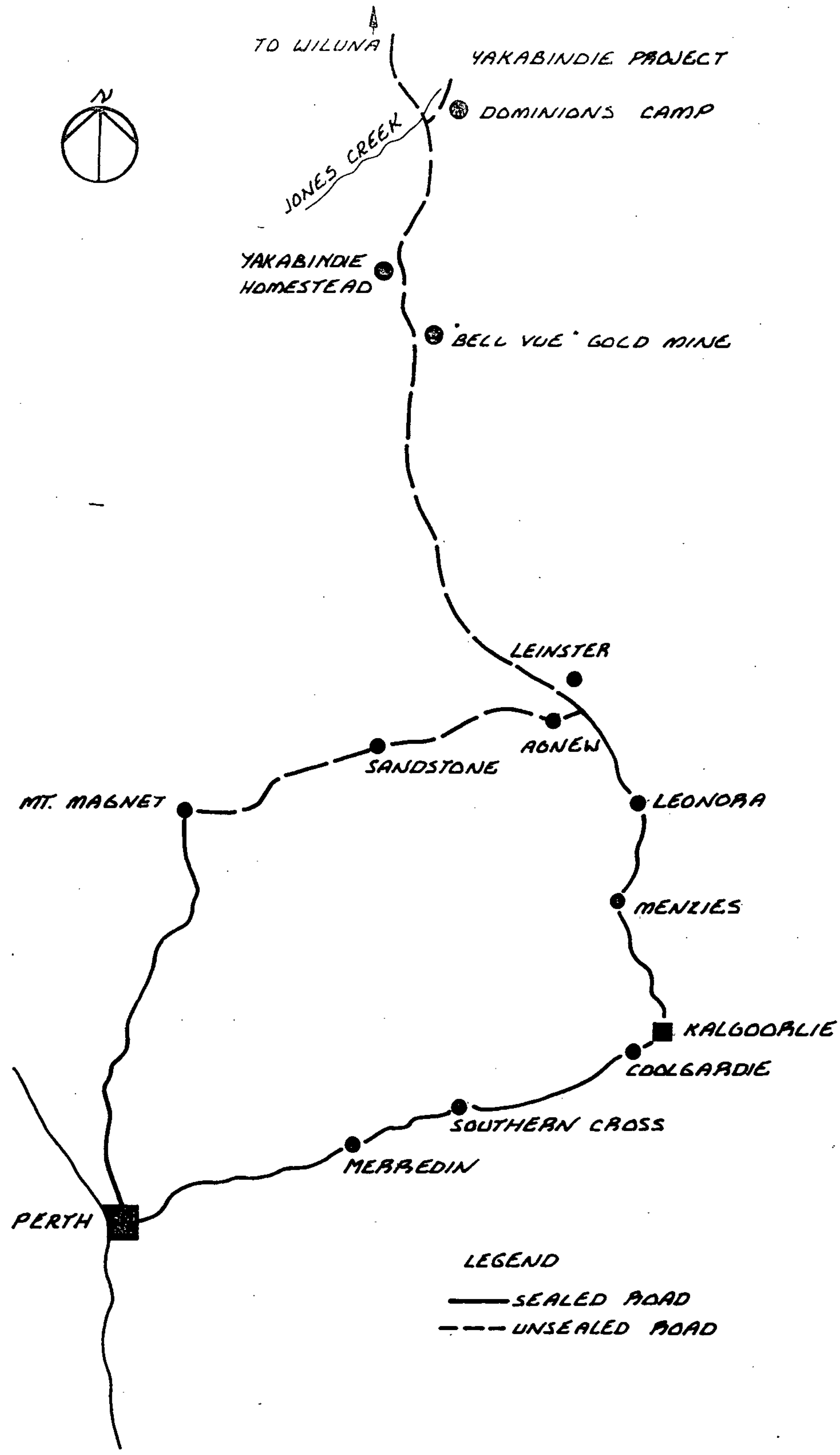
-biologically significant species including rare fauna.
-introduced exotic or declared pest species and their impact.
-environmental impacts and recommendations for fauna management.

C) An assessment of;

-the regional and local conservational value of the flora and fauna of the intended development area.

## 1.1 Previous Biological Studies

The Northern Goldfields Region is of considerable environmental significance, lying on the northern limits of the "South West Interzone" (Burbidge, 1960; Beard, 1979) to which the goldfields woodlands are largely confined. This region includes species from both the south-west, a region of high species endemism (Marchant, 1973; Hopper, 1979), and the arid interior, as well as numerous species which are either endemic to the goldfields or have restricted geographic distributions (BSC, 1984). Little previous biological research has been carried out in the northern goldfields despite the importance of the region. Beard (1976) details previous exploration in the area, while broad scale vegetation mapping was first carried out by Burbidge (1960) and later refined by Carnahan (1976) and Beard (1979). Early flora survey work was carried out by Burbidge (1943), Mabbutt *et al* (1963) and Kenneally (1968). However it was not until the Biological Survey of the Eastern Goldfields program conducted by the BSC of the late 1970's and early 1980's that any detailed flora surveys were conducted (McKenzie *et al*, in press).



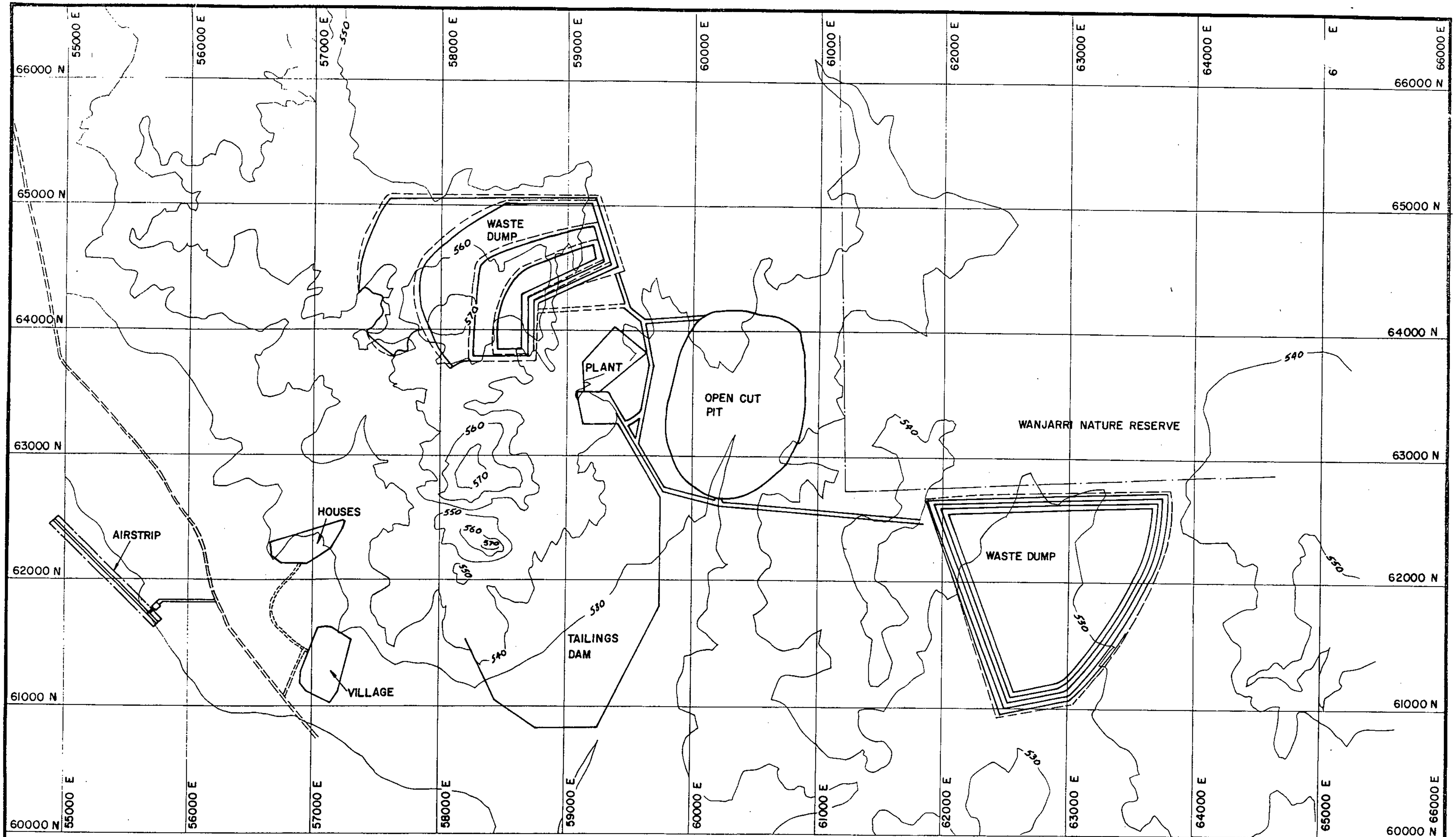

# YAKABINDIE PROJECT

NOT TO SCALE

**LOCATION PROJECT AREA**

**FIGURE 1**

**Soil & Rock Engineering Pty. Ltd.**




**Proposed Developments for the Yakabindie Nickel Project**

Figure 2

The vegetation was classified into types on the basis of structure, species composition of upper stratum and landform. In general low woodlands and shrublands dominated by acacias predominate in the region. The density and height of vegetation reflects the moisture content of the soils, with low vegetation being recorded on skeletal, shallow, saline or impermeable soils, especially those associated with granite exposures and salt lakes (Keighery and Milewski, in press). The flora contains a large number of elements not penetrating further south. These are mainly species with arid tropical affinities, particularly the grasses. Correspondingly southern elements such as the Proteaceae and Myrteaceae are very impoverished. Prior to the BSC survey the regions flora had not been systematically recorded and documented. However there is still scope for intensive botanical investigation of particular habitats which were under sampled, and groups of plants that have been inadequately explored. One such group is the "fire weeds" (Beard, 1976).

Knowledge of the region's fauna reflects that of the flora being very incomplete. Prior to the BSC fauna survey the only detailed study undertaken was a long term systematic account of the birds of Wanjarri Station, Kathleen Valley, now Wanjarri Nature Reserve, by Moriarty (1972). The BSC fauna survey work was confined to Wanjarri Nature Reserve and sampled all major habitats and all vertebrate groups. The biogeographic patterns of the fauna parallel those of the flora with the area being an overlap zone between groups with predominantly northern or southern distributions, resulting in a high species richness (Mckenzie and Rolf, in press). Continued sporadic information on the region's fauna arises from EIA's of proposed mining developments, such as the Mt. Keith project, CALM research projects and opportunistic collecting by amateur naturalists. However given the diversity of landforms (all recognised goldfields landform units occur within the region (Milewski, in press) and the paucity of biological survey work, the region is undoubtedly richer in fauna than currently known. Numerous species with their known distributions and habitats encompassing the region have yet to be recorded.

### 1.2 Wanjarri Nature Reserve

The only conservation area which exists in the Northern Goldfields region is Wanjarri Nature Reserve, situated adjacent to the project area and 53,248 ha in area (EPA, 1975). Historically Wanjarri station was owned by Tom Moriarty who was a keen amateur naturalist. During the late 1960's the property was deemed nonviable as a pastoral area and offered to the then W.A. Dept. Fisheries and Fauna as a nature reserve. The area was subsequently purchased and gazetted as a Class A Nature Reserve (A30897) for the purpose of Conservation of Flora and Fauna on July 18th 1971 and vested in the National Parks and Nature Conservation Authority. Currently the reserve is administered and managed by CALM. The status of Wanjarri as a reserve (A30897) for the purpose of Conservation of Flora and Fauna was endorsed by the EPA in 1975 and the State Cabinet in 1976 (EPA, 1975). The landforms conserved in Wanjarri are predominately Broad Valleys with minor areas of Granite Exposures, Hills, Breakaways, Sandplains and Dunefields. However whilst rich in flora and fauna, the conservation status of the reserve is poor. Much of the mulga vegetation is in a degraded condition and although no known species is known to be threatened with extinction, the composition and resilience of the biological communities has been changed dramatically (McKenzie *ét al*, in press). Nonetheless Wanjarri Nature Reserve remains critical by virtue of being the sole conservation area in the region. Due to the severe degradation of the environment over the whole of the region, particularly on Undulating Plains and Broad Valleys (section 1.3), Keighery and Milewski (in press) recommended that Wanjarri Nature Reserve:

1. Be enlarged to the north-west to include a greater area of granite exposures, hills and breakaways. These key habitats are very poorly conserved within Wanjarri.

2. Be greatly enlarged to ensure effective conservation of the biota since the vertebrate populations in the goldfields are scattered and at very low densities.

### 1.3 Land-use History

The first exploration of the Northern Goldfields was undertaken by Austin, who reported the area to be "the finest goldfields in the world", although the gold rush occurred more than 30 years later. By the early 1890's extensive development associated with mining had occurred with rail lines and towns established at Leonora, Laverton and Wiluna. By the 1930's pastoral settlement had spread eastwards to all suitable land up to the ecological boundary represented by the edge of the Austin Botanical District. Beyond this point the vegetation is unsuitable and no successful pastoral settlement has occurred (Beard, 1976). During the mining boom extensive tracts of timber were taken for mine construction and building. The impact has been greatest on the Undulating Plains and Broad Valleys where; (i) palatable plants previously occurred and (ii) soils are shallow, fragile and easily compacted (McKenzie *et al*, in press).

The project area occurring on the Yakabindie Station pastoral area is typical of the northern goldfields in having a severely degraded under-storey. This has arisen from historical pastoral practices and little present regeneration, particularly of the mulgas, due to increasing populations of feral herbivores.

## 2 PHYSICAL ENVIRONMENT

### 2.1 Climate

The Northern Goldfields region has been classified as a Hot Arid Desert (Dick, 1975) and has an arid climate deficient in rainfall in all seasons while possessing a bimodal rainfall distribution (Beard, 1976). Light rainfalls in winter are associated with southerly low pressure systems while summer rain is derived from thunderstorms associated with northerly weather systems. Average annual rainfall is 210 mm. A major feature of the rainfall is the unreliability and variation in annual recordings (Newbey, 1984). The nature of the rainfall is of biological significance. While the sporadic summer rainstorms are intense, prolonged and efficient for plant growth, the light regular winter rains are ineffective for growth other than of herbs and grasses (Milewski, 1981). The region experiences hot, dry summers alternating with cool winters. Mean annual temperature is 29° C with average maximum temperatures ranging from 37°C (Jan.) to 18° C (July) (Milewski, in press). Frosts occur in winter.

### 2.2 Geology and Soils

The Northern Goldfields region lies in the north-eastern corner of the Archaean Yilgarn Block consisting of predominately gneisses and granites. Sequences of metamorphosed sedimentary volcanic and intrusive rocks from linear greenstone belts separated by large areas of granitoid rocks (Bunting and Williams,1979). The project area is dominated by a north-south greenstone band, with a large block of granite adamellite to the west and tertiary laterite to the east. The physiognomy is weakly correlated to underlying rock type (section 2.3).

Soils are generally skeletal sandy loams and shallow stony earthy loams on hills and ridges (Beard, 1976). These soils are relictual and unfavourable for plant growth due to low moisture and nutrient status (Milewski, 1981).

### 2.3 Landforms

For the biological survey of the eastern goldfields carried out by BSC, Newbey and Milewski developed a landform classification system with 10 major units and a series of sub-units (Newbey, 1984). Within the project area 5 units and sub-units are present (Fig. 3).

Breakaway (B): A series of breakaways occur in the western third of the project area associated with granite. Bluffs are 3-4 m high with a free face, have scree slopes of $12^{o}$-$15^{o}$ and are partially covered with shallow gravelly loams. Numerous small caves and overhangs occur, particularly on the south-facing side of the escarpment.

Hills (H): Hills rise more than 30m above the surrounding plains and have slopes ranging from $5^{o}$ to $20^{o}$. The surface is largely covered with skeletal and well-drained soils, with substantial areas of exposed rock.

Hills, granite (HG): the western third is comprised largely of granite and Adamelite hill country (Geol. Survey, 1987) with gravelly soils and is typical of this sub-category.

Undulating Plain (U): Differential weathering of bedrock resulting in low hills ridges and joining colluvial flats and slopes of $5^{o}$ to $10^{o}$. This unit was subdivided on the basis of bedrock type.

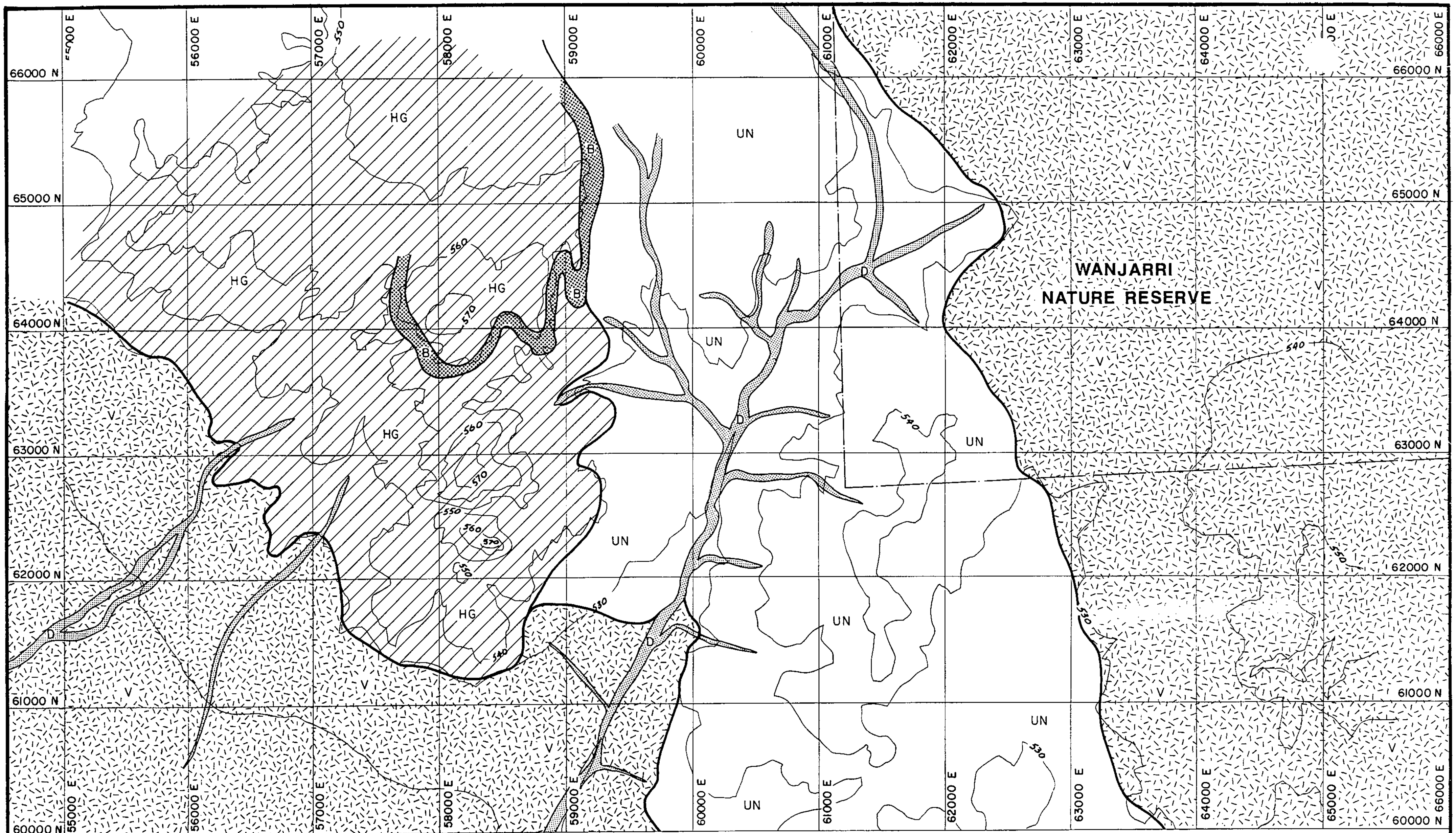
Undulating Plain, greenstone (UN): within the project are the north-south greenstone belt consists of undulating plain of Komalite and basalt with eroded ridges of Chert 2-3m high.

Drainage Lines (D): Drainage lines are uncommon in the region being confined to areas immediately surrounding undulating plains and hills. There are generally eroded earth banks 1-3m high with a sandy or gravelly wash line. The Jones Creek, which flows through Wanjarri Nature Reserve and Six Mile Prospect is atypically large with semi-permanent water present.

Broad Valley (V): Overlying granite are well drained valleys with slopes rarely exceeding $2^{o}$ and relief less than 20m. In the project area this landform only occurs west of the granite hills and the Wiluna - Leinster road and has an overlying colluvium of quartzfeldspar with sand and silt.

| Landform | Code | Description | Percent |
|---|---|---|---|
| Breakaway | B | bluffs 3-4 m high,gravelly loams on scree slope slopes 12°-15° | 7 |
| Hills, granite | HG | greater than 30 m high, gravelly skeletal soils, exposed rock | 35 |
| Undulating Plain,green stone | UN | greenstone belt and joining colluvial flats with chert ridges 2-3 m high | 28 |
| Drainage Line | D | The Jones Creek, eroded earth banks 1-3m high, sandy-gravel bed, semi-permenant water | 10 |
| Broad Valley | V | relief less 20m, sandy colluvium overlying granite | 20 |

**TABLE 1 : Landform habitat units in Yakabindie Nickel Project Area with approximate percent occurrence.**




LEGEND

- Broad valley (V)
- Hills, granite (HG)
- Drainage line (D)
- Undulating plain (UN)
- Breakaway (B)

**Map Showing Landform - Habitat Units of the Yakabindie Nickel Project Area**

Figure 3

YAKABINDIE PROJECT

200 0 200 400 600 800 METRES
SCALE 1:10000

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# 3. SURVEY METHODOLOGY

## 3.1 Flora

The flora of the area was surveyed on February 5-7, and on March 12-13, 1990. Plant species were identified in the field or specimens were collected for later identification and verification. Plotless sampling sites were chosen by means of aerial photographs and field observations so that the array of vegetation types were represented. Vegetation type, life-form strata, percentage cover, surface soil type, drainage, and litter cover were recorded at 35 sites. The positions of the sites are shown in Figure 2. The dimensions of each site varied somewhat according to the nature of the site, e.g. the dimensions of creek bank sites, breakaways and outcrops were defined by topography and changes in vegetation type. The sites situated in broad valleys and plains were approximately 100 m square, and the data collected at each one was generally representative of a much larger surrounding area. The site data was later examined and grouped into defined associations according to habitats, which were then mapped.

The time of year, late summer, was not suitable for the observation and identification of ephemeral species, likely to be found in large numbers in August to October. Several species of winter or spring-flowering perennial grasses and herbs were also impossible to identify, as vegetative parts were poorly developed and flower and fruit material was not present. The main plant families thus affected were Poaceae (grasses) and Asteraceae (daisies). It is likely that if such plants were to be included in the species lists for each site, the total number of species recorded would be doubled or even tripled.

The presence and depth of leaf litter on the soil surface was recorded at all sites. However, in all cases where litter was present, it appeared to have been deposited by the recent unusually heavy rains on and around the bases of plants, and was largely absent from the open ground. The litter depth as recorded, therefore may not necessarily represent that which would normally be found in a drier season.

Nomenclature and taxonomy is based on Green (1985,1988).

## 3.2 Fauna

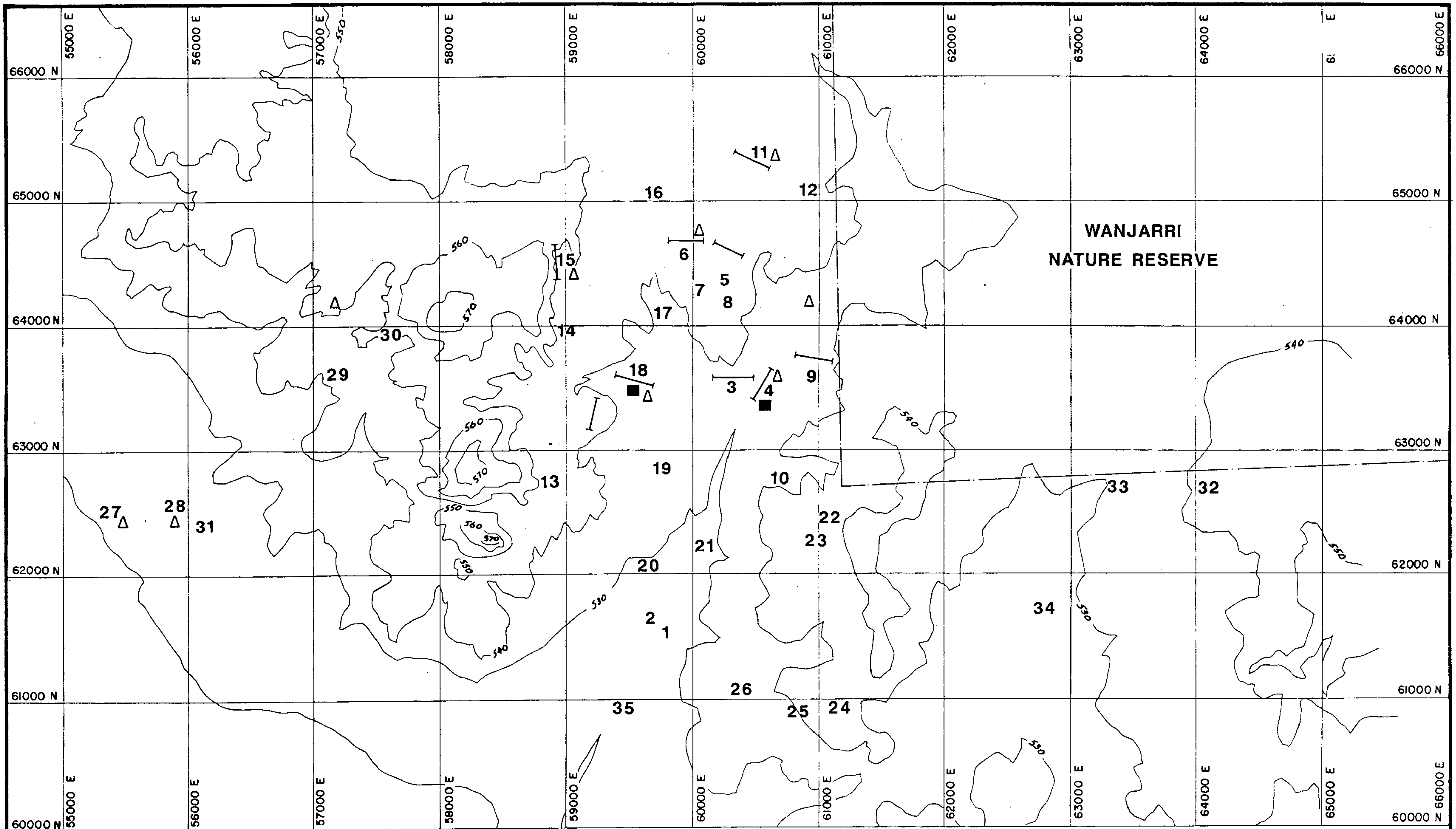
An intensive five day field survey was carried out in the project area from 5 th to 9 th February 1990. Assessment of the vertebrate fauna was carried out using a variety of trapping, searching and observation techniques. During the field work all fauna and secondary evidence of fauna, such as tracks, diggings and scats were recorded.

Ten trapping areas (Fig 2) were chosen as being; (i) representative of major habitat landforms and (ii) areas of major environmental impact from proposed development. Trapping methods employed were;

A) Pit-trap drift fence - two lines of five PVC (16cm diam., 40cm deep)pits, 30m apart with 10m flywire drift fence (30cm high) were dug in the ground and baited with universal bait (rolled oats, peanut paste, honey, sardines).

B) Elliot box traps - eight lines of 10 medium box traps 20m apart, baited with universal bait.

Quantitative assessment of bird habitat utilization centred on 200m x 200m Bird Observation Quadrats located at nine sites (Fig 2). Bird observations were collected between 0700hr and 1700hr by systematic foot traversing through the Quadrats for 30 minutes. Total species and number of each species present were recorded for each quadrat.




LEGEND

| | |
|---|---|
| 2 | Flora survey sites |
| ⊢—⊣ | Fauna Elliot trap lines |
| ■ | Fauna pit trap lines |
| Δ | Bird observation quadrats |

**Map Showing Flora and Fauna Survey Sites of the Yakabindie Nickel Project Area**

Figure 4

YAKABINDIE PROJECT

200 0 200 400 600 800 METRES

SCALE 1:10000

Soil & Rock Engineering Pty. Ltd.

Opportunistic fauna sightings were recorded while searching or travelling. All major habitats were searched for cryptic species and nocturnal species were assessed by spot-lighting and head-torch searching.

Nomenclature is based on; Birds - Pizzey (1983), Mammals - Strahan (1983), Amphibians - Tyler *et al* (1984), Reptiles - Storr *et al* (1981,1983,1986,1990).

## 4. VEGETATION AND FLORA

The proposed Yakabindie Nickel Project falls within the Wiluna Sub-region of the Austin Botanical District of the Eremean Botanical Province. A broad scale survey of the vegetation of the region was carried out by Beard (1976), in which three general vegetation types were recognised, (1) `mulga' shrubland and low woodland, which was associated with lower plains, granite hills and rocky ranges; (2) `steppe', associated with sandplains and sand-ridges, which included hummock grassland (spinifex) communities with scattered trees and shrubs of various mallee *Eucalyptus* and *Acacia* species; and (3) `halophyte communities' which included *Acacia*, *Eremophila,* and Cassia chenopodiaceous woodland and shrubland vegetation associated with greenstone hills, salt flats and playa lakes. A more detailed survey of the vegetation and flora of the Sandstone-Sir Samuel area, and in particular the Wanjarri Nature Reserve, the western and southern boundaries of which adjoin the project area, was carried out by Keighery and Milewski (in press). These authors categorised various observed vegetation types according to the landforms with which they were associated. Ten categories were used: breakaways, drainage lines, dunefields, granite exposures, hills, salt-lake features, calcareous plains, sandplains, undulating plains and broad valleys (Newbey,1984) (section 2.3). For the present survey, the same classification method and set of names was used where appropriate so that comparisons could be made between the project area vegetation and that which is found in the Nature Reserve.

### 4.1 Vegetation Associations

All the areas sampled appear to fit Beard's categories `mulga' and `halophyte communities'. Of the 10 vegetation landform classifications recognised and described by Keighery and Milewski, dunefields, salt-lakes, calcareous plains and sandplains were not represented within the Yakabindie project area. The vegetation associated with the five landform habitats occurring in the project area is described below (Appendix B).

Breakaways (B): Sites 15 and 35 were situated on or adjacent to hills composed of heavily eroded weathered granitic materials. Site 35 included the whole of a small steep rocky hill, where the taller species which dominated the vegetation of the surrounding plain were absent from all but the lowest fringes, and the vegetation consisted principally of low shrubs of *Dodonaea, Eremophila, Cassia* and chenopods. All species observed at this site were also present as understorey species at other sites, apart from *Eremophila `pungens'* and *Frankenia sp.*, which were otherwise only found in the more exposed, rocky areas of site 15. Site 15 was situated in a broad gully between two weathered granite ridges, which formed a natural drainage basin. Although no water was visible at the ground surface, the presence of *Eucalyptus lucasii* and *Brachychiton gregorii* in the lower parts of the site indicated a moist environment similar to some of the creek sites e.g. site 17. In the flattish but drier areas of the site was *Acacia* woodland very similar to many of the `undulating plain' areas. Higher up, on the rocky, exposed slopes the vegetation resembled that of site 35. Around the upper edges of the area the gymnosperm *Callitris glaucophylla* was observed, a species otherwise not found in the survey area. Site 24 was unique amongst the areas inspected, in that it consisted of an exposed chert ridge which rose sharply above the surrounding undulating plain. The soil was restricted to shallow deposits in crevices, which undoubtedly was the reason for the almost complete lack of plants taller than 0.5m. Most of the species recorded there were not recorded at other sites, although none were considered to be rare or of particular taxonomic interest (R. Cranfield pers. comm.).

Hills, granite (HG): Sampling sites 13, 14, 29 and 30 were associated with granite hills which rise above the surrounding plains. At these sites the vegetation was dominated by a tall shrub layer of *Acacia quadrimarginea*, with a lower shrub understorey dominated by species of *Eremophila* (*E. exilifolia* at 13, 14 and 29, *E. latrobei* at 30), *Dodonaea* and *Cassia*. Below these was evidence of a stratum of ephemerals including grasses and herbs, of which in most cases only vegetative parts were seen, and could not therefore be identified. A maidenhair' fern, *Cheilanthes tenuifolia* was present at all these sites, and some unidentified lichen species on exposed rock surfaces were also observed.

Drainage lines (D): The Jones' Creek, which runs north-south through the proposed site for the main pit, is the largest drainage line in the area, and most other significant drainage lines form its tributaries. Vegetation was sampled at 3 sites (sites 2, 4 and 21) and found to consist of a tall woodland dominated by *Eucalyptus camaldulensis*, with a relatively dense, unstructured shrub understorey provided by mainly *Acacia aneura*, and *A. burkitti.* Three other creek sites showed many similarities to the Jones' Creek sites in vegetation physiognomy. The vegetation at site 28, on a creekline well removed from Jones' Creek, was also dominated by *E. camaldulensis*, with an *Acacia* understorey of similar structure. The vegetation at sites 5 and 17, each located on different tributaries of Jones' Creek, showed similarities to the above sites in their overall structures, densities and understorey flora. However, the dominant tree species differed, these being *E. striaticalyx* at site 5, and *E. lucasii* at site 17. As mentioned above, the time of year was not ideal for the identification of ephemeral species. However, between the first and second visits to the site, there had been a considerable amount of rainfall, and this produced a flush of growth of such plants, mainly grasses, particularly along the creek banks. Several species had grown to heights of 0.5-1 m in a period of 5 weeks. Although time did not permit a complete collection of ephemerals, a number of species collected on 13-3-90, approximately 100 m downstream from site 4, were identified, at least to the level of genus, and these have been listed in Appendix B below the species list for site 4.

Undulating Plains (UN): Most of the sampling sites were situated on undulating plains which were of two types, which could be differentiated by their colour in aerial photographs, (1) greenstone/ironstone plains and (2) granite/quartz plains. The proposed site for the main open-cut pit encompasses most of the greenstone plain area, and it was therefore in this area that attention was concentrated, hence the relatively high density of sampling sites. Greenstone plains: Sites 3, 6, 7, 8, 11, 16, 22, 23, 25, 26. The vegetation at all of these sites consisted of *Acacia* woodland, in which the dominant species was *Acacia aneura*. This species was present as trees and shrubs of 2 to 4m in height. Other species commonly present in the upper stratum were *Santalum spicatum, Hakea preissii* and *H. suberea*. The canopy cover density varied from about 10% in the flat areas to over 70% in some small thickets, such as that at site 22 which was associated with a broad drainage line. *Acacia pruinocarpa* trees up to 10m tall were very sparsely scattered through most of these areas. The understorey consisted of a shrub layer of variable height and density, commonly consisting of *A. tetragonophylla, Scaevola spinescens*, and various species of *Eremophila* and *Cassia*. The lowest stratum consisted almost invariably of *Ptilotus obovatus, Solanum lasiophyllum* and various chenopods, the most common being *Maireana triptera* and *Sclerolaena sp.* Quartz plains: At sites 9, 10 and 12, the ground was strewn with quartz gravel and rocks up to 10cm diameter. In these areas the dominant tall shrub species was *Hakea preissii,* although *Acacia aneura* and other *Acacia* species were also present. Shrubs of *Eremophila oldfieldii* and *E. scoparia* were common, and in some areas this shrub layer was of greater density than the upper stratum. Beneath these shrubs, the vegetation was generally the same as that of the ironstone plains, i.e. *Ptilotus obovatus, Solanum lasiophyllum* and chenopods. Sites 32, 33 and 34 were difficult to categorize. At these sites both quartz and ironstone rocks were abundant on the soil surface, and the vegetation showed similarities to both the quartz and greenstone plains described above. *Acacia aneura* was dominant at all three sites, with *Hakea preissii* also fairly common at 33 and 34. *Acacia coolgardiensis* and *Eremophila freelingii* were observed at site 32 and were not seen elsewhere during this survey, although they are both widespread species. The middle and lower strata at all three sites were similar to those of other plains sites.

Broad valleys (V): Sites 18, 19, and 20 were all situated in a broad valley situated between a low ridge of granite and the main creek area. The vegetation was *Acacia aneura* low woodland, with emergent trees of *A. pruinocarpa*. The tall shrub stratum included, in addition to *A. aneura,* the species *A. craspedocarpa*, *A. quadrimarginea*, *A. tetragonophylla*, *Santalum lanceolatum* and *Eremophila oldfieldii*. *Scaevola spinescens* and *Eremophila fraseri* were the commonest members of shrub strata of 0.5-2m, while *Ptilotus obovatus, Solanum lasiophyllum* and chenopods were again present in the third and lowest stratum. Site 27 was situated on a particularly flat and sparsely vegetated part of a very broad valley, which includes the site for the proposed airfield. The dominant stratum was provided by shrubs of *Eremophila fraseri* ranging in height from 0.5 to 2m. Other species in that stratum, although much rarer were *Eremophila latrobei* and *Cassia desolata*. Taller plants of *Acacia aneura, Hakea suberea* and *A. tetragonophylla* were present, but extremely sparsely distributed. Low shrubs, where present were the same species as those of the plains sites, with the addition of *Cassia helmsii* and *Podolepis capillaris*. Site 31 was situated on a broad plain not far from site 27, and was chosen to represent a broad area which extends from the Leinster-Wiluna road, to the foot of the granite hills situated to the east. The vegetation in this area was a low shrubland dominated by *Eremophila exilifolia*, with occasional emergent shrubs of *A. tetragonophylla* and *Eremophila fraseri*. The lowest shrub layer was virtually identical to the other plains and broad valley sites.

## 4.2 Flora

In total, 71 vascular plant species were identified to species level, with an additional 7 species determined to genus level only, owing to the lack of flowers or fruits necessary to enable a complete identification. No introduced weed species or cultivated plants were observed. Plants identified in this survey included members of 28 families, 16 of which were represented by only a single species (Appendix A). The genera most well represented in the area were *Acacia* (11 species found), *Eremophila* (11 species) and *Cassia* (5 species). By far the most common species in the area was Mulga *Acacia aneura* which was present at all but five sites. The genus *Eucalyptus* was notably rare in the area, represented only by 3 species, all of which were associated with creeks or major drainage lines. No species of *Casuarina* or *Allocasuarina* were observed.

None of the plant species identified in this survey were listed in the CALM Declared Rare Flora Schedule, 1989. However some undescribed or imperfectly known species are known from the area of the proposed mine site, and details are given below.

*Eremophila `pungens'* - This taxon, found at sites 15 and 35 is an unpublished species commonly associated with laterite breakaways in the Wiluna-Laverton area. It is one of a group of taxa related to *E. georgei* for which the formal taxonomy is yet to be finalised. (R.J. Chinnock, pers. comm.).

*Grevillea inconspicua* - This species is on the C.A.L.M. reserve list of rare and endangered species. The W.A. Herbarium contains a specimen collected by R. Cranfield a short distance outside the south-western boundary of the Wanjarri Nature Reserve near Six Mile Well, and it appears likely that this locality is inside the S.E. edge of the proposed pit area (R. Cranfield, pers. comm.). Several hours of searching the area on 12-3-90 and 13-3-90 failed to reveal any *Grevillea* species. It is possible that heavy grazing by sheep, goats etc. has caused the species to disappear or become unrecognisable, or that the search location was incorrect.

*Acacia aff. citrinoviridis* - This species, fairly abundant at site 26 is an imperfectly known taxon, for which the geographic distribution and the taxonomic status are not known. Specimens collected on 6-2-90 and 12-3-90 were inspected by Mr. B.R. Maslin, and were considered to be similar to two or three specimens in the W.A. Herbarium, the nearest being one collected from Windidda Station, 200 km to the north-east. Until further taxonomic studies are completed, it is impossible to say whether or not the plants on the Yakabindie prospect are deserving of particular conservation attention.

*Acacia aneura* - This is known to be an extremely variable species, a matter discussed at some length, and illustrated by Beard (1976). The considerable amount of between-plant variation known to occur in the phyllode morphology of this species was demonstrated at most sampling sites, where plants

with broad flat phyllodes of various sizes, narrow flat phyllodes, and terete phyllodes were almost invariably found in close proximity. There was also a wide range of variation in habit and size. In the taller woodland and shrub communities this species was seen both as a single-stemmed `tree' and as a many-stemmed mallee-like shrub. Dwarf shrub forms were also commonly observed which formed a definite understratum, e.g. site 6. It is likely that further taxonomic studies will reveal that this taxon consists of several species or subspecies (B.R. Maslin pers. comm.), and although *A. aneura sens. lat.* is one of the most widely distributed plant species in Australia, regional and localized forms may exist which deserve special protection.

### 4.3 Wanjarri Nature Reserve

The Wanjarri Nature Reserve is the only conservation area in the Sandstone-Sir Samuel region (Keighery & Milewski, in press). Landforms present on the mining site which are conserved in Wanjarri are broad valleys, exposed granite hills, breakaways and drainage lines. Undulating plains, which account for a large proportion of the proposed mine site, particularly in the main pit and eastern waste-dump area, are poorly represented in the Reserve. Comparison of the vegetation descriptions and species lists from the present study with those of Keighery and Milewski indicates that all broad vegetation types and consequently many of the plant species found on the proposed mine site are present in the reserve. In the event that a complete list of plants found in the Reserve becomes available in the future a more reliable comparison can be made.

## 5 FAUNA

The project area lies just to the north of the boundary of the major zoogeographic regions of the mesic South West and arid central Australian Eyrean region. As a result the Northern Goldfields is an overlap zone species rich in fauna with representatives from both zoogeographic regions. The field survey recorded 45 species of bird,8 native and 6 introduced mammals, 11 reptile and 2 amphibians. The survey added two species of reptile *Diplodactlyus squarrosus* and *Varanus tristis*, and one frog *Limnodynastes spenceri* which had not been recorded previously in the surrounding area. On the basis of literature searches and known habitat preferences the project area may support approximately 101 bird species,15 native and 7 introduced mammal, 48 reptile and 7 amphibians (Appendix C).

Within the project area three species are gazetted as "rare, or otherwise in need of special protection". They are the Lesser stick-nest Rat *Leporillus apicalis*, Peregrine Falcon *Falco peregrinus* and the Alexandra Parrot *Polytelis alexandrae*:

Lesser Stick-nest Rat *Leporillus apicalis*: - This large rat species is gazetted "rare,possibly extinct". It formerly ranged over much of central Australia as is evident by the nest remains found in small caves and breakaways, but has not been seen since 1933. However there are several unconfirmed reports of contemporary nests (Gratle,1972). Within the project area the remains of two nests and two roosting sites were found in breakaways, indicating that the species did inhabit the area previously.

Peregrine Falcon *Falco peregrinus*: - Gazetted as "in need of special protection". This species is widely distributed throughout Australia. It's status is considered to be "generally uncommon, probably declining in settled regions; still well established in remote areas (Pizzey,1983). While occurring in the project area it is a wide ranging species and is not dependent on any habitat which is to be disturbed.

Alexandra Parrot *Polytelis alexandrae*: - Gazetted as "rare and endangered". Rare, highly nomadic and irregular. Moriarty (1972) recorded one individual from Wanjarri Station in over 30 years of observation. The project area is on the western limits of this arid interior species distribution. Breeds in hollow eucalypts on watercourses.

## 5.1 Mammals

Fifteen species of mammal from 10 families were recorded during the field survey, of these 8 species were native and 7 introduced (Table 2). On the basis of known habitat preferences and species distributions the project area may support an additional 7 native species.This compares favourably with Wanjarri Nature Reserve for which a total of 25 species have been recorded, 18 native and 7 introduced. All species occurring in the project area, except the Goat *Capra hircus* , occur in Wanjarri. However as is typical of the Eastern Goldfields region, population densities of native species, excluding macropods, appear to be very low. Only a single individual of three species, *Ningaui ridei, Pseudomys hermannsburgensis* and *Nyctophilus geoffroyi,* was recorded during the field survey. In keeping with the known low densities of arid populations of the Echidna *Tachyglossus aculeatus* (Strahan,1983), only a few scattered signs of this species presence were noted. Conversely the two macropods, the Euro and the Red Kangaroo, were moderately common. A single Little Cave Eptesicus *Eptesicus pumilus* population of approximately 60 individuals is resident in a cave in the breakaway area close to the proposed plant site.

The greater proportion (60%) of the native mammals which occur or are expected to occur in the project area are Eyrean in biogeographic affinities with the major proportion of their distributions in arid central Australia. The only predominately mesic south western species which may occur in the area is the Fat-tailed Dunnart *Sminthopsis crassicaudata*. The project area lies on the northern limits of this species distribution. Of the Eyrean species the Little Cave Eptesicus and the Wongai Ningaui *Ningaui ridei* are near the southern limits of their range. Another six species, such as the Echidna and Dingo, have Australia wide distributions.

The project area occurring within the Yakabindie Station pastoral area is subject to grazing by sheep, although few sheep were present except in the western broad valley area where the proposed airstrip and village are sited. Throughout the central granite and undulating plains feral goats are abundant with herds of up to 30 individuals being sighted. Evidence of heavy grazing pressure by goats was wide spread. Rabbits were uncommon and generally occurring in undulating plain habitat. Very little evidence of the presence of foxes, horse or cattle were noted aside from occasional scats or track, again in the central undulating plain area. A single House Mouse *Mus musculus* was captured beside Six mile Well on The Jones Creek.

## 5.2 Birds

Bird surveys of the project area recorded 45 species, 16 non passerines and 27 passerines (Table 3). The area may support up to 101 species based on known habitat preferences and species distributions,55 non passerines and 46 passerines (Appendix C). This is a lower percentage of passerines (46%) than recorded for Wanjarri nature reserve (55%),the difference being due to the extensive spinifex sandplain habitat which is absent from the project area. The total anticipated species number is only slightly less than Wanjarri were 124 species are recorded, 58 non passerines and 66 passerines, and 99 species (80%) are expected to be common to both areas.

The low number of field records reflects the short duration of the survey and seasonal influences with mid summer being the least productive period for biological surveys.The species list for Wanjarri represents data collected over a 30 year period of which 22 to 25 species were rare, occasional vagrant visitors and 31 species occurring only in good seasons after heavy rain (Moriarty,1972).

In contrast to the mainly arid Eyrean mammals, the project area lies in a zone in which the ranges of species with predominately southern or northern distributions overlap. Numerous mesic southern species such as Splendid Blue Wren, Regent Parrot, Western Magpie and Grey Currawong are at the northern limit of their range. While arid northern species such as Bourke's parrot, Spotted Bowerbird and Grey Honeyeater are at their western or south western distribution limits.

Within the project area the passerines predominate in abundance (55%), particularly the honeyeaters and thornbills, with large numbers of Chestnut-rumped Thornbills and Yellow-throated Miners being present. Among the non passerines the granivorous parrots make up 91% with the Galah, Cockatiel and Budgerigar being the most common.

| | Landform Code | HG | D | UN | B | V |
|---|---|---|---|---|---|---|
| **MONOTREMATA** | | | | | | |
| TACHYGLOSSIDAE | | | | | | |
| *Tachyglossus aculeatus* | Echidna | X | | X | X | |
| **MARSUPIALIA** | | | | | | |
| DASYURIDAE | | | | | | |
| *Ningaui ridei* | Wongai Ningaui | | X | | | |
| MACROPODIDAE | | | | | | |
| *Macropus robustus* | Euro | X | X | X | X | |
| *Macropus rufus* | Red Kangaroo | | X | X | | X |
| **CHIROPTERA** | | | | | | |
| VERSPERTILIONIDAE | | | | | | |
| *Eptesicus pumilus* | Little Cave Eptesicus | | | | X | |
| *Nyctophilus geoffroyi* | Lesser Long-eared Bat | | X | | | |
| **RODENTIA** | | | | | | |
| HYDROMYINAE | | | | | | |
| *Leporillus apicalis* | Stick nest rat | | | | old nests | |
| MURIDAE | | | | | | |
| *Pseudomys hermannsburgensis* | Sandy Inland Mouse | | | X | | |
| **INTRODUCED MAMMALS** | | | | | | |
| *Mus musculus* | House Mouse | | X | | | |
| *Bos taurus* | Cow | | | | | X |
| *Ovis aries* | Sheep | | X | X | | X |
| *Capra hircus* | Goat | X | X | X | X | |
| *Equs caballus* | Horse | | | X | | |
| *Oryctolagus cuniculus* | Rabbit | | X | X | | X |
| *Vulpes vulpes* | Fox | | X | | | |
| | species richness | 3 | 9 | 8 | 5 | 4 |

Key: HG - Hills,granite; D - Drainage Line; UN - Undulating Plain, greenstone; B - Breakaway; V - Broad Valley.

**TABLE 2: Mammals recorded in habitats of the proposed Yakabindie Nickel project area.**

| | Landform Code | HG | D | UN | B | V |
|---|---|---|---|---|---|---|
| CASUARIDAE | | | | | | |
| *Dromaius novaehollandiae* | Emu | | X | 2 | | 11 |
| ANATIDAE | | | | | | |
| *Anas supercillosus* | Black Duck | | 3 | | | |
| ACCIPITRIDAE | | | | | | |
| *Aquila audax* | Wedge-tailed Eagle | | | | nest | |
| FALCONIDAE | | | | | | |
| *Falco berigora* | Brown Falcon | | | X | | |
| *Falco cenchroides* | Nankeen Kestrel | | | | 1 | |
| OTIDIDAE | | | | | | |
| *Eupodotis australis* | Bustard | | | 1 | | |
| COLUMBIDAE | | | | | | |
| *Ocyphaps lophotes* | Crested Pigeon | | 5 | 2 | 1 | 2 |
| *Phas chalcoptera* | Common Bronzewing | X | | 2 | | |
| PSITTACIDAE | | | | | | |
| *Barnardius zonarius* | Port Lincoln Parrot | | 10 | 2 | | |
| *Cacatua roseicapilla* | Galah | | 90 | 50 | | |
| *Melopsittacus undulatus* | Budgerigar | | 22 | X | | |
| *Nymphicus hollandicus* | Cockatiel | | | 15 | | 20 |
| *Psephotus varius* | Mulga Parrot | | 4 | X | | |
| CULIDAE | | | | | | |
| *Chrysococcyx basalis* | Horsefield's Bronze Cuckoo | | | X | | |
| STRIGIDAE | | | | | | |
| *Ninox novaeseelandiae* | Boobook Owl | | 1 | | | |
| AEGOTHELIDAE | | | | | | |
| *Aegotheles cristatus* | Australian Owlet-nightjar | | 1 | | | |
| CAMPEPHAGIDAE | | | | | | |
| *Coracina novaehollandiae* | Black-faced Cuckoo-shrike | | 6 | X | | |
| PACHYCEPHALIDAE | | | | | | |
| *Oreocica gutturalis* | Crested Bellbird | | 2 | 2 | 2 | 1 |
| *Pachycephalus rufiventris* | Rufous Whistler | | 2 | 2 | 4 | |
| *Petroica goodenovii* | Red-capped Robin | | | 4 | | |
| MONARCHIDAE | | | | | | |
| *Rhipidura leucophrys* | Willie Wagtail | | 8 | X | | |
| ORTHONYCHIDAE | | | | | | |
| *Pomatostomus superciliosus* | White-browed Babbler | | 2 | 2 | 3 | |
| ACANTHIZIDAE | | | | | | |
| *Acanthiza apicalis* | Broad-tailed Thornbill | X | | | | |
| *Acanthiza chrysorrhoa* | Yellow-rumped Thornbill | X | 1 | | 6 | |
| *Acanthiza uropygialis* | Chestnut-rumped Thornbill | | 21 | 38 | | |
| *Smicrornis brevirostris* | Weebill | | 20 | | 1 | |

**TABLE 3: Birds recorded in habitats of the proposed Yakabindie Nickel project area.**

| | Landform Code | HG | D | UN | B | V |
|---|---|---|---|---|---|---|
| DAPHOENOSITTIDAE | | | | | | |
| *Daphoenositta chrysoptera* | Australian Sittella | | 4 | X | | |
| MELIPHAGIDAE | | | | | | |
| *Acanthagenys rufogularis* | Spiny-cheeked Honeyeater | | 1 | | | |
| *Certhionyx variegatus* | Pied Honeyeater | | 12 | | | 5 |
| *Manorina flavigula* | Yellow-throated Miner | | 66 | 3 | | 1 |
| *Meliphaga ornata* | Yellow-plumed Honeyeater | | 19 | | | |
| *Meliphaga penicillata* | White-plumed Honeyeater | | 3 | | | |
| *Meliphaga virescens* | Singing Honeyeater | | 4 | 1 | | 2 |
| PLOCEIDAE | | | | | | |
| *Poephila guttata* | Zebra Finch | | | | 8 | |
| GRALLINIDAE | | | | | | |
| *Grallina cycanoleuca* | Magpie-lark | X | 13 | X | | |
| ARTAMIDAE | | | | | | |
| *Artamus cinereus* | Black-faced Woodswallow | 1 | X | | 6 | |
| *Artamus minor* | Little Woodswallow | | | 4 | | |
| *Artamus personatus* | Masked Woodswallow | | 1 | | | |
| CRACTICIDAE | | | | | | |
| *Cracticus nigrolgularis* | Pied Butcherbird | | 9 | 2 | | |
| *Cracticus torquatus* | Grey Butcherbird | X | 3 | 3 | 1 | |
| *Gymnorhina dorsalis* | Western Magpie | | X | | 2 | |
| PARADISAEIDAE | | | | | | |
| *Ptilonorhynchus maculatus* | Spotted Bowerbird | | 2 | X | | |
| CORVIDAE | | | | | | |
| *Corvus bennetti* | Little Crow | | 1 | | | 10 |
| | species richness | 5 | 33 | 24 | 11 | 10 |
| | abundance/transect | | 77 | 28 | 15 | 30 |
| | # of transects | 0 | 4 | 3 | 2 | 1 |

Key: HG - Hills,granite; D - Drainage Line; UN - Undulating Plain, greenstone; B - Breakaway; V - Broad Valley.

**TABLE 3 cont: Birds recorded in habitats of the proposed Yakabindie Nickel project area.**

### 5.3 Reptiles and Amphibians

Pit trapping and opportunistic collecting yielded 11 reptile and 2 amphibian species from the project area (Table 4). With examination of known species distributions and habitat preferences it is expected that up to 48 reptile and 7 amphibians may occur in the area. The survey added two species of reptile *Diplodactlyus squarrosus* and *Varanus tristis*, and one frog *Limnodynastes spenceri* which had not been recorded previously in the surrounding area. However similar to the birds, the limited survey duration and seasonal timing resulted in a low number of records. Wanjarri Nature Reserve with a recorded 52 reptile and 3 frog species has a richer herpetofauna, even though the area is currently under collected for snakes and amphibians. It is expected that the actual species number is higher. The increased species richness over the project area is a direct result of the presence of extensive spinifex sandplains with 38% of Wanjarri reptiles being sandplain specialists (Section 5.5). However 38 species present within Wanjarri occur or are expected to occur in the project area.

The largely arid Eyrean component of the mammal fauna is repeated in the herpetofauna. Twenty two species (45%) have Eyrean biogeographic affinities only, while a further 9 species (19%) such as *Morelia stimsoni* and *Varanus gouldii* have a predominately arid distribution with range extension into the South West. Three species *Gehyra variegata, Heteronotia binoei* and *Lialis burtonis* have Australia wide distributions occurring mainly in arid and semi-arid habitats. Only three species, *Neobatrachus kunapalari, N. wilsmorei* and *Ctenophorus ornatus,* are mesic Southwestern in their distribution, with the project area being on the northern limits of their range. Within the frogs *Cyclorana maini* and *C. platycephalus* are at their southern limits, while *Neobatrachus centralis* is at the southeastern extremity of it's range. Similarly *Diplodactlyus strophurus* and *Varanus caudolineatus* are near their southeastern distribution limits.

In terms of abundance, the arboreal skink *Egernia depressa* was common among dead *Acacia* trunks in Undulating Plain areas along with *Gehyra variegata.* This gecko was also the most abundant reptile to be found in the granite hill and breakaway area. Also widespread and common over the project area was the monitor *Varanus panoptes.* Numerous individuals were captured during the survey while fresh diggings and tracks were ubiquitous. Notably absent were the terrestrial skinks, particularly of the genus *Ctenotus,* due in part to the absence of sandplain habitat and also undoubtedly the degraded nature of the understorey.

### 5.4 Faunal Habitats

Faunal habitats are closely aligned with landform - vegetation associations. The Drainage line habitat produced the richest faunal assemblages with 49 species (9 mammal, 33 bird, 7 reptile/amphibian). additionally the quantitative bird survey revealed that this habitat was the most heavily utilised with 51% of all individuals recorded (Table 3). The Jones Creek system provides a centre for resources for many nomadic and resident bird species. The tall River Red Gums contain numerous hollows for nesting and the upper storey is utilised for foraging by birds and bats. The dense understorey vegetation and aquatic environment provides niches for many species of invertebrate, frog, reptile and small mammals. Although a distinctive faunal assemblage occurs in the granite hill area ,with rock inhabiting geckos, Euros and Echidnas, this habitat is the poorest with only 12 species recorded (3 mammal, 5 bird, 4 reptile) and few individuals. Within the breakaway habitat the small caves and overhangs provide refuge for Euros, Echidnas, bats, cave crickets and Goats. The widely occurring low open *Acacia* woodland and shrublands of the undulating plain are dominated by a highly mobile avian community and arboreal lizards. This landform - habitat is the next richest after the drainage line habitat with a total of 40 species (8 mammal, 24 bird, 8 reptile).

| | Landform Code | HG | D | UN | B | V |
|---|---|---|---|---|---|---|
| HYLIDAE | | | | | | |
| *Cyclorana platycephalus* | Water-holding Frog | | X | | | |
| LEPTODACTYLIDAE | | | | | | |
| *Limnodynastes spenceri* | | | X | | | |
| GEKKONIDAE | | | | | | |
| *Diplodactylus squarrosus* | | | | X | | |
| *Gehyra variegata* | Tree Dtella | X | | X | | |
| *Heteronotia binoei* | Bynoe's Gecko | X | X | X | | |
| AGAMIDAE | | | | | | |
| *Ctenophorus sp.* | | X | | | | |
| SCINCIDAE | | | | | | |
| *Egernia depressa* | Pygmy Spiny-tailed Skink | | | X | | X |
| *Eremiascincus richardsonii* | Broad-banded Sand Swimmer | | X | X | X | |
| *Lerista desertorum* | | | X | | | |
| *Lerista muelleri* | | | | | | X |
| VARANIDAE | | | | | | |
| *Varanus caudolineatus* | | | | X | | |
| *Varanus gouldii* | Gould's Monitor | | | X | | X |
| *Varanus panoptes rubidus* | | X | X | X | X | |
| *Varanus tristis* | | | X | | | |
| | species richness | 4 | 7 | 8 | 1 | 3 |

Key: HG - Hills,granite; D - Drainage Line; UN - Undulating Plain, greenstone; B - Breakaway; V - Broad Valley.

**TABLE 4: Herpetofauna recorded in habitats of the proposed Yakabindie Nickel project area.**

### 5.5 Wanjarri Nature Reserve

The project lies on the immediate south-western corner of Wanjarri Nature Reserve. This reserve exhibits a high species richness with 124 bird, 18 native and 7 introduced mammal, 3 frog and 52 reptile species being recorded (Appendix D). The occurrence of spinifex-sandplains, a landform-habitat absent from the project area, on Wanjarri is a significant factor in this richness (Moriarty,1972) This is reflected in the reptiles with 38% of the species recorded from Wanjarri occurring on this habitat. Additionally the area is an overlap zone between species which have predominately arid northern or mesic southern distributions, resulting in in a species richness higher than adjacent regions. The relative richness of the area compared to other arid regions is illustrated by the avifauna with 124 species recorded on Wanjarri as against only 88 species at Mileura Station 320 km to the north-west (Davies,1970).

## 6. ECOLOGICAL SIGNIFICANCE

The project area encompasses landform and vegetation associations which are widespread throughout the Northern Goldfields Region. Despite this only a small area representative of these associations is conserved within Wanjarri Nature Reserve, the only conservation area in the region.Thus the habitats which support the greatest biodiversity, such as the Jones Creek drainage system, or which are refugia for specialist species, eg breakaways, remain of ecological significance. The Jones Creek drainage system is of particular value for breeding and aquatic species. While no aquatic invertebrate survey was undertaken, Jones Creek being the largest watercourse in the region with semi-permenant water provides a refuge for many aquatic species during summer from which dispersal to other ephemeral drainage systems occurs during wetter periods.

The Drainage Line and Breakaway landform habitats are in relatively good condition and most closely represent pre-pastoral settlement status, whereas the other habitats have been severely affected by disturbance. The conditions are a reflection of historical pastoral practices and timber cutting during the mining boom in the early 1900's. The result is a severely degraded understorey with evidence of little regeneration due to grazing pressures from feral herbivores, particularly goats.

The landform - vegetation type present in the area of the project area which is least well conserved in the Wanjarri Nature Reserve is the greenstone Undulating Plain. Such areas where they occur in the goldfields region of Western Australia are often associated with mineral deposits and are commonly mined. It is therefore of great importance that some such areas are set aside for flora and fauna conservation. Although the present survey revealed very few plant taxa which were restricted to the greenstone plains, further studies, which must be carried out during a season when the ephemeral flora becomes apparent and identifiable, will almost undoubtedly reveal significant peculiarities associated with the flora of such areas.

Biota of significance which occur within the project area are the three plant species of uncertain status which MAY require further investigation (Section 4.2). With confirmation of status, these species may require special protection at specific localities within the area.

Wanjarri Nature Reserve is of critical significance as a conservation area within the Northern Goldfields Region. The region is ecologically diverse, encompassing biotic assemblages which do not occur elsewhere and is an overlap zone between arid northern and mesic southern elements of both flora and fauna. Recognition of the biological importance of Wanjarri lead to the EPA and State Cabinet endorsement of the current reservation conservation status (EPA,1975).

# 7. ENVIRONMENTAL IMPACT AND MANAGEMENT

The principle impacts from the construction of the proposed developments will be the loss of vegetated area, reduction in area of breakaway habitat and the impositions on the Jones Creek drainage system. The area loss from the developments (990 ha) is insignificant in comparison to the ecological landform units represented. The area is already of a degraded nature due to historical pastoral practices.

The Jones Creek drainage system is the only ecological unit which may undergo significant alteration from the proposed developments due to siltation and leaching from waste dumps.

The impact on the fauna is generally secondary. There will be major local impacts initially with destruction of habitat and relocation of mobile species into adjacent habitats. Impacts will be minimised by staging clearing, limiting clearing to absolute essential minimum, fencing off dangerous areas and limiting road and track development. Some bird mortality may occur during the project life as a result of birds gaining access to open water surfaces on the tailings dam. Increased traffic may cause localised death of larger mobile species, predominately kangaroos and monitor lizards.

The only perceived factors which may impact the biota of Wanjarri Nature Reserve are dust and increased visitation by the public. The subsequent localised mortality of adjacent vegetation within the reserve through excessive dust will be minimised by dust inhibition methods. Public education programmes and liaison with CALM will reduce the potential for adverse impacts associated with any increased visitation to the reserve . No other environmental impacts are perceived to impinge upon the integrity of the reserve.

## 7.1 Pit Area

All vegetation will be cleared from the pit area. Reduction in size of pit to minimum essential will minimise impact to the undulating plain greenstone *Acacia* woodland in this area. Major impact will occur locally to the Jones Creek drainage system involving the removal of approximately 3 km of the main creek bed and 4 km of the western tributaries. The Jones Creek bundwall and spill way diversion will cut through adjacent laterite plain with low open *Acacia* woodland. Severe local environmental impacts in the pit area will occur. However the impacts are deemed not significant for these widely distributed vegetation associations. Modification to the Jones Creek while extreme is of significance only at the local level. No fauna species will be adversely affected by this development. Only a single plants species, *Grevillea inconspicua*, currently on the CALM reserve "rare and Endangered " list may be affected by the pit and creek diversion. This species was reported by CALM Herbarium officers to occur on the south-eastern edge of the pit approximately 100 m south of Six Mile Bore. Despite an intensive survey of the location the species was not found. Further consultation and or field survey to ascertain the exact distribution of the species may be required.

## 7.2 Tailings Dam

This area encompasses low open *acacia* woodland on the lower slopes of granite hills and undulating granite plain. Vegetation will be removed from the embankment area while left in situ within the impoundment area allowing progressive relocation of fauna as material accumulates. With decommissioning the impoundment will be rehabilitated. Impact of this development is limited to an abundant habitat with no flora or fauna of significance being adversely affected.

### 7.3 Waste Dumps and Plant

Two waste dumps are proposed, a northern and eastern;

a) the eastern dump will involve the removal of low open *Acacia* woodland and the interruption of some minor drainage lines . no significant impact will occur other than the removal of local vegetation. A major consideration regarding the location of the dump is the close proximity to Wanjarri Nature Reserve. Potential impacts to the reserve include dust, leaching and erosional runoff. It is widely recognised that erosional runoff material has a drastic adverse effect on adjacent native vegetation.

b) northern waste dump and plant - these two development sites will impinge upon an area of breakaway habitat for approximately 1.5 km. Degradation to this habitat will occur on a local scale and may impact the only known population of the Little Cave Eptesicus (bat) *Eptesicus pumilus* .within the project area. However this will not affect the status of this common widespread species regionally. The shrub *Eremophila 'pungens'* with uncertain conservation status, occurs on these sites may be reduced in local population size. Further field survey may be required to determine the extent of the Yakabindie population. removal of the chenopod shrubland will not significantly affect any other flora or fauna.

### 7.4 Support Facilities

The campsite and airstrip are situated within a severely degraded low shrubland. Past intensive grazing has reduced the vegetation to predominately unpalatable *Eremophila* species with little or no understorey. No flora or fauna of significance occurs in this area and it is considered the developments will make little impact to the environment other than local vegetation removal. Development of an extensive vegetation community surrounding the campsite may actually enhance the attractiveness of the area for the fauna, particularly birds.

### 7.5 Dust

The close proximity of the project site to Wanjarri Nature Reserve and the predominate east-west wind patterns, dictates the control of dust generation in order to protect the integrity of the reserve. The duration of potential dust generation from the waste dumps will be minimised under the progressive rehabilitation strategy outlined in section 8, whereby top soil, is spread over the terraces and revegetated progressively as the waste dumps are raised. Additionally dust inhibition measures would minimise dust production on site to ensure no impact to Wanjarri occurs.

### 7.6 Noise

The only fauna which will respond to noise are large mobile species of macropods and birds where it may act as a deterrent a local scale adjacent to the developments. The result of localised noise would be the avoidance of the noise origin area. This behaviour would be beneficial to the fauna by avoiding potentially hazardous areas. Monitoring fauna response to noise is confounded by other factors such as habitat disturbance, mining activities and continual human presence. It is considered that no significant impact will occur to the biota through noise.

## 7.7 Feral Animal Eradication

The eradication of feral grazing animals from the project area will significantly enhance vegetation rehabilitation of disturbed areas and the remaining natural vegetation. Eradication would thus benefit the surrounding environment, as well as being a cost effective method for reducing damage to revegetation areas, as opposed to other methods such as fencing. An eradication program can be devised in consultation with CALM and the APB. Specific target species will be;

- Goats
- Rabbits
- any other feral herbivores
- any feral predators, Foxes and Cats.

Eradication of feral goat populations will be undertaken by a controlled shooting program while local rabbit populations may be poisoned with 1080 in accordance with APB guidelines.

# 8. REHABILITATION

Rehabilitation of mined pit sites with indigenous flora is a necessary part of mining operations. Many ecological and aesthetic benefits result from such treatment while good planning and careful implementation of the work should reduce the cost and time involved. Rehabilitation of mine sites in arid areas has been successfully carried out at a number of operations in the Pilbara and Goldfields and new techniques are regularly being developed. The objectives of a rehabilitation program should include:

a. Slope stabilisation
b. Dust suppression
c. Aesthetic improvement
d. Social and legal responsibility

The return of mined and otherwise detrimentally impacted areas to near-natural conditions would satisfy the objectives mentioned. A revegetation program should be aimed at establishing plant cover including a range of species which is self-sustaining and similar to that in surrounding areas. A self-sustaining community is desirable to reduce long term cost and time commitments and to create a suitable environment for local fauna. The reintroduction and establishment of local native flora aids in minimising the visual impact of mining works as well as providing suitable faunal habitat.
Revegetation of arid areas is made more difficult than that of wetter areas by a number of factors. These include:

a. Low and uncertain rainfall
b. Sparse and often species-poor natural vegetation
c. Poor soils
d. The effect of seed and seedling predators and grazers.

Site conditions at waste dumps vary further from those applicable in the general area. The height and slope of the dump provides an exposed and generally unfavourable habitat for plant growth due to the difficulties in water harvesting and, conversely, possible problems with erosion after seasonal heavy rainfall. Slopes on the leeward side of prevailing hot easterly and northerly winds may be more favourable for plant establishment. A rehabilitation programme which incorporates latest developments and appropriate techniques for the project area will be developed in consultation with CALM and other relevant authorities.

## 8.1 Site Preparation

Compacted terraces and slopes should be ripped to a depth of 30cm and, where possible, windrowed along the contour into mounds of no less than 20cm. Windrowing is necessary to collect water from the sparse rainfall and to prevent erosion down the slopes. Ideally, terrace slopes should be at a steepness of no more than $20^{o}$. If windrowing cannot be achieved on slopes, it is recommended that small scale surface irregularity be achieved in some way. The presence of any depressions, mounds, shrub or log litter aids in collecting water and protecting seeds and seedlings and has been found to be a significant factor in successful minesite rehabilitation (E.M. Mattiske, personal communication).

In all areas to be disturbed all vegetation, litter and topsoil to a depth of 15 cm should be salvaged. This material provides a mulch of crushed vegetation and topsoil which will greatly assist later revegetation programmes. The topsoil/vegetation material should be removed progressively in front of advancing overburden dumps and be immediately redeployed where possible and reapplied to conform to natural thickness. Immediate redeployment ensures maximum benefit from seed, nutrients and soil bacteria contained within the material. Where this is not possible the material needs to be stockpiled for minimum time periods in shallow piles which are surfaced ripped, seeded and fertilised. This will assist in maintaining biological activity within the soil. Subsequent plant growth produces a seed store and reduces wind and water erosion. Stockpiles should be located in areas specifically reserved for this purpose or immediately adjacent to redeployment areas for short term storage.

## 8.2 Species Selection

Species used in revegetation should include as many species which are adapted to the local conditions as is possible. A range of species from tall shrubs to annuals herbs and grasses should be suitable with tree species confined to the base of the dump where the run-off is likely to be greatest.

Selection has often been subject to availability and condition of seed. Some seed may be obtained through larger seed merchants but ideally should be provided by local collectors. This may be achieved by purchasing supplies from known nurserymen or collectors in Kalgoorlie or engaging contractors under supervision to collect from the areas around the minesite. The latter method is often more suitable as seed is fresh and plants are well adapted to local conditions and soil types.
Suggested species are:

SHRUBS
*Acacia kepeana*
*Acacia quadrimarginea*
*Acacia tetragonophylla*
*Cassia spp.*
*Santalum spicatum*
*Hakea arida*
*Hakea suberea*
*Dodonaea spp.*
*Hibiscus leptocladus*
*Sida calyxhymenia*
*Maireana spp.*
*Scaevola spinescens*

HERBS AND GRASSES
*Ptilotus spp.*
*Podolepis capillaris*
*Sclerolaena spp.*
*Cymbopogon ambiguus*
*Eragrostis sp.*

The above list includes species and genera which are generally known to regenerate easily from seed. Many of the grass and herb species are disturbance opportunists which easily re-establish in cleared areas. However, as the area to be revegetated will have been long altered from its original state and seed supply from natural vectors such as wind and animals is less likely, seeding will be required.

Tree species such as *Eucalyptus camaldulensis* (Red River Gum), *E. intertexta, E. striaticalyx, Callitris column, Brachychiton gregorii* (Kurrajong)and *Pittosporum phylliraeoides* (Desert Oak) may be suitable for areas at the base of the waste dump or in other disturbed areas near drainage lines where they can be watered until established.

### 8.3 Seed Pretreatment

Hard-seeded species such as *Cassia* and some *Acacia* species require boiling to assist germination. Good results have been shown in arid area rehabilitation when seeds are pretreated in this way. Other methods include seedcoat scarification and acid treatment but boiling is the easiest and most effective treatment in most cases. Experimentation could be carried out with the species to be used.

### 8.4 Irrigation

Studies on sprinkler irrigation of seeded areas in arid land revegetation have shown that watering causes more rapid establishment of species, but favours early-colonising plants, thus reducing the overall range of species established. It is believed that although irrigation is necessary for establishing planted nursery stock and particularly trees, its use in seeded areas is not essential over the long-term. If a quick result is required this technique may be employed.

### 8.5 Monitoring

Monitoring of revegetated sites is useful to gain further knowledge of the success of techniques and species, which can then be applied to further rehabiltation work. Monitoring of seeded areas should be carried out at regular intervals of approximately 6 months over a period of not less than 3 years. Such a time scale is necessary to account for variable seasonal rain and the effects of drought periods on established seedlings.

Follow-up work may include the addition of soil-stabilising litter where necessary, re-seeding of failed areas and further ripping or other soil disturbance to recreate suitable conditions.

## 9. RECOMMENDATIONS

In order to reduce impact to the biota of the project area, it is recommended that the proponent;

- Minimise clearing of land to essential minimum consistent with safe and efficient operations.

- Minimise impact and encroachment to The Jones Creek drainage system and breakaway habitat.

- Carry out progressive rehabilitation of waste dumps, tailings dam embankment and other developments to the level of existing land use in accordance with the rehabilitation programme devised in consultation with CALM and other relevant authorities.

- Install silt traps to collect run-off and prevent sediment from entering the drainage systems

- Cap all boreholes and pipes, backfill costeans when no longer required.

- Control dust in the project area.

- Restrict non avian faunal access to potentially hazardous areas, by fencing if required.

- Establish feral animal eradication programme.

- Prohibit domestic pets in the project area.

- Prohibit off road driving and shooting in the project area.

- Maintain strict fire control procedures.

- Set up an educational programme for employees which enhances awareness of the conservation value of both the project area and Wanjarri Nature Reserve.

- Ensure that employees and sub contractors are made aware of any environmental restrictions placed on the project by the EPA.

In order to adequately assess environmental impact arising from the project and to develop appropriate techniques which will ensure successful rehabilitation and minimal impact, it is additionally recommended that the proponent;

- Establish fauna monitoring programme developed in consultation with CALM.

- Carry out base line survey of The Jones Creek aquatic environment, including water quality and biota, prior to project construction and establish periodic monitoring.

- Keep abreast of developments in rehabilitation, monitoring techniques and environmental management procedures.

Upon decommissioning the proponent should remove all structures and equipment and rehabilitate all disturbed areas.

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The Yakabindie Nickel Mine Project flora and fauna survey described in this document was planned, coordinated and executed by;

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1. Mr N.L. McKenzie, CALM Research Woodvale, and Mr A. Chapman, CALM Kalgoorlie, kindly provided access and permission to use unpublished data for Wanjarri Nature Reserve.

2. Mr L.A. Smith, Western Australian Museum Perth, supplied reptile and amphibian collection records for the Northern Goldfields from the Museum's collection databases

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## ABBREVIATIONS

| | |
|---|---|
| APB | Agriculture Protection Board |
| BSC | Biological Surveys Committee |
| CALM | Department of Conservation and Land Management, Western Australia. |
| CER | Consultative Environmental Review |
| CTRC | Conservation Through Reserves Committee |
| DMWA | Department of Mines Western Australia |
| EPA | Environmental Protection Authority |
| ha | hectares |
| km | kilometres |
| WAM | Western Australian Museum |

Plate 1: Breakaway habitat on southern edge of northern waste dump.

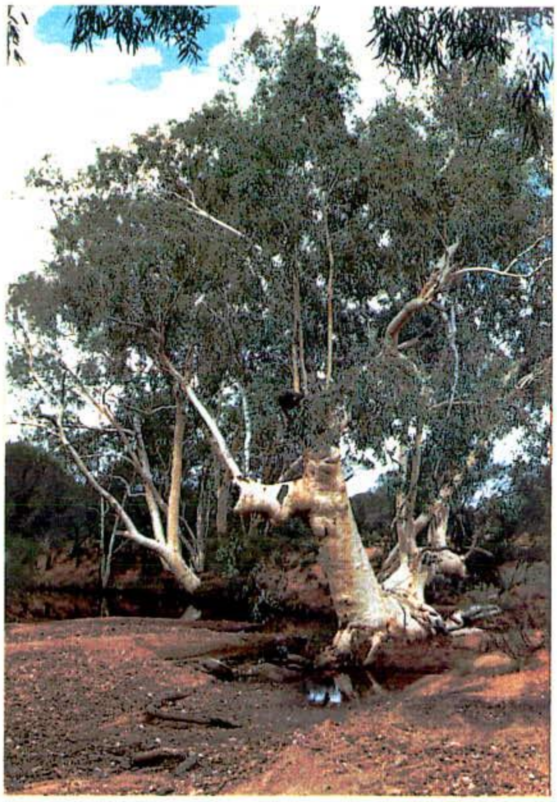

Plate 4: River Red Gums, Jones Creek, S.E. corner of pit area.

Plate 2: Granite hills, overlooking tailings dam.

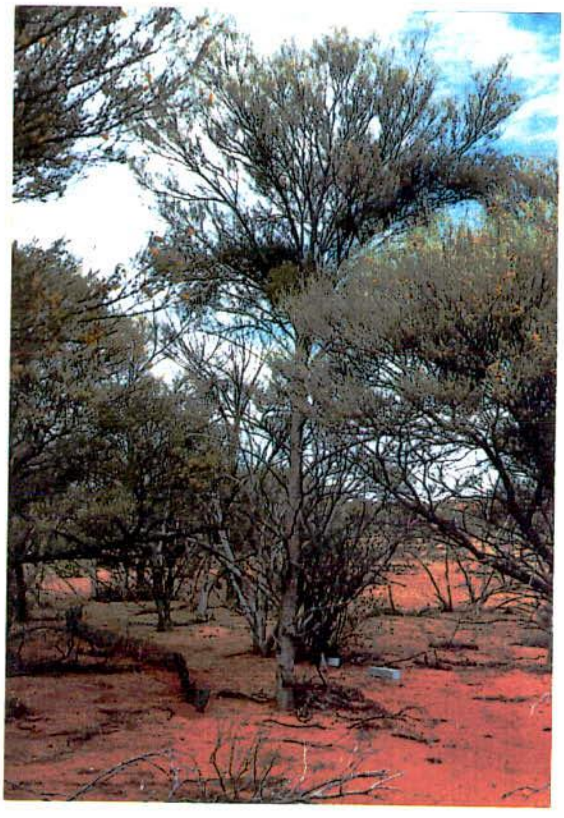

Plate 5: Mulga *Acacia aneura* woodland.

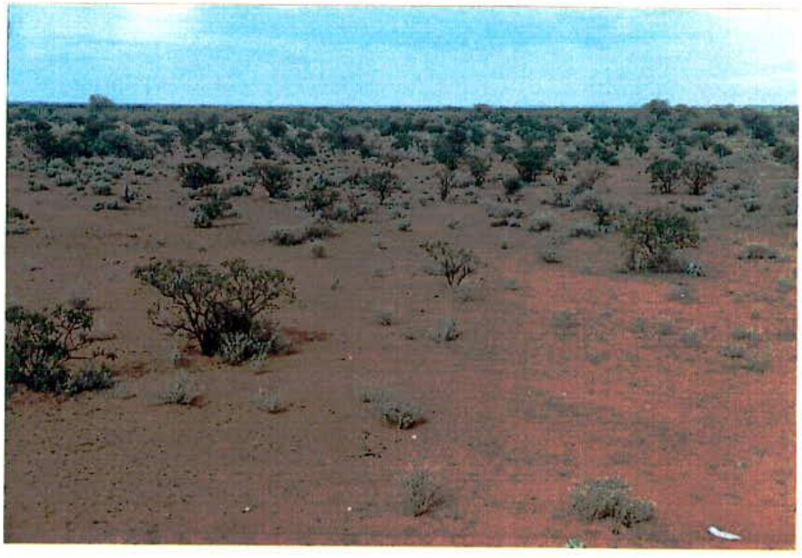

Plate 3: Airstrip and village site, low open shrubland, heavily grazed.

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# APPENDIX A

Flora Species List

**APPENDIX A**

LIST OF PLANT SPECIES COLLECTED AT YAKABINDIE NICKEL PROJECT AREA

Classification and nomenclature according to J.W. Green, `Census of the Vascular Plants of Western Australia', 2nd ed.(1985) and supplement no. 6 (1988).

PETRIDOPHYTA
- Adiantaceae
    - *Cheilanthes tenuifolia*

SPERMATOPHYTA
- Asclepiadaceae
    - *Leichardtia australis*
- Amaranthaceae
    - *Amaranthus mitchellii*
    - *Ptilotus exaltatus*
    - *Ptilotus helipteroides*
    - *Ptilotus obovatus*
- Asteraceae
    - *Cratystylis subspinescens*
    - *Podolepis capillaris*
    - *Pluchea sp.*
- Chenopodiaceae
    - *Maireana planifolia*
    - *Maireana triptera*
    - *Maireana villosa*
    - *Salsola kali*
    - *Sclerolaena diacantha*
    - *Sclerolaena fusiformis*
    - *Sclerolaena sp.*
- Cucurbitaceae
    - *Cucumis sp.*
- Cupressaceae
    - *Callitris glaucophylla*
- Cyperaceae
    - *Cyperus sp.*
- Frankeniaceae
    - *Frankenia sp.*
- Goodeniaceae
    - *Scaevola spinescens*
- Juncaceae
    - *Juncus gymnocalus*
- Leguminosae
- (Subfamily Caesalpinioideae)
    - *Cassia artemisioides*
    - *Cassia helmsii*
    - *Cassia nemophila*
    - *Cassia sturtii*
    - *Cassia desolata*
- (Subfamily Mimosoideae)
    - *Acacia aneura*
    - *A. burkittii*
    - *A. aff. citrinoviridis*
    - *A. coolgardiensis*
    - *A. craspedocarpa*
    - *A. kempeana*
    - *A. pruinocarpa*

*A. quadrimarginea*
*A. rigens*
*A. sessiliceps*
*A. tetragonophylla*

Lobeliaceae
*Isotoma petraea*

Malvaceae
*Abutilon sp.*
*Hibiscus leptocladus*
*Sida calyxhymenia*

Myoporaceae
*Eremophila aff. glutinosa*
*Eremophila exilifolia*
*Eremophila fraseri*
*Eremophila freelingii*
*Eremophila georgei*
*Eremophila latrobei*
*Eremophila longifolia*
*Eremophila oldfieldii*
*Eremophila oppositifolia*
*Eremophila scoparia*
*Eremophila `pungens'*

Myrtaceae
*Eucalyptus camaldulensis*
*Eucalyptus lucasii*
*Eucalyptus striaticalyx*

Oleaceae
*Jasminum calcareum*

Pittosporaceae
*Pittosporum phylliraeoides*

Poaceae
*Aristida contorta*
*Cymbopogon ambiguus*
*Eragrostis sp.*
*Monachather paradoxa*
*Themeda australis*

Proteaceae
*Hakea arida*
*Hakea preissii*
*Hakea suberea*

Rubiaceae
*Canthium latifolium*
*Canthium attenuatum*

Santalaceae
*Exocarpus aphyllus*
*Santalum spicatum*

Sapinidaceae
*Brachychiton gregorii*

Solanaceae
*Solanum lasiophyllum*

Sterculiaceae
*Brachychiton gregorii*

Thymelaeaceae
*Pimelea microcephala*

Violaceae
*Hybanthus floribundus*

Zygophyllaceae
*Tribulus hirsutus*

# APPENDIX B

Description of Vegetation Sites

## APPENDIX B

Listed below are descriptions of vegetation sites including data on landforms, topography, drainage and soils. Vegetation types are separated by structure and life form into broad classes based on Muir's (1977) notation.

**Site No.1**
Date sampled: 5-2-90
Landform: Broad valley
Topography: Flat sloping plain
Drainage: Poor to moderate.
Surface soil: Red sandy loam, with ironstone gravel. Litter layer: Negligible. Less than 1 cm depth, only under shrubs.

Vegetation: *Acacia aneura* low woodland

Stratum 1: Trees & shrubs 2-6m. 2-10% cover. *Acacia kempeana, Acacia aneura*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Acacia aneura, Acacia tetragonophylla, Acacia rigens, Eremophila fraseri*

Stratum 3: Shrubs 0.2-0.5m. 2-10% cover. *Solanum lasiophyllum, Eremophila latrobei, Sida calyxhymenia, Eremophila georgei*

Stratum 4: Herbs <0.2m. <2% cover. *Podolepis capillaris*

**Site No.2**
Date sampled: 5-2-90
Landform: Drainage line.
Topography: Creek bed & banks
Drainage: Good
Surface soil: Coarse sandy loam. Red on banks, paler in creek bed. Litter layer: Negligible.

Vegetation: *Eucalyptus camaldulensis* woodland.

Stratum 1: Trees 5-8m. 10-30% cover. *Eucalyptus camaldulensis*

Stratum 2: Trees & shrubs 2-5m. 10-30% cover. *Acacia aneura*

Stratum 3: Shrubs 1-2m. 2-10% cover. *Acacia quadrimarginea, Acacia burkittii, Cassia artemisioides, Acacia tetragonophylla, Eremophila exilifolia*

Stratum 4: Herbs etc. <0.5m. <2% cover. Perennial grass sp., moss sp.

**Site No.3**
Date sampled: 5-2-90
Landform: Undulating plain;greenstone
Topography: Plain, sloping towards Jones' Creek. Ironstone/quartz. Drainage: Good.
Surface soil: Red gravelly loam.
Litter layer: Negligible. Less than 1 cm depth, only under shrubs.

Vegetation: *Acacia aneura* open woodland.

Stratum 1: Trees 2-4m. 10-30% cover. *Acacia aneura, Canthium latifolium*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Acacia tetragonophylla*

Stratum 3: Shrubs 0.5-1m. 10-30% cover. *Cratystylis subspinescens, Scaevola spinescens, Eremophila latrobei*

Stratum 4: Shrubs & herbs <0.5m. 2-10% cover. *Hibiscus leptocladus, Sida calyxhymenia, Tribulus hirsutus, Ptilotus obovatus, Solanum lasiophyllum*

**Site No.4**
Date sampled: 5-2-90
Landform: Drainage line
Topography: Creek bed & bank..
Drainage: Excellent.
Surface soil: Red sandy loam. Quartz gravel in creek bed. Litter layer: Negligible. Less than 1 cm depth, only under shrubs.

Vegetation: *Eucalyptus camaldulensis* woodland.

Stratum 1: Trees & shrubs 5-8m. 30-70% cover. *Eucalyptus camaldulensis, Acacia burkittii*

Stratum 2: Trees & shrubs 2-4m. 30-70% cover. *Acacia aneura, Acacia kempeana, Brachychiton gregorii, Acacia craspedocarpa, Pimelea microcephala*

Stratum 3: Shrubs 1-2m. 2-10% cover. *Acacia tetragonophylla, Exocarpus aphyllus, Cassia artemisioides*

Stratum 4: Shrubs & herbs <0.5m. 2-10% cover. grass sp., *Ptilotus obovatus, Abutilon sp.*

Grasses (collected 13-3-90, see text): *Aristida contorta, Cyperus sp., Eragrostis sp., Juncus gymnocalus, Monachather paradoxa, Themeda australis*

**Site No.5**
Date sampled: 5-2-90
Landform: Undulating Plain; greenstone.
Topography: Flat, with drainage line to Jones Creek.
Drainage: Moderate
Surface soil: Red/brown clay/loam, much ironstone gravel. Litter layer: Negligible. Less than 1 cm depth, only under trees.

Vegetation: *Eucalyptus striaticalyx* woodland.

Stratum 1: Trees 4-8m. 30-70% cover. *Eucalyptus striaticalyx, Acacia pruinocarpa*

Stratum 2: Shrubs 2-4m. 30-70% cover. *Acacia burkittii, A. aneura*

Stratum 3: Shrubs 1-2m. 10-30% cover. *Eremophila scoparia, Acacia burkittii, Eremophila oldfieldii, Scaevola spinescens*

**Site No.6**
Date sampled: 5-2-90
Landform: Undulating plain; greenstone.
Topography: Rocky, quartz/ironstone Drainage: Poor.
Surface soil: Red sandy loam.
Litter layer: Negligible. Less than 1 cm depth, only under shrubs.

Vegetation: *Acacia aneura* open shrubland.

Stratum 1: Shrubs 3-4m. 2-10% cover. *Acacia aneura*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Hakea preissii, Scaevola spinescens*

Stratum 3: Shrubs 0.5-1m. 2-10% cover. *Cassia desolata, Eremophila fraseri, Acacia aneura*

Stratum 4: 0.1-0.4m. 2-10% cover. *Maireana triptera, Cheilanthes tenuifolia, Solanum lasiophyllum*

Lichen sp. on ground and on some rocks

**Site No.7**
Date sampled: 5-2-90
Topography: Undulating plain. Site includes chert/ironstone rise. Drainage: Moderate
Surface soil: Red loam.
Litter layer: Slight. 2 cm depth, only under shrubs.

Vegetation: *Acacia* shrubland

Stratum 1: Shrubs 0.5-3m. 10-30% cover. *Acacia burkittii, A. aneura, Eremophila oppositifolia, Acacia tetragonophylla*

Stratum 2: Shrubs 0.5-1m. 2-10% cover. *Scaevola spinescens, Hybanthus floribundus, Cassia artemisioides*

Stratum 3: Shrubs 0.2-0.5m. 2-10% cover. *Hibiscus leptocladus, Ptilotus obovatus*

**Site No.8**
Date sampled: 5-2-90
Landform: Undulating plain; greenstone.
Topography: Site includes rocky rise. Drainage: Moderate
Surface soil: Red loam
Litter layer: Depth 1 cm, patchy.

Vegetation: *Acacia aneura* open shrubland

Stratum 1: Trees & shrubs 2-4m. 10-30% cover. *Acacia aneura, Hakea preissii, Acacia sessiliceps, Santalum lanceolatum*

Stratum 2: Shrubs 1-2m 2-10% cover. *Acacia aneura*

Stratum 3: Shrubs 0.5-1m. 10-30% cover. *Cassia desolata*

Stratum 4: Shrubs <0.5m. 2-10% cover. *Ptilotus obovatus*

**Site No.9**
Date sampled: 5-2-90
Landform: Undulating plain.
Topography: Flat plain between low ridge and minor drainage line Drainage: Poor
Surface soil: Red sandy loam. Quartz and ironstone rocks (up to 10 cm diameter) on surface. Litter layer: Negligible.

Vegetation: *Eremophila scoparia* shrubland.

Stratum 1: Trees 2-3m. <2% cover. *Hakea preissii*

Stratum 2: Shrubs 1-2m. 30-70% cover. *Eremophila scoparia*

Stratum 3: Shrubs 0.2-0.5m. *Sclerolaena sp., Solanum lasiophyllum*

**Site No.10**
Date sampled: 5-2-90
Landform: Undulating plain.
Topography: Flat plain
Drainage: Poor to moderate; some minor drainage lines. Surface soil: Red sandy loam, hard surface. Quartz and ironstone rocks (up to 10 cm diameter) on surface. Litter layer: Negligible.

Vegetation: *Eremophila scoparia/Acacia* shrubland.

Stratum 1: Shrubs 2-3m. 2-10% cover. *Hakea preissii, Eremophila oldfieldii, Acacia aneura*

Stratum 2: Shrubs 1.5-2m. 10-30% cover. *Eremophila scoparia, Acacia burkittii, A. aneura, A. sessiliceps*

Stratum 3: Shrubs .5-1m. <2% cover. *Cassia nemophila*

Stratum 4: 0.1-0.5m. 2-10% cover. *Solanum lasiophyllum, Ptilotus exaltatus*

**Site No.11**
Date sampled: 5-2-90
Landform: Undulating plain; greenstone.
Topography:. Gentle slope to creek. Drainage: Poor
Surface soil: Red sandy loam. Ironstone and some quartz on surface. Litter layer: Up to 15 cm depth, very patchy.

Vegetation: *Acacia aneura* woodland

Emergent trees 10m. <2% cover. *Acacia pruinocarpa*

Stratum 1: Trees & shrubs 1.5-3m. 10-30% cover. *Acacia aneura, Acacia tetragonophylla, Eremophila fraseri, Eremophila oldfieldii*

Stratum 2: Shrubs & herbs <0.5m. 2-10% cover. *Solanum lasiophyllum, Cassia helmsii, Ptilotus obovatus, Eragrostis sp., Sclerolaena sp.*

**Site No.12**
Date sampled: 5-2-90
Landform: Undulating plain
Topography: sloping plain
Drainage: Moderate
Surface soil: Fine sandy loam. Rocky surface (ironstone and quartz). Litter layer: Negligible.

Vegetation: Open shrubland.

Stratum 1: Shrubs 2-4m. 10-30% cover. *Hakea preissii, Acacia aneura, A. craspedocarpa*

Stratum 2: Shrubs 1.5-2m. 2-10% cover. *Eremophila oldfieldii, Cassia desolata*

Stratum 3: Herbs <0.4m. 10-30% cover. *Sclerolaena sp., Solanum lasiophyllum*

**Site No.13**
Date sampled: 6-2-90
Landform: Hills;granite.
Topography: Gully between granite outcrops
Drainage: Good
Surface soil: Red gravelly loam. Much exposed granite. Litter layer: To 1 cm depth, only under shrubs.

Vegetation: *Acacia quadrimarginea* shrubland

Stratum 1: Shrubs 3-4m. >70% cover. *Acacia quadrimarginea*

Stratum 2: Shrubs 1-2m. 30-70% cover. *Eremophila exilifolia, Acacia quadrimarginea*

Stratum 3: Herbs <0.4m. 2-10% cover. grass sp., *Cheilanthes tenuifolia*, Lichen sp. on rocks

**Site No.14**
Date sampled: 6-2-90
Landform: Hills; granite.
Topography: Valley between granite outcrops. Rocky surface. Drainage: Good
Surface soil: Red sandy loam. Granite and quartz rocks on surface. Litter layer: To 1 cm depth, only under shrubs.

Vegetation: *Acacia quadrimarginea* shrubland.

Stratum 1: Shrubs 2-4m. 30-70% cover. *Acacia quadrimarginea, A. aneura*

Stratum 2: Shrubs 1.5-2m. 30-70 *Eremophila exilifolia, Cassia helmsii, Dodonaea petiolaris*

Stratum 3: Herbs <0.3m. <2% cover. *Cheilanthes tenuifolia*, grass sp.

**Site No.15**
Date sampled: 6-2-90
Landform: Breakaway
Topography: Valley between granite/pallid zone hills Drainage: Good.
Surface soil: Grey/white clay/loam.
Litter layer: Less than 10 cm, very patchy.

Vegetation: *Acacia/Eucalyptus* woodland.

Stratum 1: Trees & shrubs 2-5m. 30-70% cover.. *Acacia aneura, Eucalyptus lucasii, Brachychiton gregorii, Acacia craspedocarpa, A. tetragonophylla*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Dodonaea viscosa var. spathulata, Cassia artemisioides*

Stratum 3: Shrubs 0.5-1m. *Eremophila 'pungens'*

Stratum 4: <0.5m. 2-10% cover. *Ptilotus obovatus, Frankenia sp., Solanum lasiophyllum, Cheilanthes tenuifolia*

*Callitris glaucophylla* on tops of slopes.

**Site No.16**
Dates sampled: 6-2-90 and 13-2-90
Landform:Undulating plain.
Topography: Sloping plain. Site includes minor drainage line. Drainage: Moderate
Surface soil: Red sandy loam, very rocky (ironstone, quartz, chert) Litter layer: To 5 cm depth, patchy.

Vegetation: *Acacia* open woodland

Stratum 1: Trees & shrubs 2-4 m. 30-70% cover. *Acacia aneura, A. burkittii, A. quadrimarginea*

Stratum 2: Shrubs 1-2 m. 2-10% cover. *Hakea arida, Eremophila scoparia, Acacia tetragonophylla, A. aneura, Eremophila fraseri*

Stratum 3: Shrubs 0.5-1m. 2-10% cover. *Scaevola spinescens, Cassia helmsii,*

Stratum 4: <30cm. <2% cover. *Sclerolaena diacantha, Sclerolaena fusiformis*

**Site No.17**
Date sampled: 6-2-90
Landform: Drainage line.
Topography: Shallow creek bed & banks
Drainage: Good
Surface soil: Red sandy loam.
Litter layer: Patchy, from 0-20 cm, deposited around plant bases by recent flooding.

Vegetation: *Eucalyptus/Acacia* woodland.

Stratum 1: Trees 5-8m. 30-70% cover. *Eucalyptus lucasii, Acacia aneura, A. burkittii*

Stratum 2: Trees & shrubs 2-4m 2-10% cover. *Santalum lanceolatum, Acacia aneura, Jasminum calcareum, A. tetragonophylla, Exocarpus aphyllus*

Stratum 3: Shrubs 0.5-1m. <2% cover. *Cassia artemisioides*

**Site No.18**
Date sampled: 6-2-90
Landform: Undulating plain
Topography: Flat plain between granite rise and creek. Includes minor drainage line.
Drainage: Moderate
Surface soil: Red gravelly loam. Surface boulders of granite and quartz.
Litter layer: Less than 1 cm, patchy.

Vegetation: Open *Acacia aneura* woodland.

Stratum 1: Emergent trees >5m. <2% cover. *Acacia pruinocarpa*

Stratum 2: Trees & shrubs 2-4m. 2-10% cover. *Acacia aneura, A. quadrimarginea, Eremophila oldfieldii, A. craspedocarpa, Santalum lanceolatum*

Stratum 3: Shrubs 0.5-2m. 2-10% cover. *Acacia tetragonophylla, A. burkittii, Scaevola spinescens, Eremophila fraseri*

Stratum 4: Shrubs <0.5m. 2-10% cover. *Sida calyxhymenia.*

**Site No.19**
Date sampled: 6-2-90
Landform: Undulating plain.
Topography: Rocky sloping plain
Drainage: Poor.
Surface soil: Gravelly sand/clay. Quartz rocks <10cm. Litter layer: Negligible

Vegetation: *Acacia* open woodland

Stratum 1: Trees & shrubs 2-4m. 2-10% cover. *Acacia aneura, A. craspedocarpa, A. pruinocarpa*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Acacia tetragonophylla*

Stratum 3: Shrubs 0.5-1m. 2-10% cover. *Eremophila fraseri*

Stratum 4: Shrubs <0.5m. 2-10% cover. *Solanum lasiophyllum, Sclerolaena sp.*

**Site No.20**
Date sampled: 6-2-90
Landform: Undulating plain
Topography: Rocky sloping plain.
Drainage: Poor.
Surface soil: Red gravelly loam. Much quartz on surface, up to 10cm. diameter. Litter layer: Negligible

Vegetation: *Acacia* open woodland.

Stratum 1: Trees & shrubs 2-4m. 2-10% cover. *Acacia aneura, A. craspedocarpa, A. tetragonophylla, Santalum lanceolatum*

Stratum 2: Shrubs 0.5-1.5m. 2-10% cover. *Scaevola spinescens, Hakea preissii*

Stratum 3: Shrubs <0.5m. 2-10% cover. *Solanum lasiophyllum, Sclerolaena sp.*

**Site No.21**
Date sampled: 6-2-90
Landform: Drainage line
Topography: Creek bed and banks
Drainage: Good.
Surface soil: Red silt and clay. Very rocky (quartz) Litter layer: Litter deposited up tree trunks to 2 m. Mostly absent from ground surface.

Vegetation: *Eucalyptus camaldulensis* woodland.

Stratum 1: Trees 5-10m. 30-70% cover. Eucalyptus camaldulensis

Stratum 2: Shrubs 2-4m. 2-10% cover. *Exocarpus aphyllus, Acacia aneura, A. burkittii, Santalum lanceolatum*

Stratum 3: Shrubs 0.5-1m. 2-10% cover. *Cassia artemisioides*

Stratum 4: <0.5m. 2-10% cover. Grass sp., *Solanum lasiophyllum, Maireana planifolia*

**Site No.22**
Date sampled: 6-2-90
Landform: Undulating plain; greenstone.
Topography: Sloping plain. Site includes minor drainage line. Drainage: Poor
Surface soil: Red clay/loam.
Litter layer: Up to 3 cm thick, around plant bases.

Vegetation: *Acacia aneura* woodland.

Stratum 1: Trees & shrubs 2-4m. >70% cover. *Acacia aneura, Eremophila latrobei* (rare)

Stratum 2: Shrubs 1-2m. 30-70% cover. *Acacia aneura, A. tetragonophylla, Eremophila scoparia, Cassia desolata, Scaevola spinescens*

Stratum 3: Shrubs 0.2-0.5m. <2% cover. *Solanum lasiophyllum, Sida calyxhymenia*

**Site No.23**
Date sampled: 6-2-90
Landform: Undulating plain
Topography: Mildly sloping plain.
Drainage: Moderate.
Surface soil: Red sandy loam. Quartz & ironstone on surface. Litter layer: Negligible

Vegetation: *Acacia aneura* open woodland

Emergent trees 10m. <2% cover. *Acacia pruinocarpa*

Stratum 1: Trees & shrubs 2-3m. 2-10% cover. *Acacia aneura*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Cassia desolata, Scaevola spinescens*

Stratum 3: Shrubs 0.2-0.5m. <2% cover. *Ptilotus obovatus, Solanum lasiophyllum, Sclerolaena sp.*

**Site No.24**
Date sampled: 6-2-90
Landform: Undulating plain; greenstone.
Topography: Uplifted rocks (chert). Cliff face on western side. Drainage: Excellent
Surface soil: Red-brown sandy clay, only in crevices. Litter layer: Negligible.

Vegetation: Mixed. Opportunistic species.

Stratum 1: (1 tree) 3m. <2% cover. *Canthium attenuatum*

Stratum 2: 0.2-0.5m. <2% cover. *Eremophila aff. glutinosa, Dodonaea petiolaris*

Stratum 3: <0.2m. <2% cover. *Amaranthus mitchellii, Isotoma petraea, Cucumis sp.*

**Site No.25**
Date sampled: 6-2-90
Landform: Undulating plain; greenstone.
Topography:
Drainage: Poor.
Surface soil: Red sandy loam with ironstone gravel and rocks to 20cm. Litter layer: 0-5cm deep, patchy.

Vegetation: *Acacia aneura* open shrubland

Stratum 1: Emergent trees 6m. <2% cover. *Acacia pruinocarpa*

Stratum 2: Shrubs 3-4m. 10-30% cover. *Acacia aneura*

Stratum 3: Shrubs 1-2m. 2-10% cover. *Cassia helmsii, Scaevola spinescens*

Stratum 4: Shrubs 0.2-0.5m. 2-10% cover. *Solanum lasiophyllum, Sclerolaena sp.*

**Site No.26**
Dates sampled: 6-2-90 and 12-3-90
Landform: Undulating plain; greenstone.
Topography: Low hill/ undulating plain.
Drainage: Moderate
Surface soil: Red clay/loam. Very rocky.
Litter layer: Negligible

Vegetation: *Acacia* woodland

Stratum 1: Trees and shrubs 2-4m. 30-70% cover. *Acacia aneura, Acacia aff. citrinoviridis, Hakea suberea, Hakea preissii, Santalum spicatum, Pittosporum phylliraeoides, Leichardtia australis* (creeper)

Stratum 2: Shrubs 1-2m. <2% cover. *Cassia desolata, Eremophila fraseri, Acacia tetragonophylla, Scaevola spinescens, Cassia helmsii*

Stratum 3: Shrubs <0.5m. <2% cover. *Solanum lasiophyllum, Sclerolaena sp., Ptilotus obovatus*

**Site No.27**
Date sampled: 7-2-90
Landform:Broad valley.
Topography: Flat plain.
Drainage: Poor.
Surface soil: Red sand with quartz gravel.
Litter layer: Negligible

Vegetation: *Eremophila fraseri* open shrubland.

Stratum 1: Trees & shrubs 1.5-4m. <2% cover. *Hakea suberea, Acacia aneura, A. tetragonophylla*

Stratum 2: Shrubs 0.5-2m. 2-10% cover. *Eremophila fraseri* (dominant), *Eremophila latrobei, Cassia desolata*

Stratum 3: Shrubs 0.2-0.5m. 2-10% cover. *Ptilotus obovatus, Solanum lasiophyllum, Sclerolaena sp., Cassia helmsii, Podolepis capillaris*

**Site No.28**
Date sampled: 7-2-90
Landform: Drainage line.
Topography: Creekline.
Drainage: Good.
Surface soil: Red/brown coarse sand.
Litter layer: Up to 10 cm deep under eucalypts, very variable.

Vegetation: *Eucalyptus camaldulensis* woodland.

Stratum 1: Trees 8m. 10-30% cover. *Eucalyptus camaldulensis*

Stratum 2: Trees & shrubs 2-4m. 2-10% cover. *Acacia aneura, A. quadrimarginea, A. tetragonophylla, Hakea suberea, Eremophila longifolia*

Stratum 3: Shrubs 1-2m. 10-30% cover. *Cassia nemophila, Cassia helmsii*

Stratum 4: Shrubs <0.5m. 2-10% cover. *Ptilotus obovatus, Solanum lasiophyllum, grass spp., Pluchea sp., Cassia desolata*, moss sp.

**Site No.29**
Date sampled: 7-2-90
Landform: Hills; granite.
Topography: Fairly steep slope from granite hill. V. rocky. Drainage: Good
Surface soil: Very gravelly red loam.
Litter layer: Negligible

Vegetation: *Acacia quadrimarginea/Eremophila exilifolia* open shrubland

Stratum 1: Trees & shrubs 2-3m. 2-10% cover. *Acacia quadrimarginea, Santalum spicatum*

Stratum 2: Shrubs 0.5-1m. 2-10% cover. *Eremophila exilifolia*

Stratum 3: Shrubs and herbs <0.5m. 10-30% cover. *Ptilotus obovatus, Cymbopogon ambiguus, Sclerolaena sp., Cheilanthes tenuifolia*

**Site No.30**
Date sampled: 7-2-90
Landform: Hills; granite.
Topography: Upper slopes and top of granite hill.
Drainage: Good.
Surface soil: Red gravelly loam. Much exposed rock.
Litter layer: Negligible.

Vegetation: *Acacia* shrubland

Stratum 1: Shrubs 1.5-4m. 30-70% cover. *A. quadrimarginea, Acacia aneura*

Stratum 2: Shrubs 0.5-1m. 2-10% cover. *Eremophila latrobei*

Stratum 3: <0.5m. 2-10% cover. *Ptilotus obovatus, Cymbopogon ambiguus, Cheilanthes tenuifolia, Solanum lasiophyllum*

**Site No.31**
Date sampled: 7-2-90
Landform: Broad valley.
Topography: Rocky plain.
Drainage: Poor
Surface soil: Red coarse gravelly loam. Quartz & granite on surface. Litter layer: Absent.

Vegetation: *Eremophila exilifolia* low shrubland

Stratum 1: Shrubs 2m. <2% cover. *Acacia tetragonophylla, Eremophila fraseri*

Stratum 2: Shrubs 0.5m. 2-10% cover. *Eremophila exilifolia* (dominant), *Cassia helmsii, Cassia sturtii, Eremophila fraseri*

Stratum 3: 0.2-0.5m. <2% cover. *Ptilotus obovatus, Solanum lasiophyllum, Podolepis capillaris,* grass sp.

**Site No.32**
Date sampled 13-3-90
Landform: Broad valley.
Topography: Broad plain, with minor drainage line.
Drainage: Moderate.
Surface soil: Red loam with ironstone and quartz gravel. Litter layer: Negligible

Vegetation: *Acacia* open woodland

Stratum 1: Trees & shrubs 2-4m. 10-30% cover. *Acacia aneura, A. pruinocarpa, Canthium attenuatum, A. craspedocarpa, Acacia coolgardiensis*

Stratum 2: shrubs 1-2m. 10-30% cover. *Acacia quadrimarginea, A. aneura, Eremophila latrobei, Eremophila fraseri*

Stratum 3: 0.5-1m. 2-10% cover. *Eremophila freelingii*

Stratum 4: <0.5m. 2-10% cover. *Ptilotus obovatus, Maireana triptera, Maireana villosa, Sida calyxhymenia, Solanum lasiophyllum*

**Site No.33**
Date sampled: 13-3-90
Landform: Undulating plain.
Topography: Very rocky laterite rise.
Drainage: Good
Surface soil: Red gravelly loam. Ironstone & quartz on surface Litter layer: Negligible

Vegetation: *Acacia* open woodland.

Stratum 1: Trees & shrubs 2-3m. 2-10% cover. *Acacia aneura, A. quadrimarginea, Eremophila oppositifolia, Eremophila oldfieldii, Hakea preissii*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Eremophila scoparia* (dominant), *Cassia desolata, Acacia craspedocarpa, Hakea preissii, Cratystylis subspinescens*

Stratum 3: Shrubs <0.5m. 2-10% cover. *Maireana triptera, Ptilotus obovatus, Solanum lasiophyllum, Podolepis capillaris.*

**Site No.34**
Date sampled: 13-3-90
Landform: Undulating plain.
Topography: Broad plain.
Drainage: Poor
Surface soil: Red gravelly loam. Very rocky surface, ironstone & quartz. Litter layer: Negligible

Vegetation: *Acacia aneura* open woodland

Stratum 1: Trees & shrubs 2-4m. <2% cover. *Acacia aneura, A. burkittii, Hakea preissii.*

Stratum 2: 0.5-2m. 2-10% cover. *Acacia burkittii, Cassia desolata, Eremophila fraseri, Scaevola spinescens, Cratystylis subspinescens, Cassia helmsii, Cassia nemophila*

Stratum 3: Shrubs and herbs <0.2m. 10% cover. Chenopods dominant incl. *Maireana tomentosa, Sclerolaena sp., Salsola kali, also Ptilotus obovatus, Solanum lasiophyllum, Ptilotus helipteroides*

**Site No.35**
Date sampled: 13-3-90
Landform: Breakaway.
Topography: Granite/ weathered granite breakaway.
Drainage: Good.
Surface soil: Very gravelly red-brown loam. Rocky surface. Litter layer: Negligible

Vegetation: Mixed shrubland

Stratum 1: Trees & shrubs 3-5m. 2-10% cover. *Acacia aneura* (dominant), *A. quadrimarginea, Exocarpus aphyllus*

Stratum 2: Shrubs 1-2m. 2-10% cover. *Hakea arida, Acacia tetragonophylla*

Stratum 3: Shrubs 0.3-1m. 10-30% cover. *Scaevola spinescens, Eremophila `pungens', Cassia desolata, Ptilotus obovatus, Eremophila exilifolia, Eremophila oppositifolia, Dodonaea viscosa var. spathulata*
Stratum 4: Shrubs <0.3m. 2-10% cover. *Maireana triptera, Sclerolaena diacantha, Sclerolaena sp., Frankenia sp., Ptilotus obovatus, Sida calyxhymenia, Eremophila latrobei*

# APPENDIX C

Yakabindie Nickel Project Area
Fauna Species List

**APPENDIX C:** MAMMAL SPECIES WHICH OCCUR OR ARE EXPECTED TO OCCUR IN THE YAKABINDIE NICKEL PROJECT AREA.

| | | |
|---|---|---|
| **MONOTREMATA** | | |
| TACHYGLOSSIDAE | | |
| *Tachyglossus aculeatus* | Echidna | |
| **MARSUPIALIA** | | |
| DASYURIDAE | | |
| *Antechinomys laniger* | Kultarr | |
| *Ningaui ridei* | Wongai Ningaui | |
| *Pseudantechinus macdonnellensis* | Fat-tailed Antechinus | |
| *Sminthopsis crassicaudata* | Fat-tailed Dunnart | |
| *Sminthopsis hirtipes* | Hairy-footed Dunnart | |
| *Sminthopsis macroura* | Stripe-faced Dunnart | |
| MACROPODIDAE | | |
| *Macropus robustus* | Euro | |
| *Macropus rufus* | Red Kangaroo | |
| **CHIROPTERA** | | |
| MOLOSSIDAE | | |
| *Mormopterus planiceps* | Little Mastif Bat | |
| *Tadarida australis* | White-striped Mastiff Bat | |
| VERSPERTILIONIDAE | | |
| *Chalinolobus gouldii* | Gould Wattled Bat | |
| *Eptesicus pumilus* | Little Cave Eptesicus | |
| *Nycticeius balstoni* | Western Broad-nosed Bat | |
| *Nycticeius greyii* | Little Broad-nosed Bat | |
| *Nyctophilus geoffroyi* | Lesser Long-eared Bat | |
| **RODENTIA** | | |
| HYDROMYINAE | | |
| *Leporillus apicalis* | Stick nest rat | extinct- old nests only |
| MURIDAE | | |
| *Pseudomys hermannsburgensis* | Sandy Inland Mouse | |
| **CARNIVORA** | | |
| CANIDAE | | |
| *Canis familiaris dingo* | Dingo | |
| **INTRODUCED MAMMALS** | | |
| *Mus musculus* | House Mouse | |
| *Bos taurus* | Cow | |
| *Ovis aries* | Sheep | |
| *Capra hircus* | Goat | |
| *Equs caballus* | Horse | |
| *Oryctolagus cuniculus* | Rabbit | |
| *Vulpes vulpes* | Fox | |
| *Felis catus* | Cat | |

**APPENDIX C:** BIRD SPECIES WHICH OCCUR OR ARE EXPECTED TO OCCUR IN THE YAKABINDIE NICKEL PROJECT AREA.

| | |
|---|---|
| CASUARIDAE | |
| *Dromaius novaehollandiae* | Emu |
| PODICIPEDIDAE | |
| *Prodiceps novaehollandiae* | Little Grebe |
| *Prodiceps poliocephalus* | Hoary-headed Grebe |
| AREIDAE | |
| *Ardae novaehollandiae* | White-faced Heron |
| *Egretta alba* | White Egret |
| ANATIDAE | |
| *Anas gibberifrons* | Grey Teal |
| *Anas superciliosus* | Black Duck |
| *Bizira lobata* | Musk Duck |
| *Cygnus atratus* | Black Swan |
| *Tadorna tadornoides* | Mountain Duck |
| ACCIPITRIDAE | |
| *Accipter cirrhocephalus* | Collared Sparrowhawk |
| *Accipter fasciatus* | Australian Goshawk |
| *Aquila audax* | Wedge-tailed Eagle |
| *Circus assimilis* | Spotted Harrier |
| *Elanus rotatus* | Black-shouldered Kite |
| *Hamirostra melanosternon* | Black-breasted Buzzard |
| *Heraaetus morphnoides* | Little Eagle |
| *Lophoictinia isura* | Square-tailed Kite |
| *Milvus migrans* | Fork-tailed Kite |
| FALCONIDAE | |
| *Falco berigora* | Brown Falcon |
| *Falco cenchroides* | Nankeen Kestrel |
| *Falco longipennis* | Little Falcon |
| *Falco peregrinus* | Peregrine Falcon |
| MEGAPODIIAE | |
| *Leipoa ocellata* | Mallee Fowl |
| TURNICIDAE | |
| *Turnix velox* | Little Button-quail |
| RALLIDAE | |
| *Gallinula ventralis* | Black-tailed Native Hen |
| *Porzana tabuensis* | Spotless Crake |
| OTIDIDAE | |
| *Eupodotis australis* | Bustard |
| BURHINIDAE | |
| *Burhinus magnirostris* | Southern Stone Curlew |
| CHARADRIIDAE | |
| *Vanellus tricolor* | Banded Plover |
| *Peltohyas australis* | Australian Dotterel |
| COLUMBIDAE | |
| *Geopelia cuneata* | Diamond Dove |
| *Ocyphaps lophotes* | Crested Pigeon |
| *Phas chalcoptera* | Common Bronzewing |
| PSITTACIDAE | |
| *Barnardius zonarius* | Port Lincoln Parrot |
| *Cacatua roseicapilla* | Galah |
| *Melopsittacus undulatus* | Budgerigar |
| *Neophema bourkii* | Bourke's Parrot |
| *Neophema elegans* | Elegant Parrot |
| *Neophema splendida* | Scarlet Breasted Parrot |
| *Nymphicus hollandicus* | Cockatiel |

| | |
|---|---|
| *Polytelis alexandrae* | Alexandra Parrot |
| *Polytelis anthopeplus* | Regent Parrot |
| *Psephotus varius* | Mulga Parrot |
| CUCULIDAE | |
| *Chrysococcyx basalis* | Horsefield's Bronze Cuckoo |
| *Chrysococcyx osculans* | Black-eared Cuckoo |
| *Cuculus pallidus* | Pallid Cuckoo |
| STRIGIDAE | |
| *Ninox novaeseelandiae* | Boobook Owl |
| *Tyto Alba* | Barn Owl |
| *Tyto novaehollandiae* | Masked Owl |
| PODARGIDAE | |
| *Podargus strigoides* | Tawny Frogmouth |
| AEGOTHELIDAE | |
| *Aegotheles cristatus* | Australian Owlet-nightjar |
| CAPRIMULGIDAE | |
| *Eurostopodus argus* | Spotted Nightjar |
| ALCEDINIDAE | |
| *Halcyon pyrrhopygia* | Red Backed Kingfisher |
| MEROPIDAE | |
| *Merops ornatus* | Rainbow Bee-eater |
| HIRUNDINIDAE | |
| *Hirundo ariel* | Fairy Martin |
| MOTACILLIDAE | |
| *Anthus novaeseelandiae* | Richard's Pipit |
| CAMPEPHAGIDAE | |
| *Coracina maxima* | Ground Cuckoo-shrike |
| *Coracina novaehollandiae* | Black-faced Cuckoo-shrike |
| *Lalage sueurii* | White Winged Triller |
| PACHYCEPHALIDAE | |
| *Oreocica gutturalis* | Crested Bellbird |
| *Pachycephalus rufiventris* | Rufous Whistler |
| *Petroica goodenovii* | Red-capped Robin |
| *Petroica cucullata* | Hooded Robin |
| MONARCHIDAE | |
| *Rhipidura leucophrys* | Willie Wagtail |
| ORTHONYCHIDAE | |
| *Cinclosoma castanotum* | Chestnut Quail-thrush |
| *Cinclosoma cinnamomeum* | Cinnamon Quail-thrush |
| *Pomatostomus superciliosus* | White-browed Babbler |
| *Pomatostomus temporalis* | Grey-crowned Babbler |
| ACANTHIZIDAE | |
| *Acanthiza apicalis* | Broad-tailed Thornbill |
| *Acanthiza chrysorrhoa* | Yellow-rumped Thornbill |
| *Acanthiza uropygialis* | Chestnut-rumped Thornbill |
| *Aphelocephala leucopsis* | Southern White-face |
| *Aphelocephala nigricincta* | Banded White-face |
| *Calamanthus fuliginosus* | Fieldwren |
| *Smicrornis brevirostris* | Weebill |
| MALURIDAE | |
| *Amytornis striatus* | Straited Grass Wren |
| *Amytornis textilis* | Western Grass Wren |
| *Malurus lambertii* | Variegated Wren |
| *Malurus leucopterus* | Blue and White Wren |
| *Malurus splendens* | Splendid Fairy-wren |
| *Stipiturus ruficeps* | Rufous-crowned Emu-wren |
| SYLVIIDAE | |
| *Cincloramphus cruralis* | Brown Songlark |
| *Eremiornis carteri* | Spinifexbird |

| | |
|---|---|
| DAPHOENOSITTIDAE | |
| *Daphoenositta chrysoptera* | Australian Sittella |
| CLIMACTERIDAE | |
| *Climacteris affinis* | White-browed Tree Creeper |
| DICAEIDAE | |
| *Dicaeum hirundinaceum* | Mistletoe Bird |
| PARDALOTIDAE | |
| *Pardalotus rubricatus* | Red-browed Pardalote |
| *Pardalotus striatus* | Striated Pardalote |
| MELIPHAGIDAE | |
| *Acanthagenys rufogularis* | Spiny-cheeked Honeyeater |
| *Conopophila whitei* | Grey Honeyeater |
| *Certhionyx variegatus* | Pied Honeyeater |
| *Ephithianura aurifrons* | Orange Chat |
| *Ephthianura tricolor* | Crimson Chat |
| *Manorina flavigula* | Yellow-throated Miner |
| *Meliphaga cratitia* | White-gaped Honeyeater |
| *Meliphaga ornata* | Yellow-plumed Honeyeater |
| *Meliphaga penicillata* | White-plumed Honeyeater |
| *Meliphaga plumula* | Yellow-fronted Honeyeater |
| *Meliphaga virescens* | Singing Honeyeater |
| *Phylidonyris albifrons* | White-fronted Honeyeater |
| PLOCEIDAE | |
| *Poephila guttata* | Zebra Finch |
| GRALLINIDAE | |
| *Grallina cycanoleuca* | Magpie-lark |
| ARTAMIDAE | |
| *Artamus cinereus* | Black-faced Woodswallow |
| *Artamus minor* | Little Woodswallow |
| *Artamus personatus* | Masked Woodswallow |
| CRACTICIDAE | |
| *Cracticus nigrolgularis* | Pied Butcherbird |
| *Cracticus torquatus* | Grey Butcherbird |
| *Gymnorhina dorsalis* | Western Magpie |
| *Gymnorhina tibicen* | Black-backed Magpie |
| *Strepera versicolor* | Grey Currawong |
| PARADISAEIDAE | |
| *Ptilonorhynchus maculatus* | Spotted Bowerbird |
| CORVIDAE | |
| *Corvus bennetti* | Little Crow |
| *Corvus orru* | Australian Crow |

**APPENDIX C:** REPTILES AND AMPHIBIANS WHICH OCCUR OR ARE EXPECTED TO OCCUR IN THE YAKABINDIE NICKEL PROJECT AREA.

**Frogs**

| | |
|---|---|
| HYLIDAE | |
| *Cyclorana maini* | |
| *Cyclorana platycephalus* | Water-holding Frog |
| LEPTODACTYLIDAE | |
| *Neobatrachus centralis* | |
| *Neobatrachus kunapalari* | |
| *Neobatrachus wilsmorei* | |
| *Pseudophryne occidentalis* | |

**Lizards**

| | |
|---|---|
| GEKKONIDAE | |
| *Diplodactylus conspicillatus* | Fat-tailed Gecko |
| *Diplodactlyus granariensis* | |
| *Diplodactylus pulcher* | |
| *Diplodactylus strophurus* | |
| *Diplodactylus wellingtoniae* | |
| *Gehyra purpurascens* | |
| *Gehyra variegata* | Tree Dtella |
| *Heteronotia binoei* | Bynoe's Gecko |
| *Nephurus vertebralis* | |
| *Rhynchoedura ornata* | Beaked Gecko |
| PYGOPODIDAE | |
| *Delma nasuta* | |
| *Lialis burtonis* | Burtons Snake Lizard |
| AGAMIDAE | |
| *Caimanops amphiboluroides* | |
| *Ctenophorus caudicinctus* | Ring-tailed Dragon |
| *Ctenophorus inermis* | |
| *Ctenophorus ornatus* | Ornate Dragon |
| *Ctenophorus reticulatus* | |
| *Ctenophorus scutulatus* | Lozenge-marked Dragon |
| *Gemmatophora longirostris* | |
| *Moloch horridus* | Thorny Devil |
| *Pogona minor* | Bearded Dragon |
| *Tympanocryptis cephala* | |
| SCINCIDAE | |
| *Ctenotus leonhardii* | |
| *Ctenotus pantherinus* | |
| *Egernia depressa* | Pygmy Spiny-tailed Skink |
| *Eremiascincus richardsonii* | Broad-banded Sand Swimmer |
| *Lerista desertorum* | |
| *Menetia greyii* | |
| *Morethia butleri* | |
| *Tiliqua multifasciata* | Centralian Blue-tongued Lizard |
| VARANIDAE | |
| *Varanus caudolineatus* | |
| *Varanus gouldii* | Gould's Monitor |
| *Varanus panoptes* | |
| *Varanus tristis* | |

**Snakes**

| | |
|---|---|
| TYPHLOPIDAE | |
| *Rhamphotyphlops hamatus* | |
| BOIDAE | |
| *Morelia stimsoni* | Stimson's Python |
| ELAPIDAE | |
| *Acanthophis pyrrhus* | Desert Death-Adder |
| *Densionia fasciata* | Rosen's Snake |
| *Furina ornata* | |
| *Pseudechis australis* | Mulga Snake |
| *Pseudechis butleri* | |
| *Pseudonaja modesta* | Ringed Brown Snake |
| *Pseudonaja nuchalis* | Gwardar |
| *Rhinoplocephalus monachus* | Monk Snake |
| *Vermicella fasciolata* | |

# APPENDIX D

Wanjarri Nature Reserve Fauna
Species List

**APPENDIX D:** MAMMALS OF WANJARRI NATURE RESERVE

| | | |
|---|---|---|
| **MONOTREMATA** | | |
| TACHYGLOSSIDAE | | |
| *Tachyglossus aculeatus* | Echidna | |
| **MARSUPIALIA** | | |
| DASYURIDAE | | |
| *Antechinomys laniger* | Kultarr | |
| *Ningaui ridei* | Wongai Ningaui | |
| *Pseudantechinus macdonnellensis* | Fat-tailed Antechinus | |
| *Sminthopsis hirtipes* | Hairy-footed Dunnart | |
| *Sminthopsis macroura* | Stripe-faced Dunnart | |
| MACROPODIDAE | | |
| *Macropus robustus* | Euro | |
| *Macropus rufus* | Red Kangaroo | |
| **CHIROPTERA** | | |
| MOLOSSIDAE | | |
| *Mormopterus planiceps* | Little Mastif Bat | |
| *Tadarida australis* | White-striped Mastiff Bat | |
| VERSPERTILIONIDAE | | |
| *Chalinolobus gouldii* | Gould Wattled Bat | |
| *Eptesicus pumilus* | Little Cave Eptesicus | |
| *Nycticeius balstoni* | Western Broad-nosed Bat | |
| *Nyctophilus geoffroyi* | Lesser Long-eared Bat | |
| **RODENTIA** | | |
| HYDROMYINAE | | |
| *Leporillus apicalis* | Stick nest rat | extinct- old nests only |
| MURIDAE | | |
| *Notomys alexis* | Spinifex Hopping Mouse | |
| *Pseudomys hermannsburgensis* | Sandy Inland Mouse | |
| **CARNIVORA** | | |
| CANIDAE | | |
| *Canis familiaris dingo* | Dingo | |
| **INTRODUCED MAMMALS** | | |
| *Mus musculus* | House Mouse | |
| *Bos taurus* | Cow | |
| *Ovis aries* | Sheep | |
| *Camelus dromedarius* | Camel | |
| *Equs caballus* | Horse | |
| *Oryctolagus cuniculus* | Rabbit | |
| *Vulpes vulpes* | Fox | |

**SOURCES**

**1** Mckenzie,N.L. and Rolfe,J.K. (in press) Vertebrate Fauna. In Mckenzie,N.L. *et al* 'The Biological Survey Of The Eastern Goldfields of Western Australia: Sandstone - Sir Samuel Area.

**2** Mr A. Chapman, Department of Conservation and Land Management. Kalgoorlie.

**APPENDIX D:** BIRDS OF WANJARRI NATURE RESERVE

| | |
|---|---|
| CASUARIDAE | |
| *Dromaius novaehollandiae* | Emu |
| PODICIPEDIDAE | |
| *Prodiceps novaehollandiae* | Little Grebe |
| *Prodiceps poliocephalus* | Hoary-headed Grebe |
| AREIDAE | |
| *Ardae novaehollandiae* | White-faced Heron |
| *Egretta alba* | White Egret |
| ANATIDAE | |
| *Anas gibberifrons* | Grey Teal |
| *Anas superciliosus* | Black Duck |
| *Bizira lobata* | Musk Duck |
| *Cygnus atratus* | Black Swan |
| *Tadorna tadornoides* | Mountain Duck |
| ACCIPITRIDAE | |
| *Accipter cirrhocephalus* | Collared Sparrowhawk |
| *Accipter fasciatus* | Australian Goshawk |
| *Aquila audax* | Wedge-tailed Eagle |
| *Circus assimilis* | Spotted Harrier |
| *Elanus rotatus* | Black-shouldered Kite |
| *Hamirostra melanosternon* | Black-breasted Buzzard |
| *Heraaetus morphnoides* | Little Eagle |
| *Lophoictinia isura* | Square-tailed Kite |
| *Milvus migrans* | Fork-tailed Kite |
| FALCONIDAE | |
| *Falco berigora* | Brown Falcon |
| *Falco cenchroides* | Nankeen Kestrel |
| *Falco longipennis* | Little Falcon |
| *Falco peregrinus* | Peregrine Falcon |
| MEGAPODIIAE | |
| *Leipoa ocellata* | Mallee Fowl |
| TURNICIDAE | |
| *Turnix velox* | Little Button-quail |
| RALLIDAE | |
| *Gallinula ventralis* | Black-tailed Native Hen |
| *Porzana tabuensis* | Spotless Crake |
| OTIDIDAE | |
| *Eupodotis australis* | Bustard |
| BURHINIDAE | |
| *Burhinus magnirostris* | Southern Stone Curlew |
| CHARADRIIDAE | |
| *Vanellus tricolor* | Banded Plover |
| *Peltohyas australis* | Australian Dotterel |
| RECURVIROSTRIDAE | |
| *Recurvirostra novaehollandiae* | Red-necked Avocet |
| COLUMBIDAE | |
| *Geopelia cuneata* | Diamond Dove |
| *Ocyphaps lophotes* | Crested Pigeon |
| *Phas chalcoptera* | Common Bronzewing |
| PSITTACIDAE | |
| *Barnardius zonarius* | Port Lincoln Parrot |
| *Cacatua roseicapilla* | Galah |
| *Melopsittacus undulatus* | Budgerigar |
| *Neophema bourkii* | Bourke's Parrot |
| *Neophema elegans* | Elegant Parrot |
| *Neophema splendida* | Scarlet Breasted Parrot |

| | |
|---|---|
| *Nymphicus hollandicus* | Cockatiel |
| *Polytelis alexandrae* | Alexandra Parrot |
| *Polytelis anthopeplus* | Regent Parrot |
| *Psephotus varius* | Mulga Parrot |
| CUCULIDAE | |
| *Chrysococcyx basalis* | Horsefield's Bronze Cuckoo |
| *Chrysococcyx osculans* | Black-eared Cuckoo |
| *Cuculus pallidus* | Pallid Cuckoo |
| STRIGIDAE | |
| *Ninox novaeseelandiae* | Boobook Owl |
| *Tyto Alba* | Barn Owl |
| *Tyto novaehollandiae* | Masked Owl |
| PODARGIDAE | |
| *Podargus strigoides* | Tawny Frogmouth |
| AEGOTHELIDAE | |
| *Aegotheles cristatus* | Australian Owlet-nightjar |
| CAPRIMULGIDAE | |
| *Eurostopodus argus* | Spotted Nightjar |
| ALCEDINIDAE | |
| *Halcyon pyrrhopygia* | Red Backed Kingfisher |
| MEROPIDAE | |
| *Merops ornatus* | Rainbow Bee-eater |
| HIRUNDINIDAE | |
| *Hirundo ariel* | Fairy Martin |
| MOTACILLIDAE | |
| *Anthus novaeseelandiae* | Richard's Pipit |
| CAMPEPHAGIDAE | |
| *Coracina maxima* | Ground Cuckoo-shrike |
| *Coracina novaehollandiae* | Black-faced Cuckoo-shrike |
| *Lalage sueurii* | White Winged Triller |
| PACHYCEPHALIDAE | |
| *Oreocica gutturalis* | Crested Bellbird |
| *Pachycephalus rufiventris* | Rufous Whistler |
| *Petroica goodenovii* | Red-capped Robin |
| *Petroica cucullata* | Hooded Robin |
| MONARCHIDAE | |
| *Rhipidura leucophrys* | Willie Wagtail |
| ORTHONYCHIDAE | |
| *Cinclosoma castanotum* | Chestnut Quail-thrush |
| *Cinclosoma cinnamomeum* | Cinnamon Quail-thrush |
| *Pomatostomus superciliosus* | White-browed Babbler |
| *Pomatostomus temporalis* | Grey-crowned Babbler |
| ACANTHIZIDAE | |
| *Acanthiza apicalis* | Broad-tailed Thornbill |
| *Acanthiza chrysorrhoa* | Yellow-rumped Thornbill |
| *Acanthiza uropygialis* | Chestnut-rumped Thornbill |
| *Aphelocephala leucopsis* | Southern White-face |
| *Aphelocephala nigricincta* | Banded White-face |
| *Calamanthus fuliginosus* | Fieldwren |
| *Smicrornis brevirostris* | Weebill |
| MALURIDAE | |
| *Amytornis striatus* | Straited Grass Wren |
| *Amytornis textilis* | Western Grass Wren |
| *Malurus lambertii* | Variegated Wren |
| *Malurus leucopterus* | Blue and White Wren |
| *Malurus splendens* | Splendid Fairy-wren |
| *Stipiturus ruficeps* | Rufous-crowned Emu-wren |
| SYLVIIDAE | |
| *Cincloramphus cruralis* | Brown Songlark |

| | |
|---|---|
| *Eremiornis carteri* | Spinifexbird |
| DAPHOENOSITTIDAE | |
| *Daphoenositta chrysoptera* | Australian Sittella |
| CLIMACTERIDAE | |
| *Climacteris affinis* | White-browed Tree Creeper |
| DICAEIDAE | |
| *Dicaeum hirundinaceum* | Mistletoe Bird |
| PARDALOTIDAE | |
| *Pardalotus rubricatus* | Red-browed Pardalote |
| *Pardalotus striatus* | Striated Pardalote |
| MELIPHAGIDAE | |
| *Acanthagenys rufogularis* | Spiny-cheeked Honeyeater |
| *Conopophila whitei* | Grey Honeyeater |
| *Ephithianura aurifrons* | Orange Chat |
| *Ephthianura tricolor* | Crimson Chat |
| *Manorina flavigula* | Yellow-throated Miner |
| *Meliphaga cratitia* | White-gaped Honeyeater |
| *Meliphaga ornata* | Yellow-plumed Honeyeater |
| *Meliphaga penicillata* | White-plumed Honeyeater |
| *Meliphaga plumula* | Yellow-fronted Honeyeater |
| *Meliphaga virescens* | Singing Honeyeater |
| *Phylidonyris albifrons* | White-fronted Honeyeater |
| PLOCEIDAE | |
| *Poephila guttata* | Zebra Finch |
| GRALLINIDAE | |
| *Grallina cycanoleuca* | Magpie-lark |
| ARTAMIDAE | |
| *Artamus cinereus* | Black-faced Woodswallow |
| *Artamus minor* | Little Woodswallow |
| *Artamus personatus* | Masked Woodswallow |
| CRACTICIDAE | |
| *Cracticus nigrolgularis* | Pied Butcherbird |
| *Cracticus torquatus* | Grey Butcherbird |
| *Gymnorhina dorsalis* | Western Magpie |
| *Gymnorhina tibicen* | Black-backed Magpie |
| *Strepera versicolor* | Grey Currawong |
| PARADISAEIDAE | |
| *Ptilonorhynchus maculatus* | Spotted Bowerbird |
| CORVIDAE | |
| *Corvus bennetti* | Little Crow |
| *Corvus orru* | Australian Crow |

**SOURCES**

**1** Moriarty,T.K. (1972) Birds of Wanjarri, W.A. EMU **72**:1-7

**2** Mckenzie,N.L. and Rolfe,J.K. (in press) Vertebrate Fauna. In Mckenzie,N.L. *et al* "The Biological Survey Of The Eastern Goldfields of Western Australia: Sandstone - Sir Samuel Area.

**3** Mr A. Chapman, Department of Conservation and Land Management, Kalgoorlie.

**APPENDIX D:** REPTILES AND AMPHIBIANS OF WANJARRI NATURE RESERVE

HYLIDAE

| | |
|---|---|
| *Cyclorana maini* | |
| *Cyclorana platycephalus* | Water-holding Frog |

LEPTODACTYLIDAE

*Neobatrachus* sp.

GEKKONIDAE

| | |
|---|---|
| *Diplodactylus conspicillatus* | Fat-tailed Gecko |
| *Diplodactylus elderi* | |
| *Diplodactylus pulcher* | |
| *Diplodactylus strophurus* | |
| *Diplodactylus wellingtoniae* | |
| *Gehyra variegata* | Tree Dtella |
| *Heteronotia binoei* | Bynoe's Gecko |
| *Nephurus vertebralis* | |
| *Rhynchoedura ornata* | Beaked Gecko |

PYGOPODIDAE

*Delma butleri*
*Delma grayii*
*Delma fraseri*
*Pygopus nigriceps nigriceps*

AGAMIDAE

| | |
|---|---|
| *Caimanops amphiboluroides* | |
| *Ctenophorus caudicinctus* | Ring-tailed Dragon |
| *Ctenophorus inermis* | |
| *Ctenophorus isolepis* | Military Dragon |
| *Ctenophorus ornatus* | Ornate Dragon |
| *Ctenophorus salinarum* | Salt Lake Dragon |
| *Ctenophorus scutulatus* | Lozenge-marked Dragon |
| *Gemmatophora longirostris* | |
| *Moloch horridus* | Thorny Devil |
| *Pogona minor* | Bearded Dragon |
| *Tympanocryptis cephala* | |

SCINCIDAE

| | |
|---|---|
| *Ctenotus ariadne* | |
| *Ctenotus calurus* | |
| *Ctenotus grandis* | |
| *Ctenotus helenae* | |
| *Ctenotus leonhardii* | |
| *Ctenotus pantherinus* | |
| *Ctenotus quattuordecimlineatus* | |
| *Ctenotus schomburgkimi* | |
| *Egernia depressa* | Pygmy Spiny-tailed Skink |
| *Egernia formosa* | |
| *Egernia inornata* | Desert Skink |
| *Eremiascincus richardsonii* | Broad-banded Sand Swimmer |
| *Lerista bipes* | |

| | |
|---|---|
| *Lerista desertorum* | |
| *Menetia greyii* | |
| *Morethia butleri* | |
| *Tiliqua multifasciata* | Centralian Blue-tongued Lizard |

VARANIDAE

| | |
|---|---|
| *Varanus caudolineatus* | |
| *Varanus gouldii* | Gould's Monitor |
| *Varanus panoptes* | |

TYPHLOPIDAE

*Rhamphotyphlops hamatus*

ELAPIDAE

| | |
|---|---|
| *Densionia fasciata* | Rosen's Snake |
| *Pseudechis australis* | Mulga Snake |
| *Pseudonaja modesta* | Ringed Brown Snake |
| *Pseudonaja nuchalis* | Gwardar |
| *Rhinoplocephalus monachus* | Monk Snake |
| *Vermicella bertholdi* | Jan's Banded Snake |
| *Vermicella semifasciata* | Southern Shovel-nosed Snake |

**SOURCES**

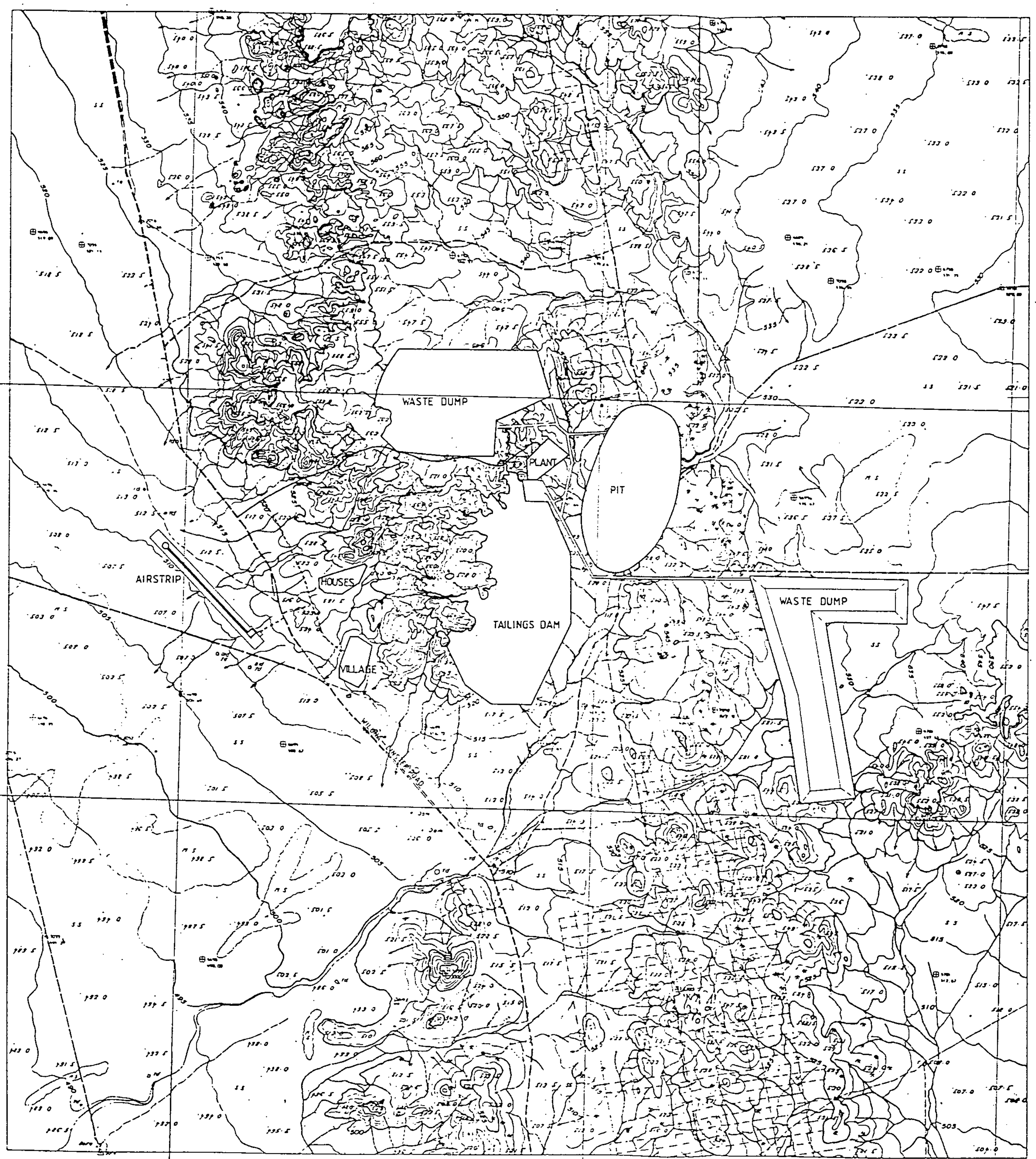
**1** Mckenzie,N.L. and Rolfe,J.K. (in press) Vertebrate Fauna. In Mckenzie,N.L. *et al* "The Biological Survey Of The Eastern Goldfields of Western Australia: Sandstone - Sir Samuel Area.

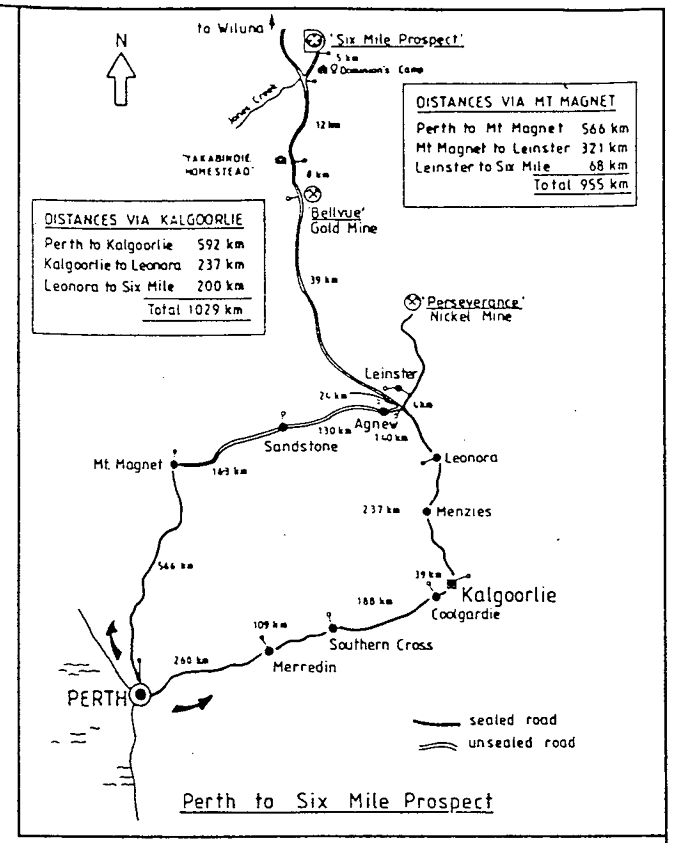
**2** Mr A. Chapman, Department of Conservation and Land Management. Kalgoorlie.

**3** Mr L.A. Smith, Reptile Department Western Australian Museum. Perth. Museum collection database.

# APPENDIX D

# APPENDIX D1




CLIENT APPROVED for CONSTRUCTION

DATE: SIGNED



MINPROC ENGINEERS PTY. LTD.

22 STIRLING HIGHWAY, NEDLANDS, W.A. 6009

TELEPHONE 389 1655

| | | |
|---|---|---|
| PROJECT APPR | BY | DATE |
| DESIGN APPR | | |
| DESIGNED | | |
| CHECKED | | |
| DRAWN | [signature] | APRIL 1990 |

PLANT GRID NORTH

CLIENT: DOMINION MINING LIMITED

TITLE: YAKABINDIE NICKEL PROJECT LOCALITY PLAN

SIZE: B1 SCALE: 1 : 25000

DRAWING No: W1292-00/G-004

PLATE D1

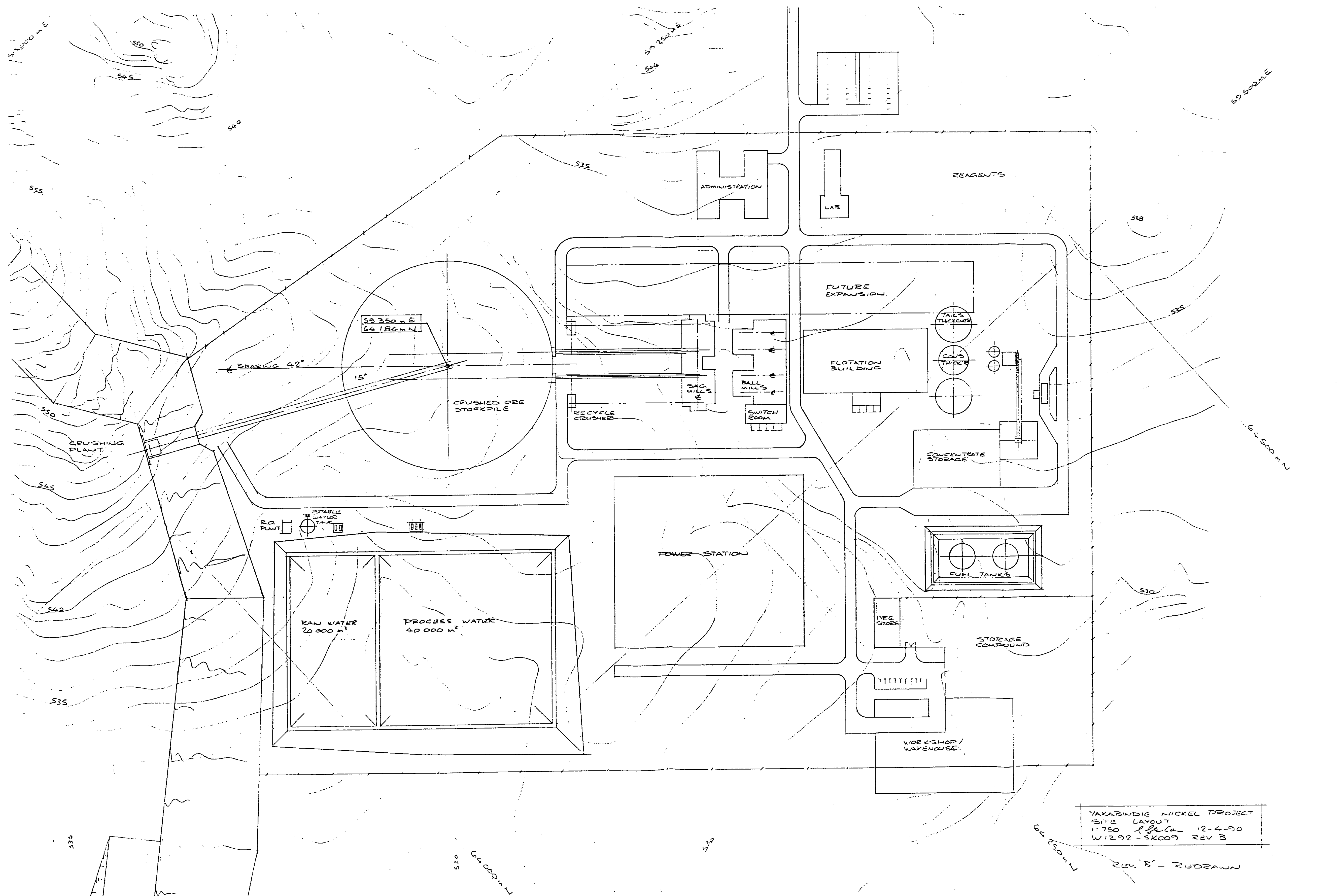

YAKABINDIE NICKEL PROJECT
SITE LAYOUT
1:750 12-4-90
W1292-SK009 REV B
REV. 'B' - REDRAWN
REAGENTS
ADMINISTRATION
LAB
FUTURE EXPANSION
TAILS THICKENER
CONS THICK'R
FLOTATION BUILDING
CONCENTRATE STORAGE
SAG MILLS
BALL MILLS
SWITCH ROOM
RECYCLE CRUSHER
CRUSHED ORE STOCKPILE
59 350 mE
64 184 mN
BEARING 42°
15°
CRUSHING PLANT
R.O. PLANT
POTABLE WATER TANK
POWER STATION
FUEL TANKS
TYRE STORE
STORAGE COMPOUND
WORKSHOP/ WAREHOUSE
RAW WATER 20 000 m³
PROCESS WATER 40 000 m³
59 350 mE
59 250 mE
59 500 mE
64 500 mN
64 250 mN
64 000 mN

PLATE D2

Our ref: 2488/00/IG/jb
I2488D/REP



PROJECT YAKABINDIE FEASIBILITY STUDY

CLIENT: MINPROC ENGINEERS PTY LTD

PROJECT MANAGERS MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS

---

## 1.0 SUMMARY OF FLOWS

$Q = VA$

Circulated for comment only
PRELIMINARY
Not Approved for Construction

Flow in all channels:

$Q = 140\ m^3/sec$

### 1.1 Jones Creek

Slope 1:322.9

Base width 20m

Average depth of flow = 2.25m

Velocity = 2.8 m/sec

Base width 30m

Average depth of flow = 1.70m

Velocity = 2.6 m/sec

Circulated for comment only

PRELIMINARY

*Not Approved for Construction*



SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

## 1.2 Jones Creek Western Tributary

Slopes 1:150 and 1:283

Base width 20m

Average depth of flow = 1.80m

Velocity = 3.6 m/sec

Base width 30m

Average depth of flow = 1.70m

Velocity = 2.6 m/sec

## 2.0 DESIGN FOR YAKABINDIE CREEK DIVERSIONS

Given:

Stream flow calculations determined using Mannings formula (reference Australian Rainfall and Runoff);

$$Q = \frac{AR^{0.66}\ S^{0.5}}{n} \quad \text{or} \quad \frac{A^{1.66}\ S^{0.5}}{n\ p^{0.66}}$$

| | | | |
|---|---|---|---|
| where | Q = flow | $m^3$/sec |
| | A = flow c/s'al area | $m^2$ |
| | S = slope | m/m |
| | n = Mannings No. | |
| | p = wetted perimeter | m |

Diversions are designed to cater for January 1990 estimated flows.

Q = 140 $m^3$/sec ........................ (Rockwater, 1990)

n = 0.030 (channel excavated rock) .... (Australian Rainfall and Runoff)

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PRELIMINARY

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Our ref: 2488/00/IG/jb
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SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

## 2.1 Jones Creek Western Tributary

$Q = 140\ m^3/sec$

$n = 0.030$

| | | | |
|---|---|---|---|
| S = 0m to 660m | 1:150 | ie. | 4.4m fall |
| 660m to 760m | 1:150 to 1:283 | ie. | 0.6m fall |
| 760m to 1610m | 1:283 | ie. | 3.0m fall |

at chainage 0m IL = 526m

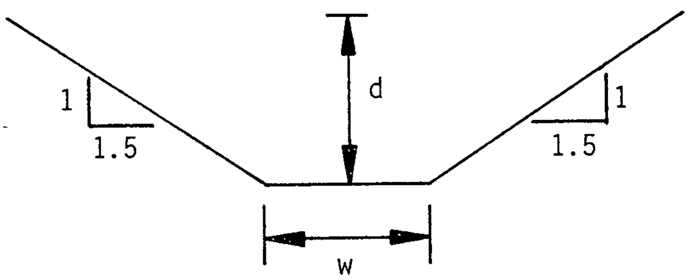
1610m IL = 518m

∴ fall = 8.0m

$$S = \frac{4.4}{660 - 0} = 0.00667 \quad \text{upper section} \quad 1:150$$

$$S = \frac{3.0}{1610 - 760} = 0.0035 \quad \text{lower section} \quad 1:283$$

Check flow depth for channels, channel profile to be trapezoidal




upper section w = 20m

lower section w = 30m

Soil & Rock Engineering Pty. Ltd.

SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

Check flow depth

### 2.1.1 Upper Section

$$Q = \frac{A^{1.66}\ S^{0.5}}{n\ p^{0.66}}$$

$Q = 140\ m^3/sec$ $\quad S = 0.00667$

$n = 0.030$ $\quad S^{0.5} = 0.816$

$$\therefore\ 140.00 = \frac{A^{1.66}\ 0.0816}{0.03 \times p^{0.66}}$$

$$\therefore\ 51.50 = \frac{A^{1.66}}{p^{0.66}}$$

$$A = dw + \frac{1.5\ d^2}{2} \times 2$$

$$p = w + (\sqrt{1.5\ d^2 + d^2}) \times 2$$

Given base width = 20m, determine depth

Try d = 1.8m

$\therefore\ A = 40.86\ m^2$

$A^{1.66} = 472.88$

$p = 26.49\ m$

$p^{0.66} = 8.69$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{472.88}{8.69} = 54.4 \text{ (need 51.5)} \quad \therefore \text{ lower}$$

Circulated for comment only

**PRELIMINARY**

*Not Approved for Construction*



SUBJECT: **DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)**

---

Try d = 1.7m

$\therefore$ $A = 38.33\ m^2$

$A^{1.66} = 425.37$

$p = 26.13\ m$

$p^{0.66} = 8.62$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{425.37}{8.62} = 49.3 \text{ (need 51.5)} \quad \therefore \text{ higher}$$

* for upper section assume flow to be 1.8 m deep

**2.1.2 Lower Section**

$$Q = \frac{A^{1.66}\ S^{0.5}}{n\ p^{0.66}}$$

$Q = 140\ m^3/sec$ $\quad S = 0.0035$

$n = 0.03$ $\quad S^{0.5} = 0.059$

$$\therefore 140.00 = \frac{A^{1.66}\ 0.059}{0.03 \times p^{0.66}}$$

$$\therefore 71.20 = \frac{A^{1.66}}{p^{0.66}}$$

$$A = dw + 1.5\ \frac{d^2}{2} \times 2$$

$$p = w + (\sqrt{1.5\ d^2 + d^2}) \times 2$$

Circulated for comment only

**PRELIMINARY**

*Not Approved for Construction*

Our ref: 2488/00/IG/jb
I2488/REP



SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

---

Base width now 30m, determine depth

Try d = 1.8m

$\therefore A = 58.86\ m^2$

$A^{1.66} = 866.76$

$p = 36.49$ m

$p^{0.66} = 10.74$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{866.76}{10.74} = 80.7 \quad \therefore \text{lower}$$

Try d = 1.7m

$\therefore A = 55.33\ m^2$

$A^{1.66} = 782.19$

$p = 36.13$ m

$p^{0.66} = 10.67$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{782.19}{10.67} = 73.3 \text{ (need 71.2)} \quad \therefore \text{assume depth is } \underline{1.7\text{m}}$$

* for lower section assume flow to be 1.7m deep.

Circulated for comment only

PRELIMINARY

*Not Approved for Construction*

Our ref: 2488/00/IG/jb
I2488/REP



SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

---

Lowest freeboard is at chainage 560m (creek crossing).

IL = 522.27 GL $\doteqdot$ 524

$\therefore$ channel depth = 1.7m

$\therefore$ channel will overtop at 140 $m^3$/sec flow (depth of flow 1.8m)

Install gabion reventment to RL 526 in this area.

### 2.1.3 Summary

| Chainage | Slope | IL |
|---|---|---|
| 0m to 660m (660) | 1:150 | 526.0 to 521.6 |
| 660m to 760m (100) | variable | 521.6 to 521.0 |
| 760m to 1610m (850) | 1:283 | 521.0 to 518.0 |

Between 660m and 760m:

Invert grade changes at a rate of 1:12 every 10m over 100m.

At the same time the invert width increases at a rate of 1m every 10m or deflection angle $\theta$ = 2.87°

SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

## 2.2 Jones Creek Diversion

### 2.2.1 Upper Section

0m to 1700m, invert width 20m.

$$Q = \frac{A^{1.66} S^{0.5}}{n\, P^{0.66}}$$

$Q = 140\ m^3/sec$ $\quad S = 0.00310$

$n = 0.030$ $\quad S^{0.5} = 0.05565$

(Slope: 7m drop over 2260m = 1:322.9)

$$\therefore\ 140.00 = \frac{A^{1.66}\ 0.05565}{0.03 \times P^{0.66}}$$

$$\therefore\ 75.47 = \frac{A^{1.66}}{P^{0.66}}$$

Design parameters for channel as before, ie. trapezoidal.

$$\therefore\ \frac{A^{1.66}}{P^{0.66}} = 75.47$$

SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

For 20m width, check 2.2m depth

Try d = 2.2m

$\therefore A = 51.26\ m^2$

$A^{1.66} = 689.02$

$p = 26.60\ m$

$p^{0.66} = 8.72$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{689.02}{8.72} = 79.02$$ $\therefore$ try lower depth

Try d = 2.1m

$\therefore A = 48.62\ m^2$

$A^{1.66} = 631.00$

$p = 27.57\ m$

$p^{0.66} = 8.93$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{631.00}{8.93} = 70.66$$

* for upper section flow will be approximately 2.15m deep.

Circulated for comment only
PRELIMINARY
Not Approved for Construction



SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

### 2.2.2 Lower Section

Lower section channel width increases to 30m
.·. determine flow depth.

From above $\frac{A^{1.66}}{p^{0.66}} = 75.47$, try flow depth of 1.7m.

Try d = 1.7m

$$\therefore A = 55.33\ m^2$$
$$A^{1.66} = 782.31$$
$$p = 36.13\ m$$
$$p^{0.66} = 10.67$$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{782.31}{10.67} = 73.32$$ .·. flow is higher

Try d = 1.9m

$$\therefore A = 62.41\ m^2$$
$$A^{1.66} = 955.38$$
$$p = 36.85\ m$$
$$p^{0.66} = 10.81$$

$$= \frac{A^{1.66}}{p^{0.66}}$$

$$= \frac{955.38}{10.81} = 88.38$$ .·. flow is lower

* for lower section flow will be approximately 1.75m deep.

SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

## 3.0 RADIUS CALCULATIONS

### 3.1 Jones Creek

Chainages

Circumference $= \pi D$
$= \pi\, 2r$

Radius

Bend 1, $\theta = 49°$, radius = 664m

$\therefore$ length of arc

$$\text{arc} = \frac{\text{ii } 2r\,\theta}{360}$$

$$= \frac{\pi \times 2 \times 664 \times 49}{360}$$

$$= 567.9\text{m}$$

Bend 2, $\theta = 14°$, radius = 520m

$\therefore$ length of arc

$$\text{arc} = \frac{\pi \times 2 \times 520 \times 14}{360}$$

$$= 127.0\text{m}$$

Bend 3, $\theta = 16°$, radius = 441m

$\therefore$ length of arc

$$\text{arc} = \frac{\pi \times 2 \times 442 \times 16}{360}$$

$$= 123.4\text{m}$$

SUBJECT: DESIGN CALCULATIONS, CREEK DIVERSIONS (cont)

## 4.0 HYDRAULIC JUMP

### 4.1 Jones Creek

Base 20m to 30m with no change in slope, ∴ small hydraulic jump.

Given $Fr_1^2 = \frac{1}{2} \frac{y_2}{y_1} \left( \frac{y_2}{y_1} + 1 \right)$ $\quad y_1 = 2.25$, $y_2 = 1.7$

$$= \frac{1}{2} \times \frac{1.7}{2.25} \times \left( \frac{1.7}{2.25} + 1 \right)$$

$$= 0.378 \times 1.755$$

$$= 0.66$$

Typically for Froude numbers below 1.7, little energy loss occurs, so no jump form.

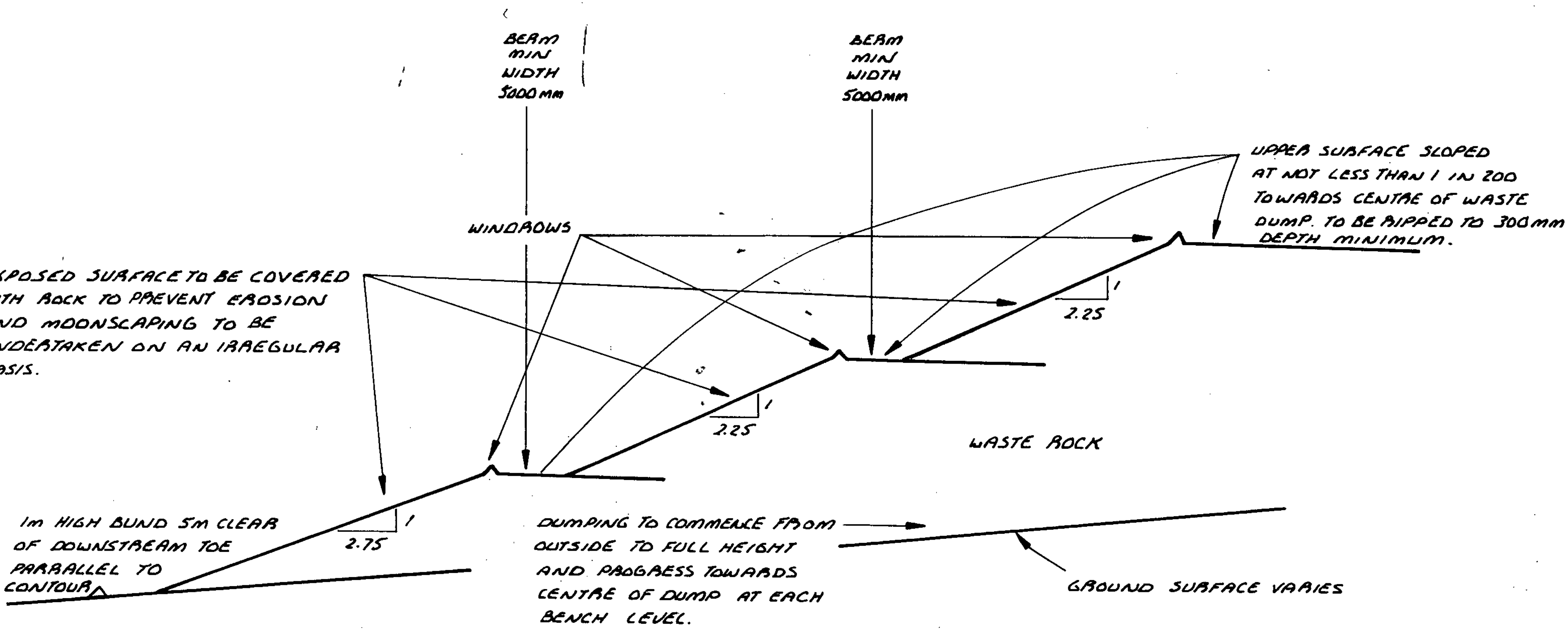
### 4.2 Jones Creek Western Tributary

$Fr_1^2 = \frac{1}{2} \times \frac{1.7}{1.8} \times \left( \frac{1.7}{1.8} + 1 \right)$ $\quad y_1 = 1.8$, $y_2 = 1.7$

$$= 0.47 \times 1.94$$

$$= 0.91$$

Fr less than 1.7, so no hydraulic jump will occur.




REHABILITATION TO BE CARRIED OUT ON A PROGRESSIVE BASIS WITH SPREADING OF TOPSOIL AND VEGETATION RECOVERED FROM CLEARING AND REVEGETATION BEING CARRIED OUT AS SOON AS PRACTICAL.

# WASTE DUMP REHABILITATION - TYPICAL SECTION
# YAKABINDIE NICKEL PROJECT

Soil & Rock Engineering Pty. Ltd.
PLATE D15

DEPARTMENT OF MINES WESTERN AUSTRALIA
EXPLOSIVES AND DANGEROUS GOODS DIVISION
MINERAL HOUSE · 100 PLAIN STREET · PERTH · WESTERN AUSTRALIA · 6000 · TEL. (09) 222 3333

FACSIMILE TRANSMISSION

FAX No. (09) 222 3525

| | |
|---|---|
| DATE: | FRIDAY 30 MARCH 1990 |
| TO: | SOIL & ROCK ENGINEERING PTY. LTD. |
| ATTENTION: | CHRIS LANE. |
| FROM: | RICHARD BILMAN |

No. of pages including this page: ......14......

MESSAGE:

From the information received from you, please be advised as follows.

1. Methyl Iso Butylcarbinol - if this material is to be stored in drums, it shall be stored as per document EB 317. It shall be conveyed as specified in document EB 311.

2. Sodium Ethyl Xanthate - prior to this material being conveyed it shall:

(i) be correctly labelled - UN N°, NAME, CLASS DIAMONDS, EMERGENCY ADVICE CONTACT AND DIAL '000' ADVICE.

(ii) be packed in approved packaging - product to either be repacked into approved packages or existing packages to be securely stored in a CSC approved freight-container.

(iii) comply with all other requirements of the Australian Code for the Transport of Dangerous Goods by Road and Rail.

3. Also enclosed is document EB 013 'Dangerous Goods in Packages'.

Yours faithfully.

R Bilman.

INSPECTOR OF EXPLOSIVES AND DANGEROUS GOODS

SHOULD ANY FAULTS OCCUR WITH THIS TRANSMISSION PLEASE PHONE (09) 222 3379

EB 317

DEPARTMENT OF MINES WESTERN AUSTRALIA

# EXPLOSIVES AND DANGEROUS GOODS DIVISION

MINERAL HOUSE · 100 PLAIN STREET · EAST PERTH · WESTERN AUSTRALIA · 6004 · TEL. (09) 222 3333

FLAMMABLE LIQUIDS REGULATIONS 1967

## GUIDE TO DRUM DEPOTS CONSTRUCTION AND LOCATION

1. Explanatory Notes:

1.1 Flammable Liquids (i.e. Class 3 products)

All liquid substances having a flash point below 150°C.

<u>Subclass</u>

3.1 Flammable liquids having a flash point less than 23°C (e.g. petrol, acetone)

3.2 Flammable liquids having a flash point less than 61°C but not less than 23°C (e.g. kerosene, white spirits)

3.3 Flammable liquids having a flash point less than 150°C but not less than 61°C (e.g. diesel, distillate).

1.2 Drum Depot:

A place where flammable liquids are stored in drums or any other approved containers each less than 250 litres capacity.

Type A - Drum ramp, platform or other open place - may have roof cover.

Type B - Closed building with lockable door but detached from other buildings.

Type C - Fully enclosed, well ventilated room, within a factory or warehouse building.

1.3 Bund: an embankment of earth, or a wall of brick, stone, concrete etc. so constructed as to retain any spill or leak within a drum depot. For bund capacity, 1 cubic metre = 1 kilolitre in volume. Minimum bund height - 150 mm.

1.4 For use of power operated machines (e.g. forklifts) in bunded areas refer to Document EB 307.

2. Licensing:

Any person wishing to store fuel (unless exempted as below) must first apply to the Chief Inspector for a Licence to Store Flammable Liquids. An application form is attached to this document.

<u>Note</u>

(i) A licence to store flammable liquids may be issued by the Chief Inspector subject to the proposal complying with the requirements of the Regulations as outlined in this document.

.../2

(ii) This Department will advise the Local Authority of all successful licence applications. The Local Authority may then make additional requirements to ensure compliance with local zoning by-laws.

3. Exemptions:

The storage of flammable liquids is exempt from the requirements of the Flammable Liquids Regulations if:

3.1 The total quantity of all flammable liquids:

a. Where subclass 3.1 is stored, does not exceed 230 l.

b. Where subclass 3.1 is not stored, does not exceed 1 200 l; or,

3.2 All the flammable liquids are stored in tins or bottles each of capacity not greater than 4 l; or,

3.3 They are industrial products (i.e. paint, enamel, insecticide, etc.) in packages each of capacity not exceeding 23 l and stored in a manner approved by the Chief Officer of the Western Australian Fire Brigade; or,

3.4 The flammable liquids are being stored by a primary producer on land exceeding 4 hectares and the total quantity of each subclass is not greater than 5 kilolitres.

4. Location:

Depots of Type "A" or "B" must be separated from all boundaries, protected works such as dwellings, work and recreation areas by the distances indicated on Tables 1 and 2. (See page 8)

Where the walls of a Type B depot are 2 hour fire rated (i.e. of cement rendered single brick) the walls may be considered as intervening screen walls and the location may be determined using column 2 in tables 1 and 2.

A depot may be built adjoining a protected work where the adjoining wall of the protected work is 4 hour rated to above the roof line and, the distance from the depot along the wall to any opening to the building equals the separation distance as indicated in column 1 of tables 1 and 2.

5. Construction and Design of Depots:

5.1 The external surface of any depot wall or roof shall be masonry, concrete or a framed structure with non combustible sheeting. (10% of the roof may be of PVC or glass fibre reinforced plastics)

5.2 Floors may be of earth, masonry or concrete.

5.3 Platforms may be:

i) Concrete deck on solid fill or on concrete supports;

ii) Hardwood timber deck on hardwood timber, steel, concrete or masonry posts or framework.

5.4 The underdeck space of the platform shall be through-ventilated, if the space is not filled with a solid material (e.g. concrete, sand, earth).

5.5 Any timber decking shall be laid with a 5 mm gap between planks or shall incorporate equivalent drainage holes.

5.6 A security fence around the depot is required.

5.7 Approval must be obtained before storing any other goods in the depot.

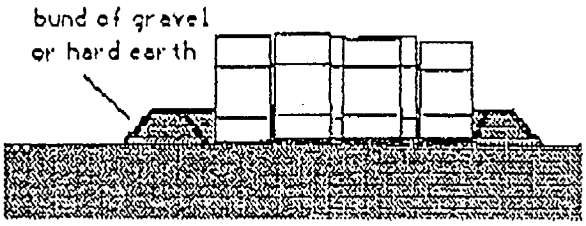
5.8 Restraining devices or other features must be provided when drums are stacked more than 1 drum high so as to retain any spilled product within the bunded area.

## 6. Type A Depots

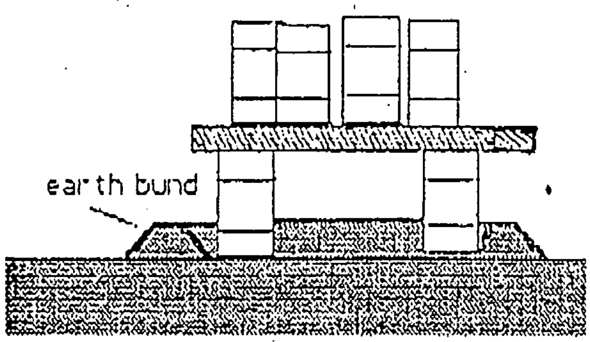
These depots must have a bund with a liquid holding capacity of at least 25% of the liquid stored.

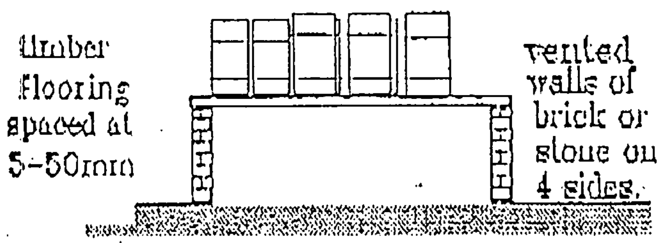
e.g.

simple form of Type A depot.



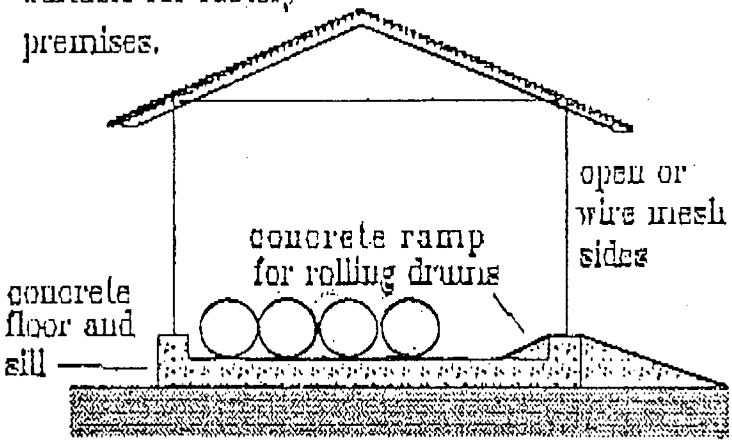

simple drum platform

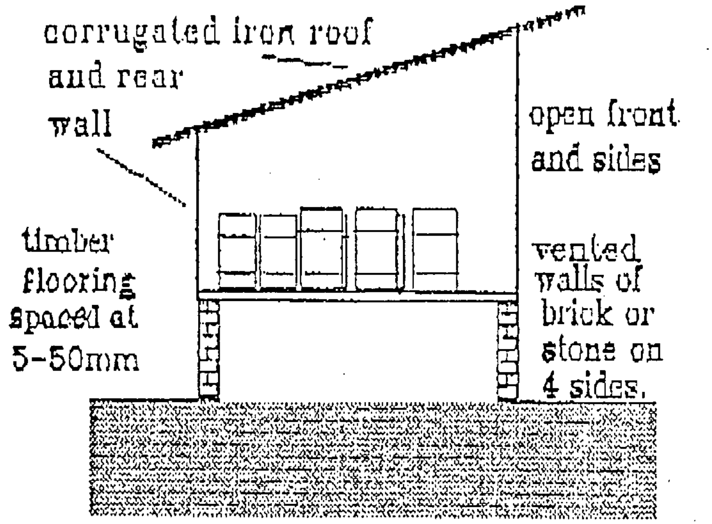


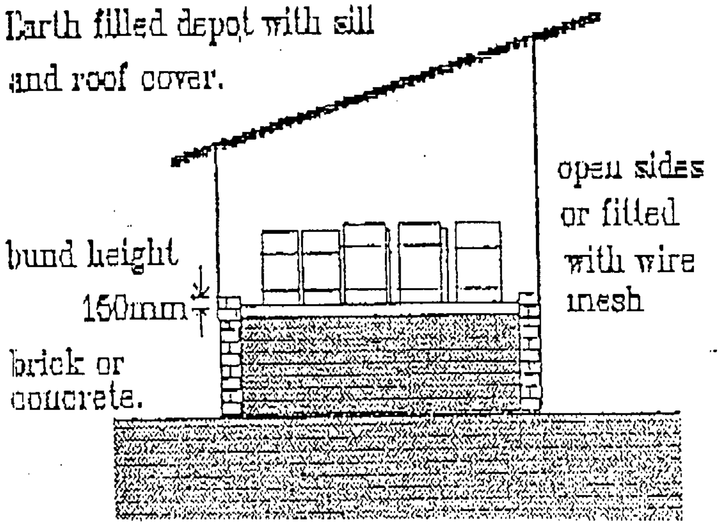
Type A Depots continued.

Open depot with roof cover suitable for factory premises.




Earth filled depot with sill and roof cover.

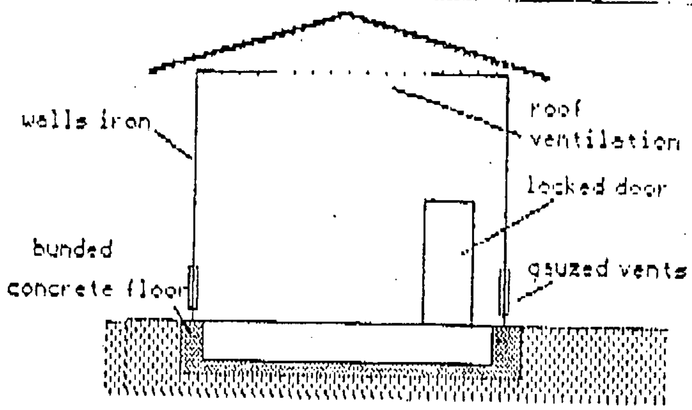


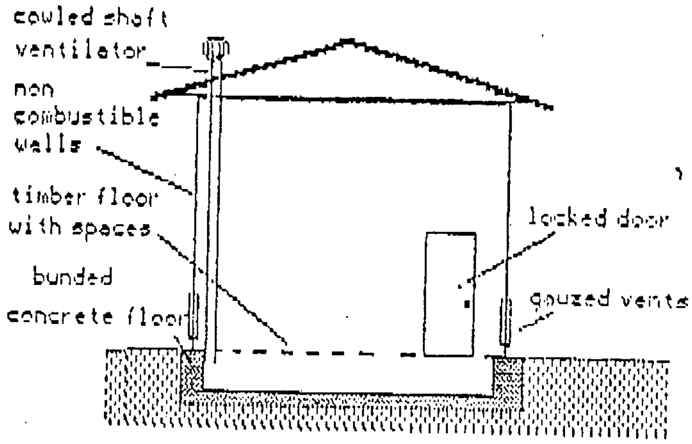
7. Type B Depots

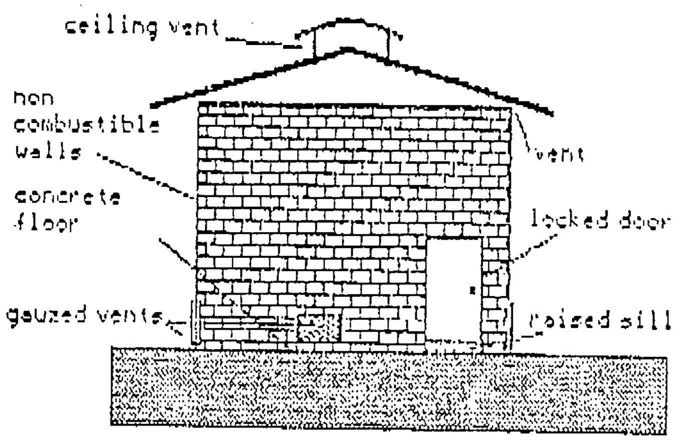
7.1 These Depots must have a bund with a liquid holding capacity of at least 25% of the liquid stored.

7.2 Good ventilation is required at both high and low level.

e.g.



8. Type C Depot.

8.1 These depots must have a bund with a liquid holding capacity of at least 100% of the liquid stored; and,

8.2 The maximum storage is:

a. For sub-class 3.1 or a combination of 3.1 and 3.2 or 3.3 - 2.5 kl

b. For sub-class 3.2 or a combination of 3.2 and 3.3 - 5 kl

c. For sub-class 3.3 alone - 10 kl

8.3 Construction.

a. All walls to be 4 hour rated (e.g. double brick walls)

b. The floors to be 3 hour rated reinforced concrete

c. The ceiling to be 3 hour rated concrete or masonry unless the walls are taken through the main roof.

d. Where possible, a door opening to the outside of the building and to open air must be provided

e. Any door leading inside to be 2 hour rated.

8.4 Ventilation.

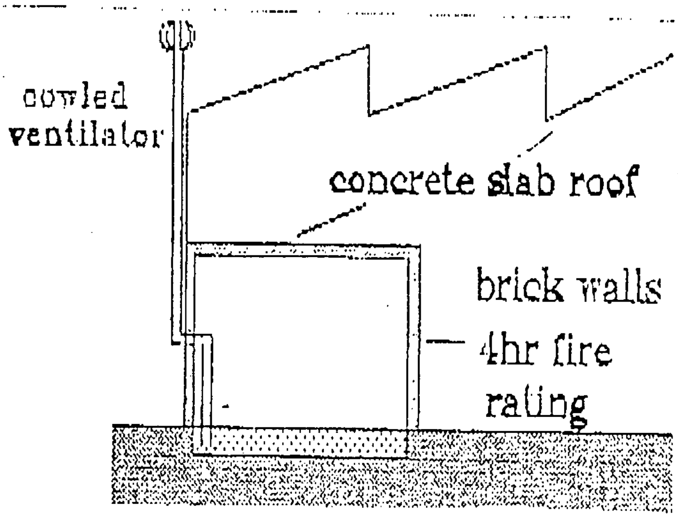
a. Ventilation shaft to be of fire resistant material and to extend from 75 mm above bund floor level to above the highest part of the building or any building within 6 m.

b. The shaft to be not less than 150 mm diameter.

c. The shaft must not pass through any part of the main building. It shall be designed to pass directly from the depot to the open air.

d. The discharge shall be fitted with an approved cowl.

e.g.




.../7

9. Fire Protection

9.1 Combustibles to be cleared from both underneath and for 3 m around all depots.

9.2 Fire Extinguishers

Depots of Type 'A' or Type 'B' for each 240 $m^2$ shall be provided with:

i) 2 Fire Extinguishers: either 2 x 9 kg Dry Chemical Powder type or 1 x 9 kg Dry Chemical Powder type and 1 x 9 l foam type;

ii) 45 l of dry sand in bins with scoop or shovels for distributing it.

Depots of Type 'C' shall be provided with 1 Fire Extinguisher being 4.5 kg Dry Chemical Powder type.

All fire extinguishers must be kept and maintained in good working order and are to be located in the vicinity of the depot as approved by the Inspector. Extinguishers already kept on the premises may serve the purpose if they are within convenient distance of the depot and if they are of suitable type and capacity.

Arrangements must be made with the Western Australian Fire Brigade or some other approved authority for maintenance and service of all fire extinguishers.

10. Warning Signs

All licensed premises shall display one or more signs "Danger, No Smoking, No Naked Lights" (red lettering on a white background) in the vicinity of the flammable liquids drum storage areas.

H Douglas

H Douglas
DIRECTOR

DB 29 August 1986

Reference Documents:

EB307 - Power operated machines in Hazardous Locations
Application for Licences to Store Flammable Liquids

TABLE 1.

Separation distances from Protected Works
Storage of Sub-class 3.1 or of Sub-class 3.1 with any of Sub-class 3.2 or Sub-class 3.3 in the Same Depot

| Distance not less than | 1<br>No Screen Wall | 2<br>Screen Wall Intervening |
|---|---|---|
| Metres | Kilolitres | Kilolitres |
| 3 | 1 | 4 |
| 4 | 2 | 8 |
| 5 | 4 | 16 |
| 6 | 7 | 28 |
| 7 | 10 | 40 |
| 8 | 14 | 56 |
| 9 | 20 | 80 |
| 10 | 26 | 104 |
| 11 | 34 | 136 |
| 12 | 42 | 168 |
| 13 | 52 | 208 |
| 14 | 64 | 256 |
| 15 | 77 | 308 |
| 20 | 170 | 680 |
| 25 | 310 | 1 240 |
| 30 | 500 | 2 000 and over |
| 35 | 750 | |
| 40 | 1 100 | |
| 45 | 1 500 | |
| 50 | 2 000 and over | |

Provided that the distances shown above may be altered proportionately for intermediate quantities.

TABLE 2.

Separation distances from Protected Works
Storage of Sub-class 3.2 or of Sub-class 3.2 and Sub-class 3.3 in the Same Depot

| Distance not less than | 1<br>No Screen Wall | 2<br>Screen Wall Intervening |
|---|---|---|
| Metres | Kilolitres | Kilolitres |
| 3 | 4 | 8 |
| 4 | 8 | 16 |
| 5 | 16 | 32 |
| 6 | 28 | 56 |
| 7 | 40 | 80 |
| 8 | 56 | 112 |
| 9 | 80 | 160 |
| 10 | 104 | 208 |
| 15 | 308 | 616 |
| 20 | 680 | 1 360 |
| 25 | 1 240 | 2 480 and over |
| 30 | 2 000 and over | |

Provided that the distances shown above may be altered proportionately for intermediate quantities.

EB311

DEPARTMENT OF MINES WESTERN AUSTRALIA

# EXPLOSIVES AND DANGEROUS GOODS DIVISION

MINERAL HOUSE · 100 PLAIN STREET · EAST PERTH · WESTERN AUSTRALIA · 6004 · TEL. (09) 222 3333

EXTRACT FROM THE DANGEROUS GOODS (ROAD TRANSPORT) REGULATIONS, 1983

## REQUIREMENTS FOR TRANSPORTING PACKAGED FLAMMABLE LIQUIDS FOR EXAMPLE PETROL

U.N. NO. 1203 CLASS 3.1 HAZCHEM 3 Y E PACKAGING GROUP II

1. The vehicle is not required to be placarded if conveying less than or up to 2000 litres. (Reg. 313). However Reg. 307*, 502* and 607(2)* still apply.

2. For conveyance of greater than 2000 litres of packaged flammable liquids the following requirements will apply

Regulations

307* - All packaged dangerous goods for transport must be suitably marked. (See sample label page 2.)

311(1)(2) - Flammable liquid Class label to be displayed front/rear of the vehicle. (250 mm square). Packaging and labelling information, see page 2.

403 - Minimum $500 000 Public Liability insurance.

406(2) - Roadworthiness inspection by Police within 12 months prior to use as a dangerous goods vehicle.

428(1) - Emergency Procedure Guides for vehicle and product fires.

428(2)(3) - Fire extinguishers; with loads:
up to 10,000 litres - one 9 kg 60B Dry Chemical Powder (DCP) extinguisher.
exceeding 10,000 litres - two 9 kg 60B DCP extinguishers.

In every cabin:

One 10B halon (e.g. BCF) or DCP extinguisher not less than 2.25 kg capacity.

428(4) - Reflective road triangles, torch (flameproofed), toolbox with relevant tools to be carried on each vehicle.

428(4) - If not fitted with spring brakes, two wheel chocks required.

502* - Load to be well secured.

511 - Flammable liquids are not to be transported with poison gases, spontaneously combustible materials, oxidising agents and radioactive substances.

607(2)* - Shipping document to be carried in the cab - the document shall contain technical details and quantity of dangerous goods being carried, for example:

.../2.

(i) Name of consignor, name of dangerous goods and U.N. number,
(ii) Class or Sub-class of dangerous goods,
(iii) Packaging Group and type of container,
(iv) Quantity to be carried.

3. Packaging Information:

All packages used for the transport of dangerous goods shall be of an approved type. (Reg. 202).

4. Labelling Information:

All packages of flammable liquids must be marked with:

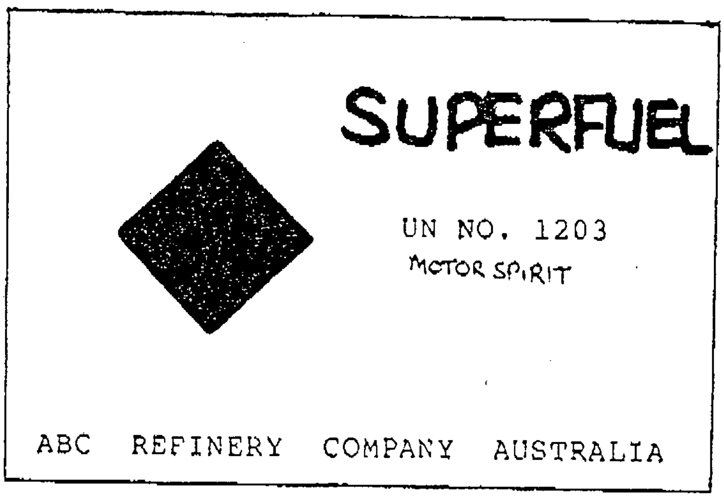
(i) Class 3 label of size:

- package capacity up to 5 litres - 20 mm square.
- package capacity up to 20 litres - 30 mm square.
- package capacity greater than 20 litres - 100 mm square.

(ii) Name of dangerous goods and identification number.

(iii) Name and address of consignor or agent.

SAMPLE LABEL




H Douglas
CHIEF INSPECTOR

15 June 1984

EB013

DEPARTMENT OF MINES WESTERN AUSTRALIA

EXPLOSIVES AND DANGEROUS GOODS DIVISION

MINERAL HOUSE · 100 PLAIN STREET · EAST PERTH · WESTERN AUSTRALIA · 6004 · TEL. (09) 222 3333

# DANGEROUS GOODS IN PACKAGES

**Definition of Packages:**

Generally refers to containers in which dangerous goods are packed which:

(a) have a water capacity less than 500 litres for gases,

(b) have a water capacity less than 250 litres for liquids,

(c) contain less than 400 kg for solids.

**Package Marking:**

Packages containing dangerous goods are to be marked with the information listed below. Where packages are contained within an outer package only item (a) is required to be marked on the individual inner packages; items (a), (b) and (c) being applicable to the outer package.

(a) the correct size class diamond (and subsidiary risk diamond where applicable).

(b) the correct technical name and identification number of the dangerous goods,

(c) the name and address of the manufacturer or distributor in Australia.

## MINIMUM LABEL SIZES

| Capacity of Packaging Litres/kg | Class Label size (mm) |
|---|---|
| 5 L/kg or less ........................ | 20 mm |
| 20 L/kg or less down to 5 L/kg ....... | 30 mm |
| more than 20 L/kg...................... | 100 mm |

.../2.

Exemption:

The above marking requirements apply to all packages containing Packaging Group I dangerous goods and for all other cases not exempted in the following table.

| Class or Sub-class | Package Capacity not requiring marking (millilitres/grams) |
|---|---|
| 3.1 | 150 |
| 3.2 | 300 |
| 4.1 | 2000 |
| 4.2 | 500 |
| 4.3 | 150 |
| 5.1 | 1000 |
| 5.2 | 150 |
| 6.1 | 500 |
| 8 | 500 |
| 9.2 | 2000 |

**Note 1:** Information relating to the Class Identification Number and packaging group of dangerous goods is detailed in the Dangerous Goods (Road Transport) Regulations 1983 and is consistent with the Australian Code for the Transport of Dangerous Goods by Road and Rail.

**Note 2:** A recent amendment to the marking requirements makes it necessary to include the following information on Packaging Group I dangerous goods greater than 5 litres/kg and Packaging Groups II and III dangerous goods greater than 20 litres/kg.

"In a Transport Emergency Dial: 000, Police, or Fire Brigade".

**Note 3:** Certain specific exemptions from marking requirements apply to some items such as aerosols, disposable lighters and Packaging Group III resins and waxes etc.

Please contact this Division for more specific details.

Package Standards:

(a) all dangerous goods of Packaging Group I are to be packed in approved containers (Approved containers will display approval markings),

(b) all dangerous goods of Packaging Groups II and III are to be packed in approved containers when the containers (inner or outer) exceed 5 litres water capacity for liquids or 5 kg for solids.

.../3.

Shipping Documents:

Shipping documents containing details as specified in Document EB 008 are to be given to the Prime Contractor/ Driver transporting your dangerous goods.

One exemption from the requirement to provide a shipping document is where all the dangerous goods are of Packaging Groups II or III, in packages not exceeding 5 litres/kg capacity and total quantity not exceeding 2000 litres/kg.

A further exemption relates only to where all the dangerous goods are owned by the driver of the vehicle and where the quantity being carried is less than that which would require the vehicle to display marking.

Vehicle Requirements:

Vehicle requirements are generally similar for all cargoes of packages but can vary slightly with the Class(es) of dangerous goods carried.

It is the responsibility of the Prime Contractor or where no Prime Contractor exists, the Consignor, to ensure that all vehicle requirements are met.

In brief these are:

- the owner must hold a $500 000 public liability insurance policy,

- the vehicle must have been inspected by the police and been given a roadworthiness certificate not more than 12 months prior to its use to convey dangerous goods,

- the vehicle must carry Emergency Procedure Guides for the vehicle and product fires; fire extinguishers; reflective road triangles; a torch; a tool box with relevant tools.

- the vehicle must be fitted with spring brakes or wheel chocks, and,

- the load must be well secured and kept away from any source of heat.

Further, more specific details are available from the Explosives & Dangerous Goods Division for specific cargoes.

H Douglas
H Douglas
DIRECTOR

21 January 1986

Department of
Occupational Health,
Safety and Welfare
of Western Australia

Your Ref: 2488/00/E
Our Ref: 501/87/V2
Enquiries: Dr Jeff Langley
Date: 19 March 1990

DATE RECEIVED 22 MAR 1990
NO. 2488/00/E

| ACTION | |
|---|---|
| REQD BY | COMPLETED |
| CC | |

Mr Chris Lane
Soil and Rock Engineering Pty Ltd
123 Colin Street
WEST PERTH WA 6005

Dear Mr Lane

**REGULATIONS GOVERNING THE HANDLING OF CHEMICALS**

The handling of methyl-iso-butylcarbinol and sodium ethylxanthate is discussed in the enclosed information. Both carboxy methyl cellulose and polyacrylamide come in many different forms and you should thus source handling information from your supplier.

In the workplace the use of chemicals must conform to the Occupational Health, Safety and Welfare Act (1984) and Regulations (1988). In particular, Section 19 fo the Act stipulates a duty of care on employers to provide a safe and healthy workplace. Further to this, employers must provide adequate information and training to their employees so that chemicals can be used without risk to safety or health.

All chemicals used in a workplace should be accompanied by a Material Safety Data Sheet (MSDS) which should be obtained from the supplier. These MSDSs should be readily available to employees who use the chemicals and to their representatives (eg Health and Safety Representative).

The MSDS can be used to determine what plant and work procedures are adopted to minimise worker exposure to hazardous chemicals.

The concerns of the environment are covered by the Environmental Protection Act (1986) which is administered by the EPA. Disposal of waste materials is administered by the Health Department.

If you have any further queries about the above matter, please do not hesitate to contact the Department.

Yours sincerely

J-W. Langley.

Dr Jeff Langley
**SCIENTIFIC OFFICER**
**OCCUPATIONAL HYGIENE BRANCH**

jl0053(dj)

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* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                        C H E M I N F O                       *
*                                                              *
*     Canadian Centre for Occupational Health and Safety      *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

### *** IDENTIFICATION ***

| | |
|---|---|
| RECORD NUMBER | 202E |
| CCOHS CHEMICAL NAME | Sodium ethyl xanthate |
| SYNONYM(S) | * Carbonic acid, dithio-, O-ethyl ester, sodium salt<br>* Carbonodithioic acid, O-ethyl ester, sodium salt<br>* Sodium ethylxanthogenate<br>* Sodium-O-ethyl carbonodithioate<br>* Sodium-O-ethyl dithiocarbonate |
| TRADE NAME(S) | Aeroxanthate 325<br>Z4 |
| CAS REGISTRY NUMBER | 140-90-9 |
| CHEMICAL FAMILY | Sodium salt of a dithiocarbonate ester |
| MOLECULAR FORMULA | C3-H5-O-S2-Na |
| STRUCTURAL FORMULA | CH3-CH2-O-CS-S-Na |
| LAST REVISION DATE | 1987-10-30 |

### *** DESCRIPTION ***

| | |
|---|---|
| APPEARANCE AND ODOUR | Pale yellow amorphous solid. Disagreable odour resembling carbon disulfide; hygroscopic (absorbs moisture from the air) |
| COMPOSITION/PURITY | Generally 90-95% purity. May contain traces of sodium hydroxide, water of hydration and decomposition products (e.g. ethyl alcohol, sodium carbonate, carbon disulfide, carbony sulfide and sodium sulfide). May be sold in the form of water solutions. |
| USES AND OCCURRENCES | Flotation agent for the froth separation of metal sulfide ores; pesticide; rubber chemical |

### *** HUMAN HEALTH HAZARD DATA ***

#### * EFFECTS OF SHORT-TERM (ACUTE) EXPOSURE *

| | |
|---|---|
| INHALATION | Airborne dust may cause irritation of respiratory airways. One case reports acut exposure of a worker who opened a tank containing sodium ethyl xanthate. The worke was not wearing respiratory protection. He lost consciousness and was removed from the worksite. On revival he complained of difficult breathing, teary eyes and hoarseness. He also was restless, vomited, had respiratory problems and convulsive twitching of muscles in arms and legs. Late he developed light sensitivity, fluid accumulation in the eyelids and eye discharge. No effects were noted 3 months after the exposure (4). |
| EYE CONTACT | Xanthate solutions may cause mild to sever eye irritation. Airborne dust may cause eye irritation. |
| SKIN CONTACT | Xanthate solutions and airborne dust may cause mild to severe skin irritations. |

 Ingestion of xanthate salts is not a likely

occupational occurrence. It may cause similar effects to ingestion of carbon disulfide including vomiting, diarrhea and headache. It may burn the mouth and oesophagus.

* EFFECTS OF LONG-TERM (CHRONIC) EXPOSURE *

HEALTH EFFECTS — Xanthate salts may cause irritation of the respiratory tract. Xanthate salts decompose to produce carbon disulfide. This may resu in effects on the central and peripheral nervous systems, on the cardiovascular system and on the gastrointestinal system. For additional information on chronic effects of carbon disulfide refer to CHEMINFO 192.

CARCINOGENICITY — No available information.

MUTAGENICITY — No available information.

REPRODUCTIVE EFFECTS — No available information.

POTENTIAL FOR ACCUMULATION — Xanthates are reported to be excreted as carbon disulfide in exhaled air in the fir hour after ingestion.

HEALTH DESCRIPTORS — Eye injuries; Irritant - eye ; nose ; thro

*** FIRST AID ***

INHALATION — Take proper precautions to ensure your own safety before attempting rescue; e.g., wea appropriate protective equipment, use the "buddy" system. Remove source of contamination or move victim to fresh air. If breathing has stopped, trained personne should begin artificial respiration or, if the heart has stopped, cardiopulmonary resuscitation (CPR) immediately. Oxygen ma be beneficial if administered by a person trained in its use, preferably on a physician's advice. Obtain medical attentic immediately.

EYE CONTACT — Immediately flush the contaminated eye(s) with lukewarm, gently flowing water for 20 minutes, by the clock, holding the eyelid( open. Take care not to rinse contaminated water into the non-affected eye. Obtain medical attention immediately.

SKIN CONTACT — Avoid direct contact with this chemical. Wear impervious protective gloves, if necessary. Remove contaminated clothing, shoes and leather goods (e.g. watchbands, belts). As quickly as possible, flush contaminated area with lukewarm, gently running water for at least 20 minutes, by the clock. If irritation persists, repeat flushing. Obtain medical attention immediately. Completely decontaminate clothing before re-use or discard. Do not re-use contaminated shoes or leather goods

INGESTION — Never give anything by mouth if victim is rapidly losing consciousness, or is unconscious or convulsing. Have victim rin mouth thoroughly with water. DO NOT INDUCE VOMITING. Have victim drink 240 to 300 ml naturally, have victim lean forward to reduce risk of aspiration. Repeat administration of water. Obtain medical attention immediately.

FIRST AID COMMENTS

Provide general supportive measures (comfort, warmth, rest). Consult a physici and/or the nearest Poison Control Centre f all exposures except minor instances of inhalation or skin contact. Some recommendations in the above sections may considered medical acts in some jurisdictions. These recommendations shoul be reviewed with a physisican and appropriate delegation obtained, as required. All first aid procedures should be periodically reviewed by a physician familiar with the material and its conditions of use in the workplace.

*** ANIMAL TOXICITY DATA ***

ANIMAL TOXICITY DATA

LDO (oral, rat): 0.5 g/kg (1) LD50 (oral, rat): 0.5 to 2.0 g/kg (2)

*** OCCUPATIONAL EXPOSURE LIMITS ***

* THRESHOLD LIMIT VALUES (TLVS) / AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH) / 1987-88 *

TIME-WEIGHTED AVERAGE (TLV-TWA)

Not established.

EXPOSURE LIMIT COMMENTS

NOTE: In many Canadian jurisdictions, exposure limits are similar to the ACGIH TLVs. Since a TLV has not been established for this substance, appropriate government agencies in each jurisdiction should be consulted to determine which regulations apply. An airborne concentration of 1 mg/ has been recommended as a guide (1).

*** SAMPLING AND ANALYSIS ***

SAMPLING & ANALYSIS

Published methods for sampling/analysis of airborne sodium ethyl xanthate are not currently available. It may be possible to estimate concentrations by measuring sodium in airborne particulate.

*** EXPOSURE CONTROL ***

* Note: Exposure to this material can be controlled in many ways. The measures appropriate for a particular worksite depend on how this material is used and on the extent of exposure. Use this general information to help develop specific control measures. Ensure that control systems are properly designed and maintained. Comply with occupational, environmental, fire, and other applicable regulations. *

* ENGINEERING CONTROLS *

ENGINEERING CONTROLS

Engineering control methods to reduce hazardous exposures are preferred. Methods include mechanical ventilation (dilution a local exhaust), process or personnel enclosure, control of process conditions, and process modification (e.g., substituti of a less hazardous material). Administrative controls and personal protective equipment may also be required.

Use a non-sparking, grounded, corrosion-resistant ventilation system separate from other exhaust ventilation systems. Exhaust cleaned air directly to t outside. Locate dust collectors outside or where permitted by regulation. Provide dus collectors with explosion vents. Use local exhaust ventilation, and process enclosure if necessary, to control airborne dust and mist. Supply sufficient replacement air to make up for air removed by exhaust systems

* PERSONAL PROTECTIVE EQUIPMENT *

RESPIRATORY PROTECTION

If engineering controls and work practices are not effective in controlling exposure this material, then wear suitable personal protective equipment including approved respiratory protection. Have appropriate equipment available for use in emergencies such as spills or fire. If respiratory protection is required, institute a comple respiratory protection program including selection, fit testing, training, maintenance and inspection. Refer to the C Standard Z94.4-M1982, "Selection, Care, an Use of Respirators," available from the Canadian Standards Association, Rexdale, Ontario, M9W 1R3.

RESPIRATORY PROTECTION GUIDELINES

No specific guidelines are available. A dust and mist respirator may be adequate for low concentrations of xanthate particulates. If carbon disulfide vapours are present, it may be necessary to select an appropriate respirator according to the concentration of carbon disulfide. Refer to CHEMINFO 192 for guidance on respiratory protection for carbon disulfide.

EYE/FACE PROTECTION

Safety glasses. Goggles or face shield are required when handling solutions.

SKIN PROTECTION

Impervious gloves, coveralls, boots, and/or other resistant protective clothing. Have a safety shower/eye-wash fountain readily available in the immediate work area.

RFSISTANCE OF MATERIALS FOR PROTECTIVE CLOTHING

No specific guidelines are available. Most materials commonly used in protective clothing are probably adequate.

PERSONAL PROTECTION COMMENTS

Remove contaminated clothing promptly. Keep contaminated clothing in closed containers. Discard or launder before rewearing. Inform laundry personnel of contaminant's hazards. Do not drink, eat or smoke in work areas. Wash hands thoroughly after handling this material. Maintain good housekeeping.

*** STORAGE AND HANDLING ***

STORAGE CONDITIONS

Store solid xanthates under cool, dark, dry conditions. Xanthate solutions should be kept cool. They should be used quickly to avoid aging and decomposition.

HANDLING

Ground drums and bond transfer containers. (Grounding clips must contact bare metal.)

Keep material away from sparks, flames and other ignition sources. Post "NO SMOKING" signs in area of use. Use dust-tight

Avoid generating mist/dust. Keep solids away from water. Post "DO NOT USE WATER" signs in area of use. Use extreme caution. Do not attempt to open container if it is of unknown age, if solid particles have formed, or if the material's physical characteristics differ from the pure substance. Heating of solid xanthate or aging or heating of xanthate solutions will cause formation of carbon disulfide. Follow handling and dissolution procedures recommended by the manufacturer or supplier of xanthate chemicals. Ensure that bulk solids and solution tanks are purged with an inert gas and drawn to avoid entrainment of carbon disulfide layers. All handling equipment should be properly bonded and grounded.

### *** SPILL AND LEAK PROCEDURES ***

PRECAUTIONS — Restrict access to area until completion of clean-up. Ensure clean-up is conducted by trained personnel only Wear adequate personal protective equipment. Ventilate area. Extinguish or remove all ignition sources. Notify government occupational and environmental authorities.

CLEANUP — Do not touch spilled material. Prevent material from entering sewers or confined spaces. Stop or reduce leak if safe to do so. Contain spill with earth, sand, or absorbent material which does not react with spilled material. Small spills of xanthate solutions: Soak up spill with absorbent material which does not react with spilled chemical. Put material in suitable, covered, labelled containers. Flush area with water. Do not get water inside containers or on spilled solid material. Vacuum spills of solids instead of sweeping. NOTE: Solid xanthates heat up in the presence of small quantities of water which could accelerate their decomposition and formation of flammable carbon disulfide.

### *** DISPOSAL ***

DISPOSAL — Review federal, provincial and local government requirements prior to disposal.

### *** FIRE AND EXPLOSION ***

FLASH POINT — Heating of solid xanthate or aging or heating of solutions will cause formation of carbon disulfide ($CS_2$). The flash point of $CS_2$ is -30 deg C (-22 deg F).

LOWER EXPLOSIVE LIMIT (LEL) — (For carbon disulfide): 1.3% (13000 ppm)

UPPER EXPLOSIVE LIMIT (UEL) — (For carbon disulfide): 50% (500000 ppm)

AUTOIGNITION TEMPERATURE — (For carbon disulfide): 90 deg C (190 deg F)

FIRE EXTINGUISHING AGENTS — Carbon dioxide, dry chemical or water

FIRE FIGHTING PROCEDURES — Heat decomposes solids and solutions into flammable carbon disulfide.

COMBUSTION (THERMAL DECOMPOSITION) PRODUCTS — Carbon disulfide, carbonyl sulfide, ethyl alcohol, sodium sulfide

### *** CHEMICAL REACTIVITY ***

Moisture and heat may result in spontaneous combustion. Tends to form a hydrated salt from moisture in air. Solids and solutions tend to release carbon disulfide which may accumulate.

INCOMPATIBILITY - MATERIALS TO AVOID

WATER - Sodium ethyl xanthate is hydrolyzed by water to produce ethyl alcohol, sodium carbonate, trithiocarbonate and carbon disulfide. ACIDS - The hydrolysis of xanthate solutions is accelerated by acidic pH.

HAZARDOUS DECOMPOSITION PRODUCTS — Carbon disulfide, ethyl alcohol, trithiocarbonate.

HAZARDOUS POLYMERIZATION — Does not occur.

*** PHYSICAL PROPERTIES ***

| | |
|---|---|
| MOLECULAR WEIGHT | 144.14 |
| CONVERSION FACTOR | 1 ppm = 5.9 mg/m3; 1 mg/m3 = 0.17 ppm at 25 deg C |
| MELTING POINT | 182 to 256 deg C (Varies with moisture content) |
| SOLUBILITY IN WATER | Very soluble (450 g/L at 10 deg C) |
| SOLUBILITY IN OTHER LIQUIDS | Soluble in alcohols, ketones, pyridine, and acetonitrile. |
| VALUE | Water solutions are alkaline. |

*** WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS) CLASSIFICATION ***

| | |
|---|---|
| WHMIS CLASSIFICATION, PROPOSED | Toxic |
| WHMIS HEALTH EFFECTS INDEX | Skin irritation - toxic<br>Eye irritation - toxic |
| WHMIS INGREDIENT DISCLOSURE LIST | Proposed A; Meets criteria for disclosure at 1% or greater. |

* DETAILED CLASSIFICATION ACCORDING TO CRITERIA *

WHMIS INFORMATION

COMPRESSED GAS: Does not meet criteria
FLAMMABLE & COMBUSTIBLE MATERIAL: Insufficient data
OXIDIZING MATERIAL: Does not meet criteria
DANGEROUSLY REACTIVE MATERIAL: Does not meet critera
CORROSIVE MATERIAL: Insufficient data
POISONOUS AND INFECTIOUS MATERIAL (TOXICITY): Classified as "Toxic"; see detailed evaluation below.
ACUTE LETHALITY: Insufficient data
CHRONIC HEALTH EFFECTS: Insufficient data
CARCINOGENICITY: Does not meet criteria; not in reference lists.
REPRODUCTIVE EFFECTS: Insufficient data
RESPIRATORY SENSITIZATION: Does not meet criteria; not reported as human respiratory sensitizer.

SKIN SENSITIZATION: Insufficient data
SKIN IRRITATION: "Toxic"; may cause severe irritation.
EYE IRRITATION: "Toxic"; may cause severe irritation.

*** SELECTED BIBLIOGRAPHY ***

BIBLIOGRAPHY

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(2) Xanthates 325 (material safety data

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(5) Merlevede, E., et al. Metabolism of xanthates in man and the guinea pig. Arch. Belg. Med. Soc. Hyg., Med. trav. et Med. Legale. Vol. 23, no. 8 (1965). p. 1-37

* Information on chemicals contained in the CHEMINFO Database is drawn from a number of publicly available sources. The sources used are available on request. *

CHEMINFO

Canadian Centre for Occupational Health and Safety

### *** IDENTIFICATION ***

| | |
|---|---|
| RECORD NUMBER | 2628E |
| CCOHS CHEMICAL NAME | 4-Methyl-2-pentanol |
| SYNONYM(S) | * 1,3-Dimethylbutanol<br>* Isobutylmethylcarbinol<br>* Methylamyl alcohol<br>* Methyl isobutyl carbinol<br>* 2-Methyl-4-pentanol<br>* 4-Methyl-2-pentyl alcohol<br>* MIBC<br>* Alcool methyl amylique<br>* Methyl-4 pentanol-2 |
| CAS REGISTRY NUMBER | 108-11-2 |
| OTHER CAS REGISTRY NUMBER(S) | 40747-85-1 72847-31-5 |
| PIN - UN/NA NUMBER(S) | 2053 |
| RTECS NUMBER(S) | SA7350000 |
| CHEMICAL FAMILY | Aliphatic alcohol |
| MOLECULAR FORMULA | C6-H14-O |
| STRUCTURAL FORMULA | (CH3)2-CH-CH2-CH(OH)-CH3 |
| LAST REVISION DATE | 1987-12-10 |

### *** DESCRIPTION ***

| | |
|---|---|
| APPEARANCE AND ODOUR | Colourless liquid; unpleasant to pleasant, sweet alcoholic odour |
| ODOUR THRESHOLD | 0.33 ppm (absolute perception limit); 0.52 ppm (50%-100% recognition) |
| WARNING PROPERTIES (ODOUR AND IRRITATION) | FAIR - Although the TLV is about 50 times the odour threshold, eye irritation occurs at about the TLV. |
| ES AND OCCURRENCES | Solvent for dyestuffs, oils, gums, resins, waxes, nitrocellulose and ethylcellulose; latent solvent in brushing and hot spray lacquers; frothing agent in froth flotation; in beneficiation of coal; in manufacture of lubricant additives, plasticizers, lacquers; used as frothing agent in brake fluids; organic synthesis |

### *** HUMAN HEALTH HAZARD DATA ***

#### * EFFECTS OF SHORT-TERM (ACUTE) EXPOSURE *

| | |
|---|---|
| EYE CONTACT | Human subjects experienced eye irritation at 50 ppm, although the odour was not objectionable at this level (1,4). |

### *** ANIMAL TOXICITY DATA ***

| | |
|---|---|
| ANIMAL TOXICITY DATA | LD50 (rat, oral): 2590-2600 mg/kg (HSDB; 1; 4; 5) Lethal dose (mouse, oral): 1000 mg/kg (HSDB; 4) LD50 (rabbit, skin): 2855 mg/kg (5) LD50 (rabbit, skin): 3560 mg/kg (HSDB; 1; 4) Two hour exposure of six rats to the saturated vapour (4600 ppm or 20 mg/l) resulted in no deaths. Exposure of six rats to 2000 ppm for eight hours resulted in 5 |

*** OCCUPATIONAL EXPOSURE LIMITS ***

* THRESHOLD LIMIT VALUES (TLVS) / AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH) / 1987-88 *

| | |
|---|---|
| TIME-WEIGHTED AVERAGE (TLV-TWA) | 25 ppm or 100 mg/m3 - Skin |
| SHORT-TERM EXPOSURE LIMIT (TLV-STEL) | 40 ppm or 165 mg/m3 - Skin |
| EXPOSURE LIMIT COMMENTS | "SKIN" NOTATION: Contact with skin, eyes and mucous membranes can contribute to the overall exposure and may invalidate the TLV. Consider measures to prevent absorption by these routes. NOTE: In many Canadian jurisdictions, exposure limits are similar to the ACGIH TLVs. Since the manner in which exposure limits are established, interpreted, and implemented can vary, obtain detailed information from the appropriate government agency in each jurisdiction. OSHA standard-air: TWA 25 ppm - Skin |

*** SAMPLING AND ANALYSIS ***

| | |
|---|---|
| SAMPLING & ANALYSIS | NIOSH METHOD(S): 1402 - NIOSH Manual of Analytical Methods. 3rd edition. Vol. 1; 1984. (Alcohols III) |

*** FIRE AND EXPLOSION ***

| | |
|---|---|
| FLASH POINT | 41 deg C (106 deg F) (closed cup); 55 deg C (131 deg F) (Tag open cup). Also reported as 40.5 deg C (105 deg F) (open cup) |
| LOWER EXPLOSIVE LIMIT (LEL) | 1% |
| UPPER EXPLOSIVE LIMIT (UEL) | 5.5% |
| FIRE EXTINGUISHING AGENTS | Carbon dioxide, dry chemical powder, alcohol foam or polymer foam |
| COMBUSTION (THERMAL DECOMPOSITION) PRODUCTS | Carbon monoxide, carbon dioxide |

* NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) HAZARD INDEX *

| | |
|---|---|
| HEALTH | 2 - Hazardous to health |
| FIRE | 2 - Must be moderately heated before ignition can occur |
| REACTIVITY | 0 - Normally stable |

*** CHEMICAL REACTIVITY ***

| | |
|---|---|
| STABILITY | Normally stable. May be unstable when heated. |
| INCOMPATIBILITY - MATERIALS TO AVOID | OXIDIZING AGENTS - Can oxidize 4-methyl-2-pentanol to ketone and/or acid. Contact with strong oxidizing agents may cause fires and explosions. ACIDS, ACID CHLORIDES - React to form esters. Reactions may be vigorous. PLASTICS, RUBBER, COATINGS - 4-Methyl-2-pentanol will attack some forms of plastics, rubber and coatings |

*** PHYSICAL PROPERTIES ***

| | |
|---|---|
| MOLECULAR WEIGHT | 102.18 |
| CONVERSION FACTOR | 1 ppm = 4.17 mg/m3; 1 mg/m3 = 0.239 ppm at 25 deg C |
| MELTING POINT | -90 deg C. Sets to a glass below -90 deg C. |
| BOILING POINT | 132-133 deg C |

RELATIVE DENSITY (SPECIFIC GRAVITY)
0.808 at 20 deg (water = 1)

| | |
|---|---|
| SOLUBILITY IN WATER | Moderately soluble (1.7 g/100 ml at 20 deg C) |
| SOLUBILITY IN OTHER LIQUIDS | Soluble in ethyl alcohol, ether, hydrocarbons and most organic solvents |
| VAPOUR DENSITY | 3.52 (air = 1) |
| VAPOUR PRESSURE | 3.8 mm Hg at 20 deg C. Also reported as 2.8 mm Hg and 5 mm Hg at 20 deg C. |
| SATURATION VAPOUR CONCENTRATION | 0.46% at 20 deg C |
| EVAPORATION RATE | 0.27 (butyl acetate = 1) |

*** WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS) CLASSIFICATION ***

| | |
|---|---|
| WHMIS INGREDIENT DISCLOSURE LIST | Confirmed A; Meets criteria for disclosure at 1% or greater. |

*** TRANSPORTATION OF DANGEROUS GOODS (TDG) SHIPPING INFO ***
* (Source: Transport Canada, Transportation of Dangerous Goods Regulations) *

TDG INFORMATION

DESCRIPTION AND SHIPPING NAME: Methyl isobutyl carbinol
PRODUCT IDENTIFICATION NUMBER (PIN): 2053
CLASSIFICATION: 3.3 - Flammable liquid, flash point not less than 23 deg C but less than 61 deg C
SPECIAL PROVISIONS: ---
IMO CLASSIFICATION: 3.3
ICAO CLASSIFICATION: 3
PACKING GROUP: III

*** SELECTED BIBLIOGRAPHY ***

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(3) Occupational health guideline for methyl isobutyl carbinol. In: NIOSH/OSHA. Occupational health guidelines for chemical hazards. Vol. II. NIOSH, September 1978
(4) Patty's industrial hygiene and toxicology. 3rd rev. ed. Vol. 2C. John Wiley & Sons, 1982. p. 4613-4616
(5) The Sigma-Aldrich library of chemical safety data. Edition 1. Sigma-Aldrich Corporation, 1985. p. 1286D

*NOTE: Records in the CHEMINFO Database are built in stages. This record is incomplete. Additional information is available from the Inquiries Service of CCOHS. *

* Information on chemicals contained in the CHEMINFO Database is drawn from a number of publicly available sources. The sources used are available on request. *

Chemical & Mining Services Pty. Ltd.
(Incorporated in N.S.W.)
P.O. Box 159 Willoughby N.S.W. 2068 Australia
Telephone. (02) 449 7966, 449 7835 Fax: (02) 449 8190

## CMS — MINING CHEMICALS

TECHNICAL & SAFETY DATA INFORMATION

SENFROTH TEB [FROTHERS]

CHEMICAL NAME [1,1,3 TRIETHOXYBUTANE]

TEB consists essentially of an alkoxy hydrocarbon. This type of frother differs markedly from most other types in having no hydroxyl group on the molecule.

TEB frother is a synthetic reagent manufactured under controlled conditions specifically for flotation use and does not vary in flotation behaviour. It is manufactured from raw materials that are not based on petroleum derivatives.

USE IN CONJUNCTION WITH OTHER REAGENTS

These reagents are compatible with all known reagents used in Flotation.

PHYSICAL PROPERTIES

| | |
|---|---|
| Form: | Yellow to light brown liquids. |
| Density: | 0.9 kg/litre [approx] |
| Solubility: | Soluble to the extent of approximately 1.4% in water. |
| PACKAGING: | 200 litre steel drums, or bulk. |

HEALTH HAZARD DATA

| | |
|---|---|
| TLV: | No data available but as with all organic chemicals adequate ventilation is recommended. |
| Inhalation: | High concentration of vapour or mist may cause irritation of eyes and respiratory tract. |
| Eyes: | Strong irritant, may cause burns. |
| Skin: | Defatting Agent. |

...2.

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SAFETY DATA INFORMATION [CONT]:

SENFROTH TEB [FROTHERS]

EMERGENCY & FIRST AID

| | |
|---|---|
| Inhalation: | Move victim to fresh air, if exposure is servere oxygen may be needed. |
| Eyes: | Flush immediately with water for at least 15 mins, refer any residual irritation to a physician. |
| Skin: | Wash well with soap and water. |
| Ingestion: | Copious quantities of water and induce vomiting. Do not make an unconsious patient vomit. Seek medical attention. |

FIRE & EXPLOSION HAZARD DATA

| | |
|---|---|
| Hazards: | Flash point 26 Deg. C. Use dry powder, foam or carbon dioxide extinguishers. In enclosed spaces, use self-contained or chemical cartridge respirators. |

SPECIAL PRECAUTIONS

| | |
|---|---|
| Storage: | Store in a cool, well-ventilated area. Bulk storage should be in stainless steel, aluminium or mild steel. |
| Handling: | Use goggles, gloves and boots if spillage is likely. If exposure to vapour is likely, use flame-proofed area. |

REACTIVITY

| | |
|---|---|
| General: | Avoid contact with strong oxidants and mineral acids. Incompatibility with some synthetic rubbers may occur. Swelling may occur. |

...3.

Chemical & Mining Services Pty. Ltd.
(Incorporated in N.S.W.)
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**CMS — MINING CHEMICALS**



SAFETY DATA INFORMATION [CONT]:

ENFROTH TEB [FROTHERS]

SPILL OR LEAK PROCEDURES

Environment: Normal effluent from tailings dams is considered safe.

Action: Flush residue with large volume of water and ensure that it is well diluted before discharge. Contaminated clothing and equipment should be well washed before re-use.

Neutralising: No neutralising reagents needed.

Disposal: Aqueous dilutions should be well diluted and their discharge controlled, preferably into a tailings dam.

# Industrial Chemicals

- FACSIMILE

ICI Industrial Chemicals
65 Rule Street
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Perth WA 6001
Telephone (09) 336 8900
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TO: CHRIS LARDER

AT: MINPROC

FROM: MICHELLE MILLER

DATE: 11/4/90 NO.OF PAGES: 4 REF: ICGF116/90

MESSAGE

PLEASE FIND FOLLOWING SAFETY DATA SHEET AS REQUESTED FOR SODIUM ETHYL XANTHATE.

RECEIVED
11 APR 1990

CIRCULATION FILE
ADDRESSEE
COPY TO:
JOB No.

1 Nicholson Street,
Melbourne, 3000 Tel: 03-665 7111
Emergency: 008-033111 (All Hours)

# Safety Data Sheet

INDUSTRIAL CHEMICALS GROUP

ISSUED: 12/87

**Product Name** SODIUM ETHYL XANTHATE

U.N. NO: 2813 HAZARD : 4.3 DANGEROUS WHEN WET
HAZCHEM: 4WE : 6.1A POISONOUS (TOXIC)

## IDENTIFICATION & PHYSICAL DATA

**OTHER NAMES**

SEX
Carbonodithioic acid, O-ethyl ester, sodium salt

**CAS NUMBER**

140-90-9

**MOLECULAR FORMULA**

C3-H5-O-S2.Na

**USES**

Ore flotation agent

**PHYSICAL PROPERTIES**

Yellow deliquescent powder with a pungent odour. Readily soluble in water, alcohol and acetone. Insoluble in hydrocarbons and ether.

Reacts with water to give carbon disulphide (toxic, flammable) and other sulphur compounds.

## HEALTH HAZARD INFORMATION

**HEALTH EFFECTS**

Considered to be harmful by ingestion. Contact with skin may result in irritation. A mild to moderate eye irritant. Inhalation of dust may result in respiratory irritation. If xanthates are wetted or heated to above 150 C carbon disulphide vapour is evolved. This is an eye irritant. Inhalation of high concentrations of this vapour can produce central nervous system depression and symptoms such as restlessness, irritation of the mucous membranes, blurred vision, nausea and vomiting, headache and unconsciousness.

**FIRST AID**

SKIN: Wash contaminated skin with plenty of soap and water. Remove contaminated clothing and wash before re-use.
EYES: Irrigate with copious quantities of water for 15 mins. Seek medical assistance if effect persists.
INHALATION: Remove victim from exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. Seek medical advice.
INGESTION: Give plenty of water to drink. If vomiting occurs give further water to achieve effective dilution. Seek immediate medical assistance.

.../2

1 Nicholson Street,
Melbourne,3000 Tel: 03-665 7111
Emergency: 008-033111 (All Hours)



**Product Name** SODIUM ETHYL XANTHATE

ADVICE TO DOCTOR
Treat symptomatically. Consider exposure to carbon disulphide.

TOXICITY
No specific LD50 data available for this material. However potassium ethyl xanthate has Oral LD50(rat): 1700 mg/kg.

Eyes: Mild to moderate irritant.
Skin: May cause irritation.

---

## PRECAUTIONS FOR USE

---

XPOSURE LIMITS
No value assigned for this specific material by the National Health & Medical Research Council.

However, Threshold Limit Value(TLV) for product of thermal decomposition or water contact - Carbon Disulphide: 10 ppm - skin
30 mg/m3
As published by National Health & Medical Research Council.

A 'skin' notation indicates that this substance will also be readily absorbed through the skin, which may be by airborne material or direct contact. The TLV is obviously invalidated if such contact should occur.

TLV is the time weighted average concentration of the work atmosphere for a normal 8-hour work day and a 40-hour work week, to which nearly all workers can be repeatedly exposed, day after day, without adverse effect.

These TLVs are issued as guidelines for good practice. All atmospheric contamination should be kept to as low a level as is practically possible. These TLV levels should not be used as fine lines between safe and dangerous concentrations.

VENTILATION
Avoid generating and inhaling dusts.

PERSONAL PROTECTION
ICI Protective Equipment Code : C
Avoid skin and eye contact. Wear impervious (PVC) gloves, chemical goggles and overalls. Use with adequate ventilation. Avoid generating and inhaling dusts. Always wash hands before smoking, eating, drinking or using the toilet.

FLAMMABILITY
Combustible solid.

.../3

Safety Data Sheet
INDUSTRIAL CHEMICALS GROUP

1 Nicholson Street,
Melbourne,3000 Tel: 03-665 7111
Emergency: 008-033111 (All Hours)

ICI

Product Name SODIUM ETHYL XANTHATE

CDS: 23111
ISSUED: 12/87


## SAFE HANDLING INFORMATION

### STORAGE AND TRANSPORT

UN No: 2813 Packaging Group: 2
Classified as a 4.3 (DANGEROUS WHEN WET) and 6.1A (POISONOUS (TOXIC)) Dangerous Substance for the purpose of transport. Refer to State Regulations for storage and transport requirements.
Not to be loaded with Flammable Gases (class 2.1), Flammable Liquids (class 3) where the flammable liquid is nitromethane, Oxidizing Agents (class 5), Corrosives (class 8) or foodstuffs.
Keep containers closed at all times. Keep dry. Reacts with water to evolve a flammable and toxic gas.

### SPILLS

Wear full protective equipment to prevent skin and eye contamination. Sweep up with sweeping powder or dry sand. Collect and seal in drums for disposal. DO NOT dilute with water.

### DISPOSAL

Refer to State Land Waste Management Authority. Normally suitable for disposal at approved land waste site.

### FIRE/EXPLOSION HAZARDS

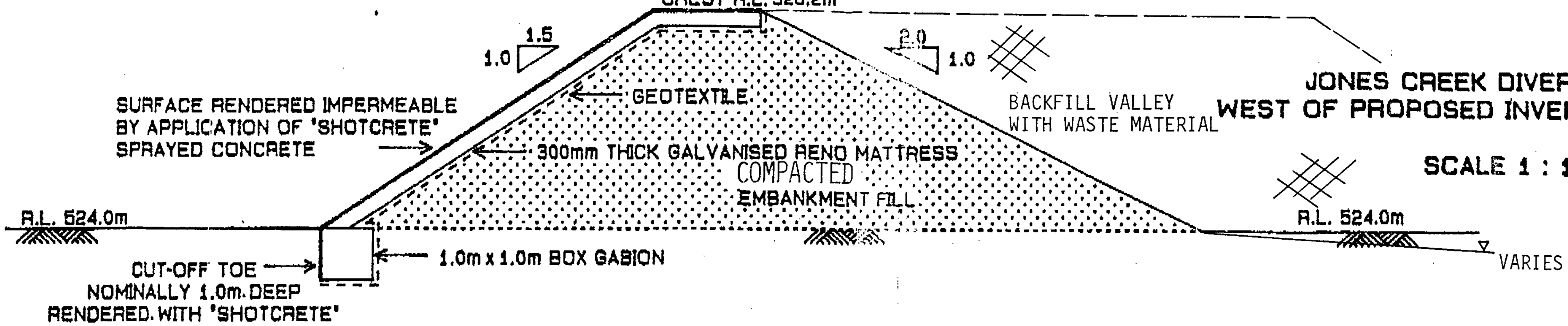
Will burn if involved in a fire. On burning will emit toxic and flammable fumes/vapours including carbon disulphide (flash point -29 C).

Fire fighters to wear self-contained breathing apparatus if risk of exposure to vapour or products of combustion.

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical powder, BCF

## OTHER INFORMATION & REFERENCES

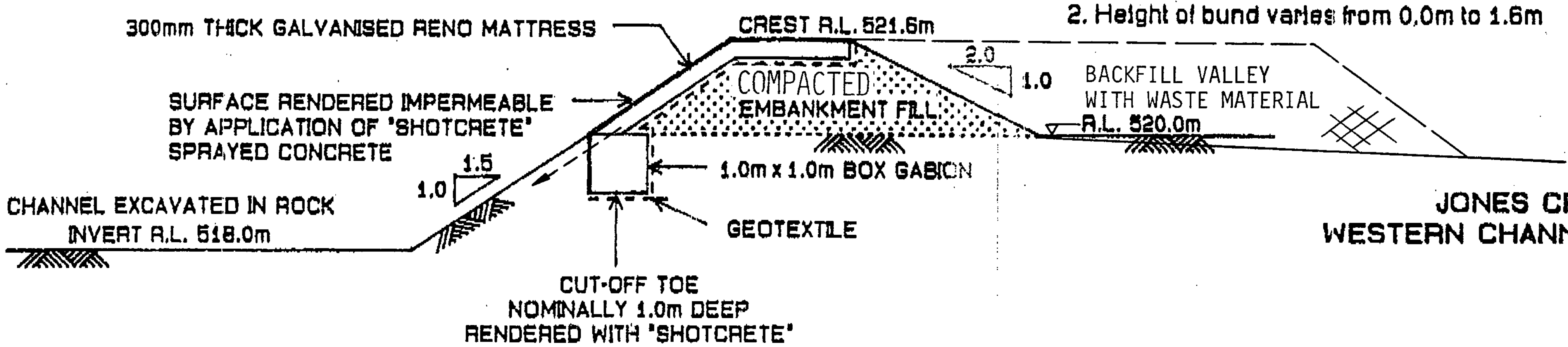
1. Length of bund approx. 430m according to info. supplied
2. Height of bund varies from 0.0m to 4.2m




## JONES CREEK DIVERSION BUND
## WEST OF PROPOSED INVERT CHAINAGE 0.0m

**SCALE 1 : 100**

1. Length of bund approx. 70m according to info. supplied
2. Height of bund varies from 0.0m to 1.6m



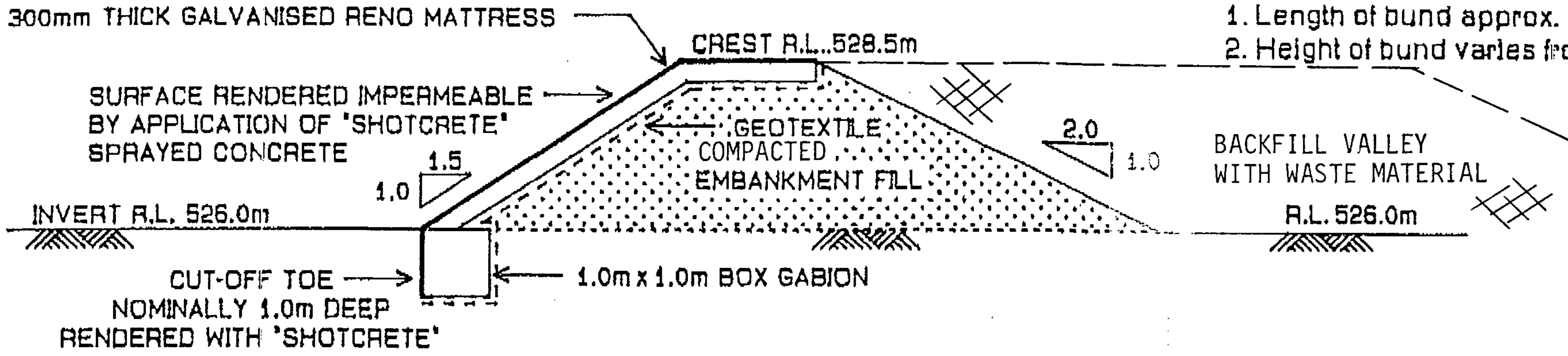

## JONES CREEK PROTECTIVE BUND
## WESTERN CHANNEL BANK AT CHAINAGE 1885.0m

**SCALE 1 : 100**

NOTE

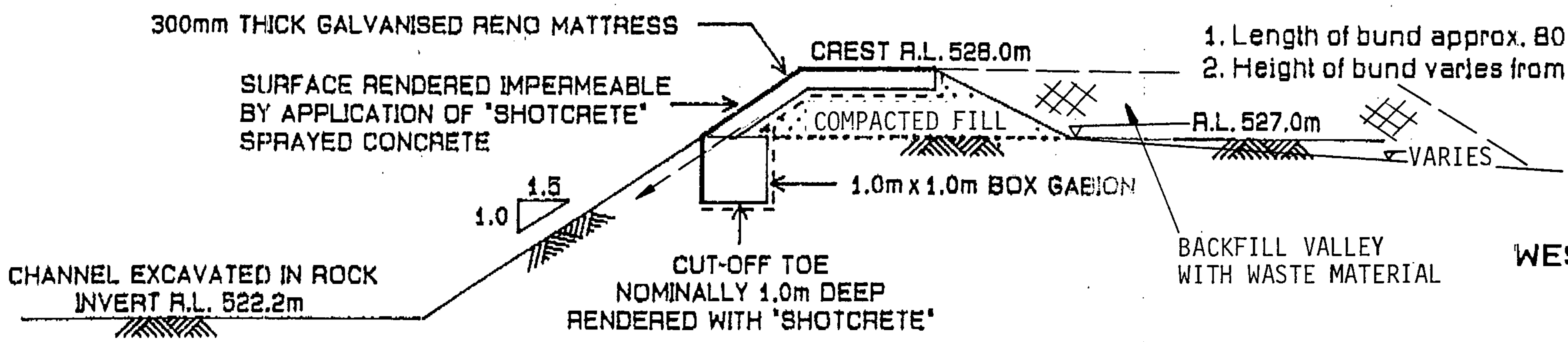
AN ALTERNATIVE TO 'SHOTCRETE' WOULD BE THE USE OF AN IMPERMEABLE LINER SUCH AS HDPE BENEATH THE GEOTEXTILE. THE GEOTEXTILE WOULD THEN ACT AS A BLINDING LAYER TO PROTECT THE LINER FROM PUNCTURE DURING CONSTRUCTION. THIS METHOD WOULD HAVE THE ADVANTAGE OF MAINTAINING THE NORMAL FLEXIBILITY OF THE RENO MATTRESS AND GABIONS.

| | | |
|---|---|---|
| MACCAFERRI GABIONS SOUTH PACIFIC PTY. LTD.<br>P.O. BOX 283 ALEXANDRIA N.S.W. 2015 Ph. (02)5503711 Fax. (02)5192452 | JONES CREEK & TRIBUTARY BUND PROTECTION<br>PREPARED FOR : SOIL & ROCK ENGINEERING | DATE : APRIL 1990<br>DRAWING No.: 108-1 |



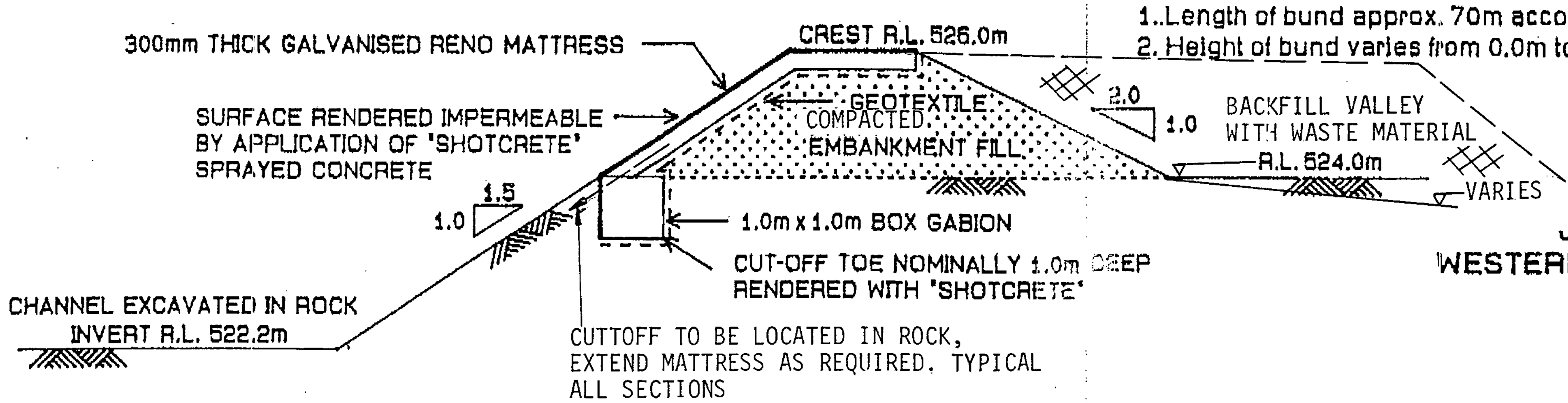

**JONES CREEK TRIBUTARY BUND**
**WESTERN CHANNEL BANK AT CHAINAGE 0.0m**

**SCALE 1 : 100**




**JONES CREEK TRIBUTARY BUND**
**WESTERN CHANNEL BANK AT CHAINAGE 265.0m**

**SCALE 1 : 100**




**JONES CREEK TRIBUTARY BUND**
**WESTERN CHANNEL BANK AT CHAINAGE 565.0m**

**SCALE 1 : 100**

| | | |
|---|---|---|
| MACCAFERRI GABIONS SOUTH PACIFIC PTY. LTD.<br>P.O. BOX 283 ALEXANDRIA N.S.W. 2015 Ph. (02)5503711 Fax. (02)5192452 | JONES CREEK & TRIBUTARY BUND PROTECTION<br>PREPARED FOR : SOIL & ROCK ENGINEERING | DATE : APRIL 1990<br>DRAWING No.: 108-2 |

# APPENDIX D2

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PRELIMINARY
Not Approved for Construction

# YAKABINDIE NICKEL PROJECT
# TAILINGS DAM
# DESIGN

Report prepared for:

DOMINION MINING LTD
10 Richardson Street
WEST PERTH WA 6005

Report prepared by:

SOIL AND ROCK ENGINEERING PTY LTD
CONSULTING GEOTECHNICAL ENGINEERS
AND GEOLOGISTS
4TH FLOOR CENTREPOINT TOWER
123 COLIN STREET
WEST PERTH WA 6005

Ref: 2488T/0.1/CL/jb
Date: 20th April 1990

Soil & Rock Engineering Pty. Ltd.

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PRELIMINARY
Not Approved for Construction

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**PRELIMINARY**

*Not Approved for Construction*

Our ref: 2488T/0.1/CL/jb
C2488A/SUM

20th April 1990

PROJECT YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: DETAILED DESIGN - TAILINGS DAM

---

## 1.0 INTRODUCTION

This report and the associated drawings (numbers W1292-00/C-002 to 006) provide a detailed design for the tailings dam for the Yakabindie Nickel Project.

The tailings dam has been designed incorporating a water recovery system. The recovery system utilises decant structures to feed external sumps, allowing water to be returned to the processing plant. The design adopted for staged heightening of the embankments utilises compacted waste rock.

The design objectives are as follows:

(i) maximise water return from the tailings;

(ii) minimise the environmental impact of the tailings disposal;

(iii) maximise storage capacity of the tailings dam; and

(iv) to allow the tailings dam to function with minimal daily input, while maintaining stability of the structure.

A separate Operations Manual ref 2488T/0.3/CL/jb has been prepared as a guide for the use of plant staff in the operation and management of the tailings dam.

Reference should be made to both documents to ensure that the design concepts and management requirements are fully understood in order that the design objectives may be attained.

## 2.0 ENVIRONMENTAL CONSIDERATIONS

The following environmental considerations have been incorporated into the tailings dam design.

(i) Tailings in the form of a slurry should be discharged subaerially into the dam in thin discrete layers, not exceeding 300mm thick. This method of deposition allows the tailings to gain higher densities and strength if each layer is subjected to a drying cycle;

(ii) Deposition of tailings in thin discrete layers which are allowed to dry will help to reduce seepage losses. Some seepage losses into regolith will be apparent during initial filling of the dam. Vertical seepage will be negligible due to the underlying granite rock layer which is of low permeability. Lateral seepage will be contained by the embankment foundations, which will be taken to refusal on rock. Upstream and downstream toe drains will intercept and collect any seepage which may occur and redirect it into the return water sump;

(iii) The storage area of the Tailings Dam will assume the form of a truncated prism with a depressed cone in the top surface. This central area could contain a considerable body of water during a rainstorm, and an adequate freeboard (0.5m) must always be available to store 1 in 100 year or greater rainfall events;

(iv) On decommissioning, the tailings dam will remain as a permanent feature of the landscape. It will drain to an increasingly stable mass. The top surface will be covered by a layer of waste rock to prevent wind erosion, and side slopes will have rehabilitation carried out as the dam is raised; and

(v) The operational design of the dam has been aimed at:
- minimising water losses by both evaporation and seepage
- providing maximum return water to the plant
- increasing tailings storage capacity.

## 3.0 DESIGN CONCEPT

The final design adopted was formulated to meet both the general requirements of the mine and the general parameters discussed in the previous sections. The final concept is shown on Drawing No. W1292-00/C-003 and W1292-00/C-006. The design concept (Plate 1) for operating the tailings dam contains the following features:

(i) the water recovered from the decant system will be piped into a lined sump, from where the water will be pumped to the plant. To allow for maintenance or shut-down, the decant overflow pipes feeding the sump are valved to allow water flow to be halted;

(ii) the decant system will operate to remove free slurry water from the dam with the objective of providing reliability, safety of operation, and minimisation of evaporation losses. The tailings dam will be divided into two ponds by a central pervious mullock embankment with each pond partially divided by pervious mullock embankments (decant access way). The embankments surrounding the decant structures will consist of clean waste rock.

The objectives of the mullock embankment is two-fold. Firstly, it will provide safe access to the decant structure for maintenance and extension (heightening) as the mass of tailings rises with time. Secondly, it will form a primary filter for the tailings;

(iii) embankment construction will be carried out using run of mine waste. Stage I construction will be to RL 530 providing approximately 3 years storage. Stage II construction is to RL 535 and construction will continue to RL 555 at this level embankments will partially enclose the tailings dam area.

## 4.0 FINAL DESIGN AND SPECIFICATION

### 4.1 Water Recovery System

#### 4.1.1 Decant Design and Operation

The decant system and pipes were designed using the following parameters:

(i) a tailings output from the mill of approximately 1400 tonnes per hour or 12 x $10^6$ million tonnes per annum; and

(ii) a water component of approximately 700 $m^3$ per hour, 6 million $m^3$ per annum i.e. percents solids 50% by weight.

The decant system consists of a vertical internal riser which is connected to an external sump. The 300mm diameter internal riser pipe contains 80mm diameter holes at 150mm intervals spiralled round the pipe. The outer pipe is built up of 1.22 m diameter by 1.8m long precast slotted concrete pipe cylinders. These cylinders contain louvered slots nominally 30mm wide by 200mm long with a total of 18 slots per cylinder section.

The decant systems located within the storage area so that the pond, if present, is situated in the area of the waste rock mound which surrounds the decant structure. As the surface of the tailings rises, the internal riser pipe is closed off by placing 300mm diameter decant pipe sleeves (closing collars) over the internal riser. This action prevents water and any tailings which have penetrated the rock mound from gaining direct access to the internal riser pipe and thus the return water sump.

Tailings ingress into the pipework or sump is a major problem, and for this reason the collaring operation is a very important aspect of the overall operation.

The addition of too many sleeves above the tailings level will result in a corresponding increase in water depth. If taken to the extreme, flooding (inundation) of the tailings beaches could occur resulting in saturated tailings of lower strength.

Infilling of the decant annulus with sand or gravels is recommended to give added stability to the vertical internal riser. Infilling also inhibits the ingress of tailings into this area (Plate 2). A disadvantage is that it prevents the easy inspection of the internal portion of the decant structure when the decant is inoperative.

Decant earthworks and raising is diagrammatically represented on Drawing No.'s W1292-00/C-003A, W1292-00/C-003B and W1292-00/C-004.

As the tailings surface rises, the entire decant offtake system is raised to maintain a minimum freeboard over the top of the pond of about 2m. This means that the decant pipes are added to and the waste rock mound raised as the perimeter embankments are being raised.

The internal offtake pipes are contained entirely in the central decant structures which are surrounded by coarse run-of-mine mullock containing no fines. This embankment allows access to the decant structure and pipework at all times. The rock surround is also designed to act as a clear water connection to the intakes, the waste rock will partially restrict the entry of tailings to the decant structure. Details of the decant systems are shown on Drawing No. W1292-00/C-004

The decant outfall pipe from the decant consist of 300mm diameter uPVC pipe with rubber ring joints. The uPVC pipes will be laid in the trenches in accordance with the details on the drawings and attached construction documentation (ref. 2488T/0.2/CL/jb, dated 20th April 1990), ensuring even grades and levels are maintained. Return water will pass via the pipes to the lined sump. As the dam fills, the soil and tailings surrounding this pipe will be slowly consolidated shedding overburden loading away from the pipe into the surrounding materials. The pipeline is quite flexible and no distortion problems are considered likely provided the pipe is laid, bedded, backfilled and tested to the manufacturer's specification.

### 4.1.2 Decant Pipework

#### 4.1.2.1 Staged Construction, Stage I

Pipe work requirements for Stage I (8 decants) will comprise 27 No. 1.8m NB standard decant pipe, with 3 rows of slots; 29m, internal riser (300 uPVC Class 6 with 80 mm diameter holes) and 200 NO. 150mm decant collars.

#### 4.1.2.2 Staged Construction, Stage II to VI

Ongoing pipe work requirements for Stage II to VI (8 decants) construction of the decant will be; 144 No. 1.8m NB standard decant pipes, with 3 rows of slots; 187 m, internal riser (300mm uPVC Class 6 with 80mm diameter holes) and the 1250 No. 150mm decant collars.

The availability of these items should be assessed to ensure that decant raising can continue without interruption, it may be more economical to order several items due to special requirements (i.e. internal risers).

Another alternative is to raise the decant structure and accessway in lifts in excess of the external embankments.

### 4.1.3 External Lined Sump

Water collected from the decant system will be discharged via a 300mm NB uPVC pipe into a lined sump. Water collected in the sump will then be returned to the plant. Details of the sump are shown on Drawing No.s W1292-00/C-002 and W1292-00/C-005.

The sump has a design storage capacity of approximately 3000 $m^3$ to BL 515.2m and BL 520.0m respectively.

Each sump will be fed by one 300 NB uPVC Class 12 pipe and one 150 NB uPVC Class 6 pipe. All pipes will be valved to allow closure of pipework in case of maintenance or emergency. Under normal operating procedures no piping is to be closed.

### 4.1.4 Tailings Dam Start Up

During the period of initial deposition into the tailings dam, a temporary mobile pump will be required to collect surface water and discharge it into the decant systems. The level at which water can enter the decant systems is approximately 4.5m and 6.2m higher than the lowest ground level of each storage area.

This pump should be positioned such that it will not be subjected to either water or tailings inundation as deposition continues and will allow routine maintenance to be undertaken with out danger to service personnel.

The pump discharge is to be fed directly into the return water sump. Once the tailings water has reached the decant and enters the internal risers, the valves on the decant outfall may be gradually opened.

It has been estimated that this arrangement will be required for a period of approximately 12 weeks from commencement of tailings deposition to the southern storage area before return water will enter decant no 1; (and period of approximately 10 weeks from commencement of tailings deposition to the northern storage area before return water will enter decant no 5).

## 4.2 Embankment Construction

The embankment alignment has been designed to partially enclose a storage area of approximately 310 hectares. This will be accomplished by constructing the starter wall, and progressively raising the wall by upstream construction methods.

The Stage I embankment is to be constructed to RL 530m. This means the embankment will initially have a maximum height of 12m in the south eastern corner of the dam. The maximum base width is approximately 82m, the crest is 15m wide with 1 to 1.7 upstream slopes and 1 to 2.75/2.25 downstream slopes. The embankment volume of this construction including the central accessway and decant accessway, is approximately 2,000,000m$^3$. The extent of Stage I earthworks are shown on Drawing No.s W1292-00/C-002 and W1292-00/C-003A.

Stages II and III embankment construction crest RL's are 535m, and 540m respectively, having a maximum wall height of approximately 22m in the south eastern corner of the dam. The crest is 15m wide with slopessimilar to those of Stage 1. Stages II and III construction is shown on Drawings No.s W1292-00/C-003A and W1292-00/C-006. Construction is by the upstream method. Stages IV, V and VI construction are by the upstream method, Stage VI construction will take the crest to RL 555m.

Run of mine waste (overburden) will be used to form the starter embankments. Clean rock waste will be used to surround the central decant structure. All rock must be placed carefully to avoid damage to the decant structure.

Prior to placement of the outfall pipes (300 NB uPVC Class 12) fill placement in the south eastern and eastern walls should be undertaken to approximately RL 520 (Decants 1, 2, 3 and 4 ) and RL 523.3 (Decants 5, 6, 7 and 8). A trench for the two outflow pipes (one decant pipe and one emergency decant pipe) shall be excavated through the compacted fill to the correct grades. The pipes will then be laid and tested prior to the trench being backfilled. A concrete cut-off is to be installed as specified on Drawing No. W1292-00/C-005 and should be at least 300mm oversize in all directions. Once the pipeline has been installed, tested, and backfilled and compacted as specified to the surrounding construction level (nominally 520 and 523.3 respectively), normal embankment construction can recommence in that area.

## 4.3 Instrumentation

The initial need for dam instrumentation in the form of piezometers does not appear warranted due to the proposed method of construction of embankments. If heightening of the embankments above the design height of RL 555m is envisaged, a review of embankment monitoring will be necessary.

The only recommended instrumentation is the installation of boreholes to monitor groundwater levels and water quality as appropriate. The location of these boreholes is shown on Drawing No W1292-00/C-002.

These monitoring holes would consist of slotted PVC inserted down a large diameter borehole to allow water samples to be taken. The use of any existing boreholes may be feasible if they are deep enough and still open.

In the deepest section of the embankment (south eastern corner), it is suggested a level control point be established to enable regular (six monthly) monitoring of the embankment to be undertaken. A line of pegs should be installed on each successive berm.

## 4.4 Stability Analysis

### 4.4.1 Method of Stability Analysis

A stability analysis of the proposed construction method has been carried out using a computer model which analyses the stability of potential circular slip planes within the mass of the tailings dam by both the Swedish method and Bishop's simplified methods.

The following range of parameters have been utilised in the model for each of the separate tailings dam components.

(i) Mullock Starter Embankment

| | | |
|---|---|---|
| Cohesion (c) | = | 5 to 0 kPa |
| Angle of internal friction ($\phi$) | = | 33 to 38° |
| Pulk density ($\gamma$) | = | 2.0 to2.3 t/$m^3$ |

(ii) Tailings Contained Within the Dam

| | | |
|---|---|---|
| Cohesion (c) | = | 5 to 10 kPa |
| Angle of internal friction ($\phi$) | = | 28 to 18° |
| Bulk density ($\gamma$) | = | 1.4 to 1.85 t/$m^3$ |

Parameters (ii) and (ii) have been selected from experience and are believed to be conservative. It is recommended that the appropriateness of these parameters be checked during construction.

The phreatic surface used in the analysis was the surface of the top layer of the dam, extending through the embankments to the ground surface.

The total number of potential slip circles analysed was 200 with 50 slices being analysed in each circle. A copy of the computer printouts showing results of the analysis are included in this report as Plate 6 to 11.

#### 4.4.2 Results of Stability Analysis

Results of the analysis indicate that safety factor against a deep seated failure through the tailings embankments and deposited tailings in excess of 1.9. A minimum factor of safety of 1.5 is recommended for these structures.

With a reduced phreatic surface, factors of safety could be increased. The tailings dam management contributes significantly to the stability of the structure. Details of appropriate management practices are provided in the document Yakabindie Nickel Project Tailings Dam Operations Manual.

## 5.0 MANAGEMENT, INSPECTION AND MAINTENANCE

### 5.1 Management

The active life of the tailings dam is advised to be at least 15 years.

During this time many changes can take place in the materials being placed which effect the stability of the embankment. The quantity and physical properties of the tailings placed in the dam may change over the years for many reasons. Such changes may alter the stability of an embankment, resulting in variations in the factor of safety.

#### 5.1.1 Quantity of Tailings

Increased tonnage from the mill without a commensurate increase in the area available to store tailings is one of the most common changes. This results in an increase in the annual rise of the tailings and reducing the factor of safety.

#### 5.1.2 Physical Properties of Tailings

A change in grind with an increase in the minus 75 micron fraction can cause a higher phreatic surface, a possible decrease in the efficiency of the drains, and increased seepage through the starter dam fill.

Any one or a combination of these changes can result in a reduced stability of the embankment. **It is therefore important that a continuous programme of inspection and maintenance of the embankment, the decant system and central sump be started at the beginning and maintained throughout the life and even after the abandonment of the storage.** The embankments should be thoroughly inspected by an experienced Engineer at least once every two years or for a 5m rise, whichever is the sooner, during the active life of the dam.

## 5.2 Inspection

### 5.2.1 Daily Inspections

Daily inspection should be made of the spigots, the position of the water pond in relation to the decant or the tailings area boundary, the decant system and central sump. The quality and quantity of water returns should be checked daily.

### 5.2.2 Two Yearly Inspection

The objectives of the two yearly inspection programme should be to answer the following questions:

(i) Are there any major changes in the foundation or the embankment that were not anticipated in the design such as heaving of the foundation at the toe, longitudinal or transverse cracks in the crest, or excessive seepage ?

(ii) Have the material characteristics changed; and if so, how will these changes affect the stability ?

(iii) Is the distribution of the material into the pond as called for in the design; and if not, how will it affect stability ?

(iv) Are the slime and water pond where they should be in relation to the perimeter embankment ?

(v) Is the dam construction rapid enough to keep the slimes and water well back from the embankments ?

(vi) Can the decants handle the storm runoff in addition to the reclaim water ?

(vii) Is there seepage on the downstream face of the embankment wall ?

(viii) Are the decant lines intact and free of cracks that could allow sand to pipe into the lines and cause a total failure ?

(ix) Is the phreatic surface (within the dam) as planned; or is there excess pore water pressure from within the foundation or perched water tables ?

(x) Have there been variations in the water levels or a sudden rise in the water level in the monitoring boreholes, the appearance of any new springs, or new seepage on the face of the embankments or foundation ?

(xi) Has there been an increase in embankment movement as indicated by the surface control points or slope indicator ?

(xii) Is there evidence of borrow from the toe or any other area of the embankments that might affect stability ?

(xiii) Is the embankment steeper than planned ?

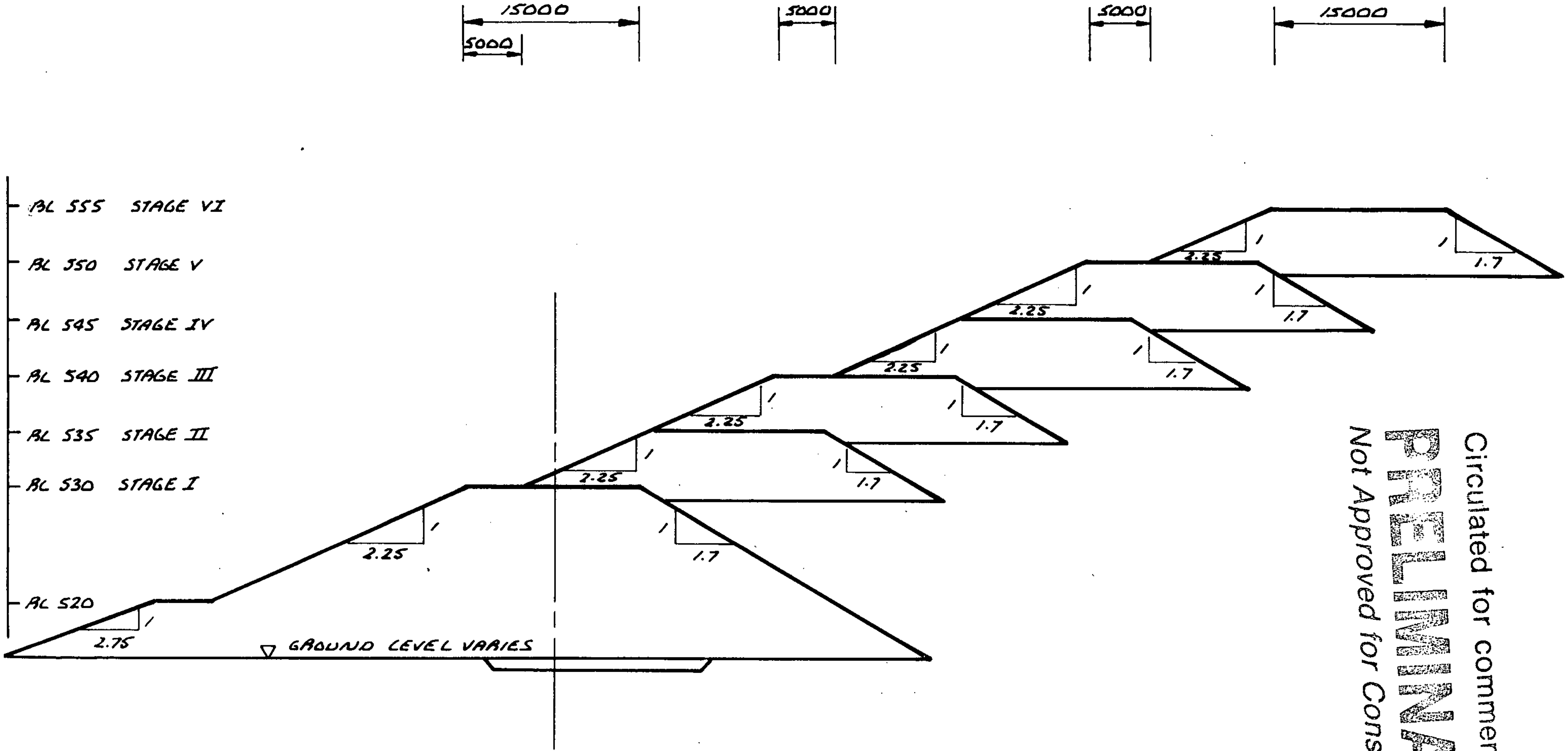
## 6.0 DRAWINGS AND PLATES

The following list is a summary of drawings and plates provided for the construction of the decant structure and peripheral embankments as well as continued raising (heightening) of the decant.

| | | |
|---|---|---|
| Drawing No. | W1292-00/C-002 | Plan - Stage I Earthworks |
| | W1292-00/C-003A ) | Embankment Sections and Details |
| | W1292-00/C-003B ) | |
| | W1292-00/C-004 | Decant Details |
| | W1292-00/C-005 | Upstream Toe Drain, Downstream Toe Drain, Return Water Sump and Silt Trap Details |
| | W1292/00/C-006 | Plan Stages II to VI Earthworks |

| | |
|---|---|
| Plate 1 | Design Concept |
| Plate 2 | Detail of Decant Water Intake |
| Plates 3 to 5 | Graphs o Storage Volume vs Height |
| | o Storage Life vs Height |
| | o Storage Volume vs Embankment Volume |
| Plates 6 to 10 | o Stability Analysis |

* * * * *

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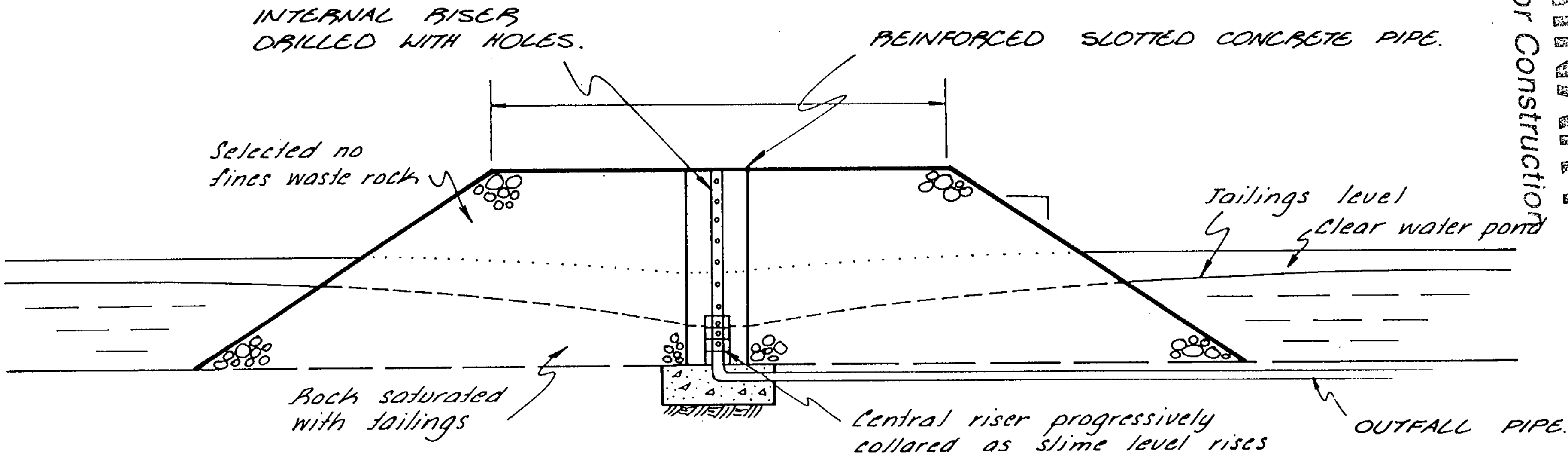
DESIGN CONCEPT
YAKABINDIE NICKEL PROJECT

Soil & Rock Engineering Pty. Ltd.

PLATE I




YAKABINDIE NICKEL PROJECT
JOB No.: 2488/00

# CENTRAL DECANT WHEN OPERATING

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PLATE 2

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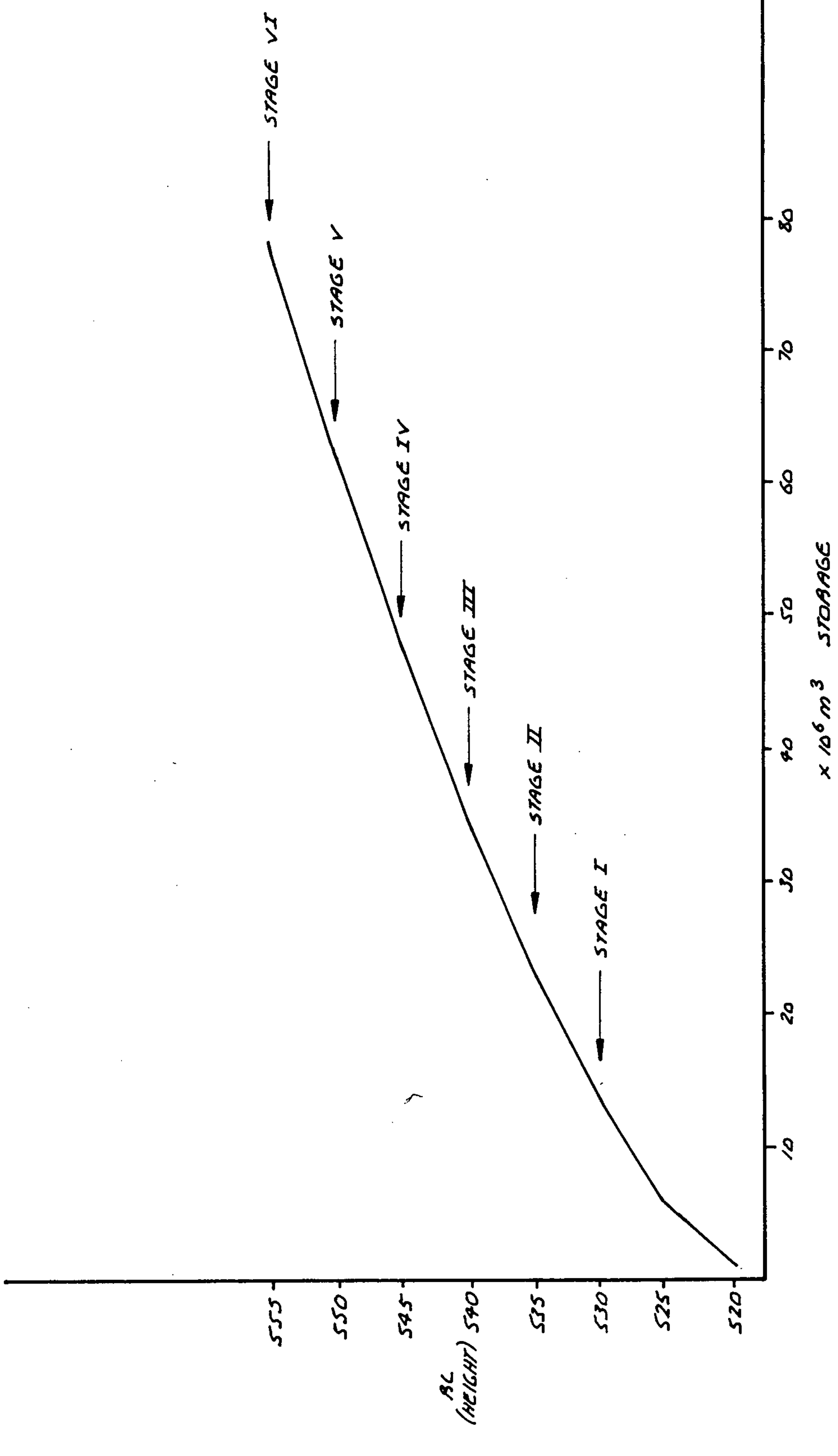


STORAGE VOLUME Vs. HEIGHT
YAKABINDIE NICKEL PROJECT

Soil & Rock Engineering Pty. Ltd.

PLATE 3

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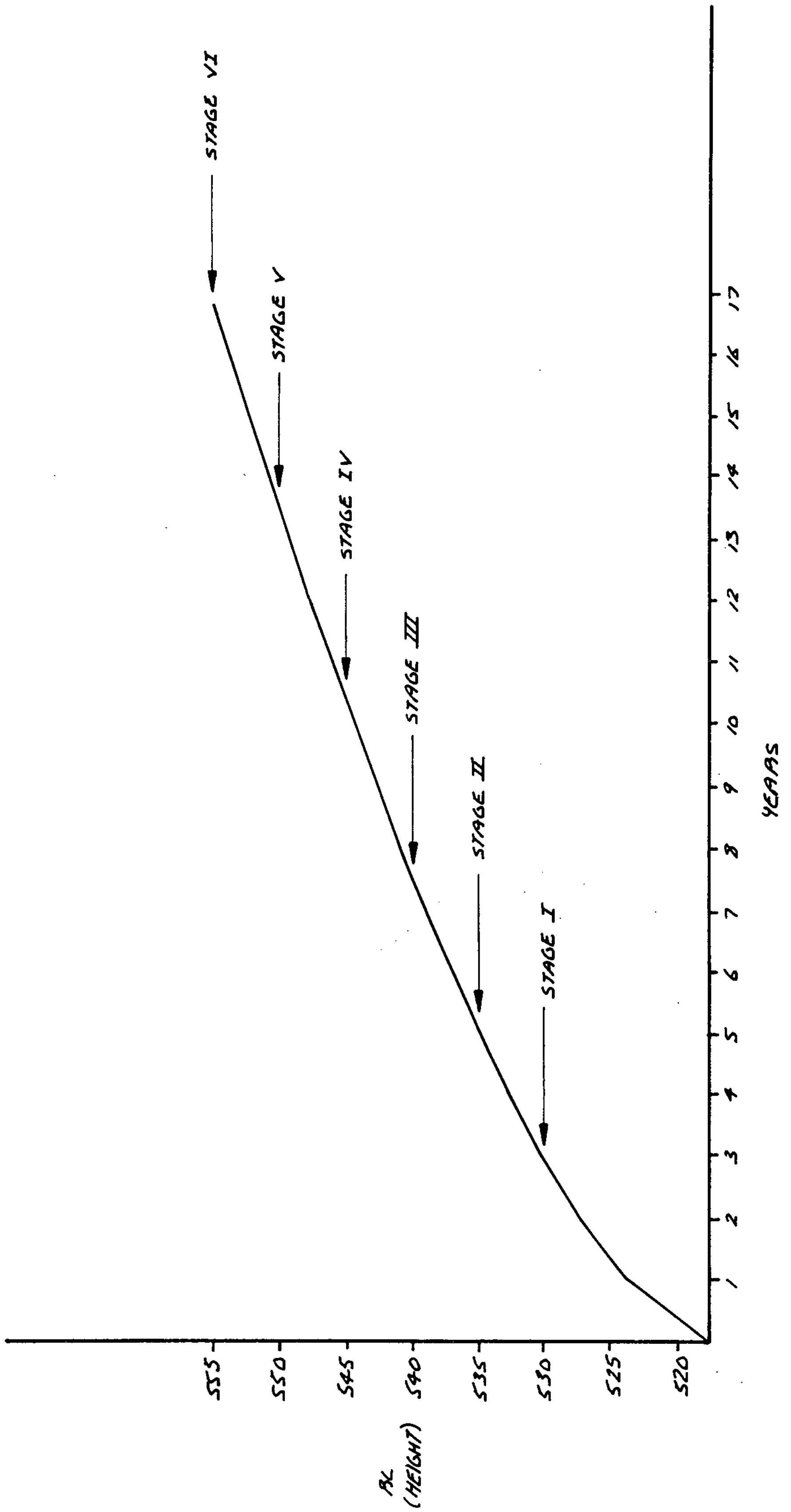
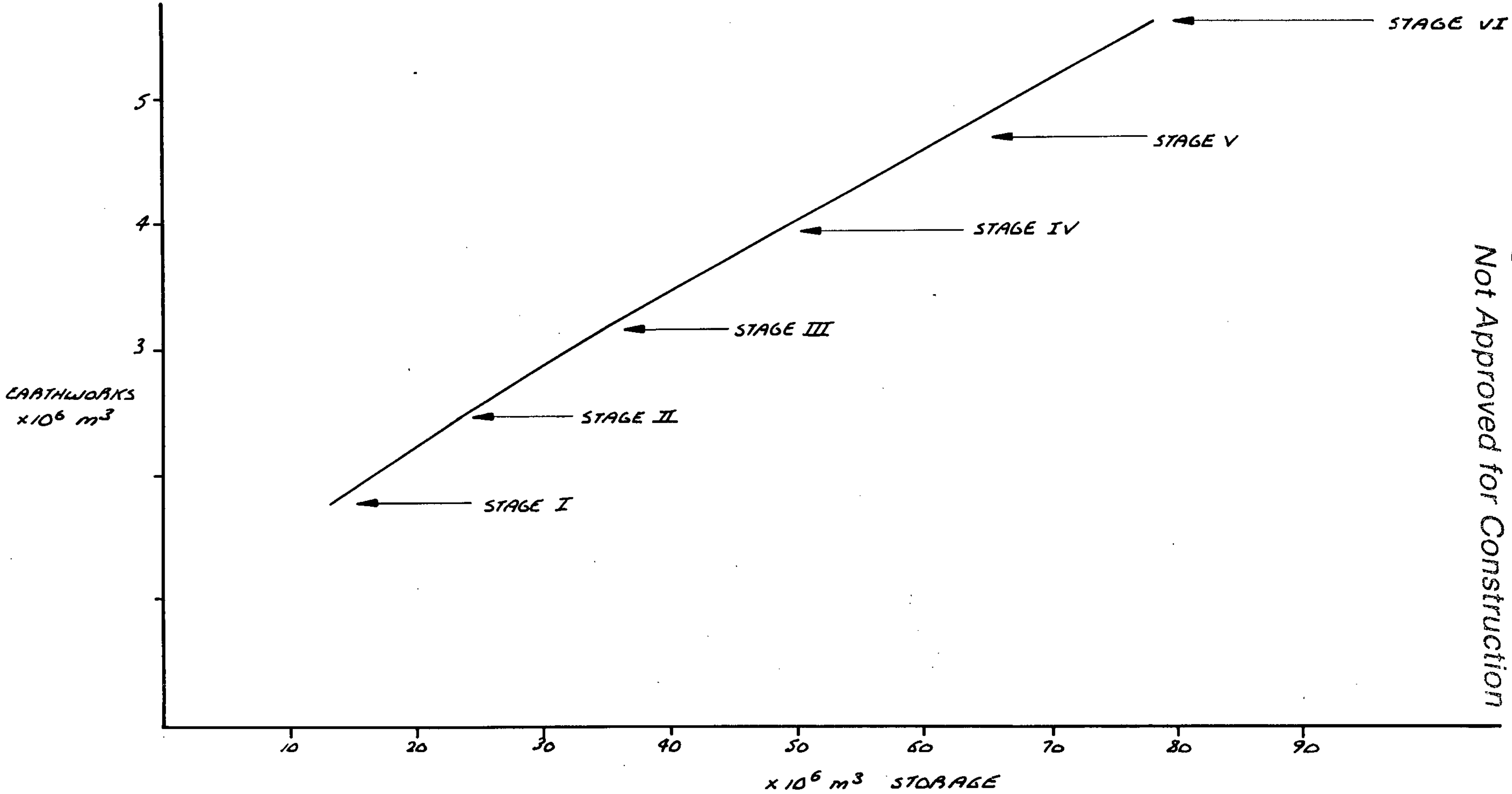



STORAGE LIFE Vs. HEIGHT
YAKABINDIE NICKEL PROJECT

Soil & Rock Engineering Pty. Ltd.

PLATE 4

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# STORAGE VOLUME Vs EMBANKMENT VOLUME
# YAKABINDIE NICKEL PROJECT

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PLATE 5

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PROJECT YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

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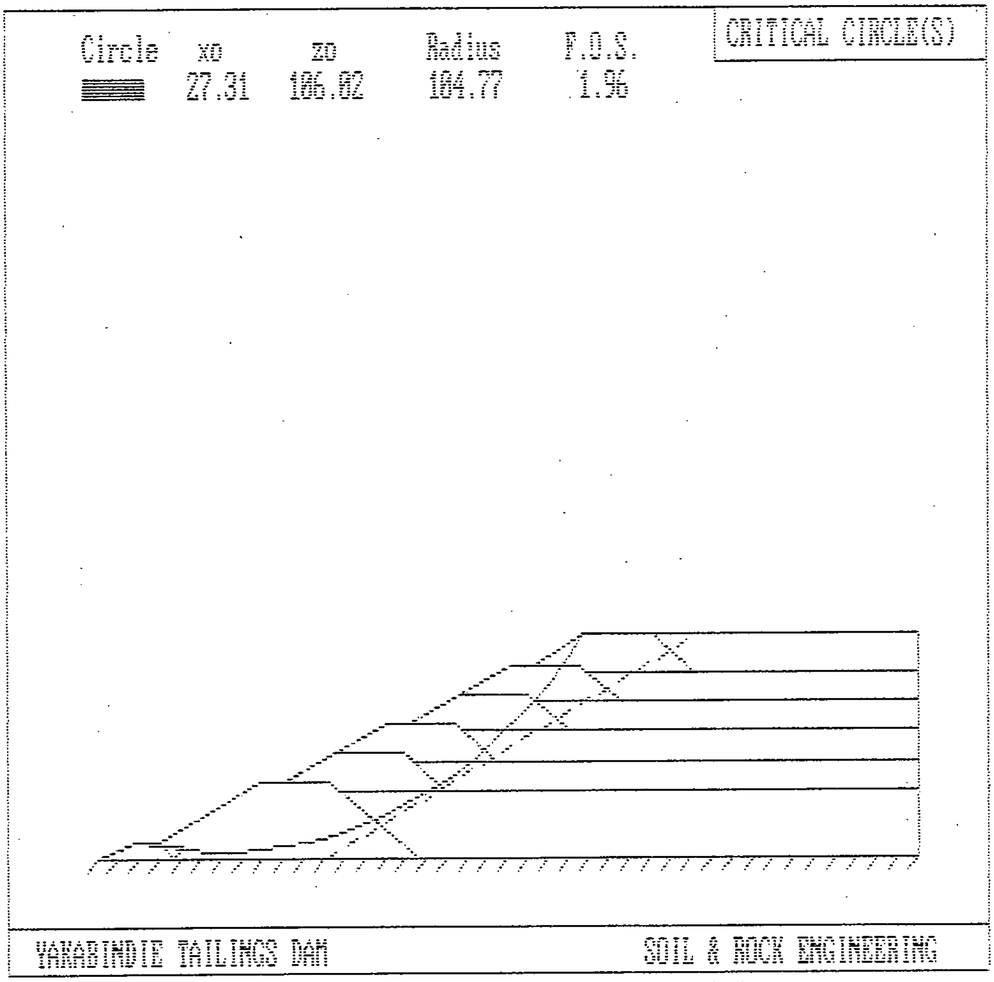
CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: SLOPE STABILITY ANALYSIS



Our ref: 2488/00/T/CL/jb
C2488T/LOG



PROJECT YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: SLOPE STABILITY ANALYSIS

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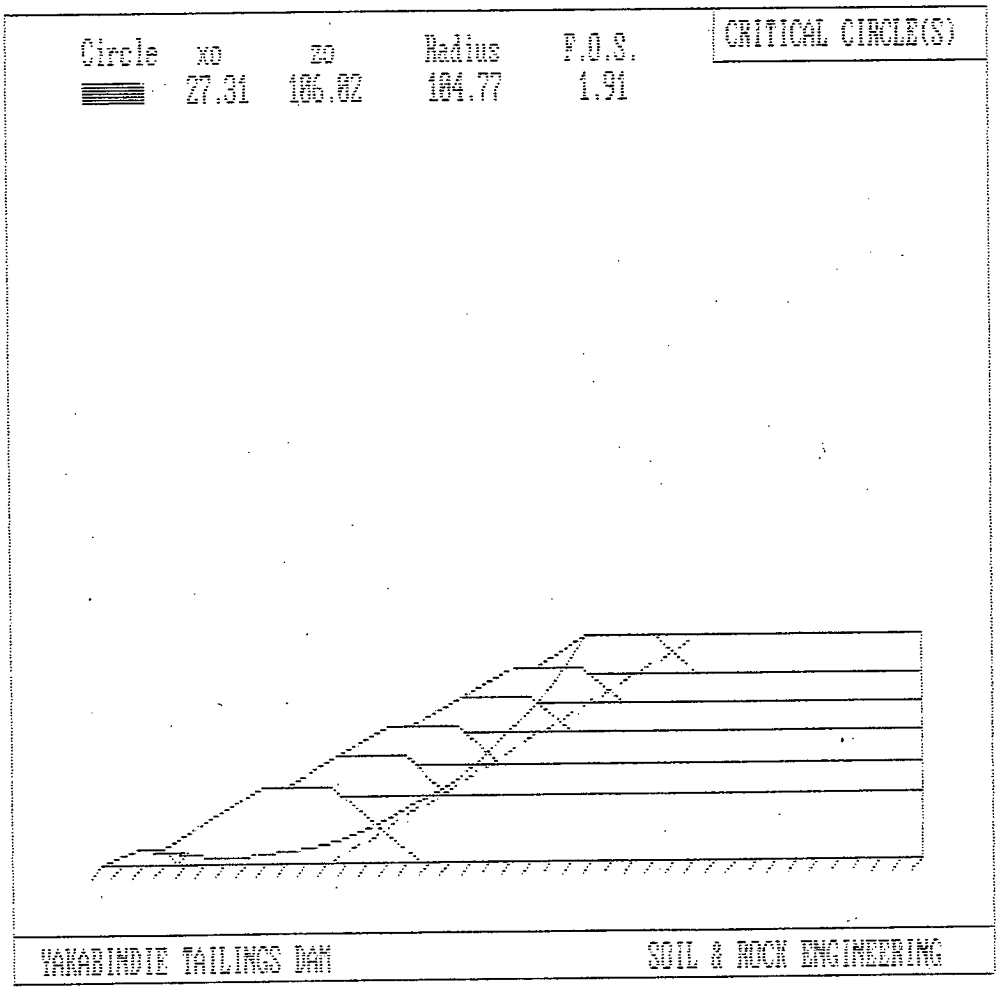

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C2488T/LOG



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PRELIMINARY
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PROJECT: YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

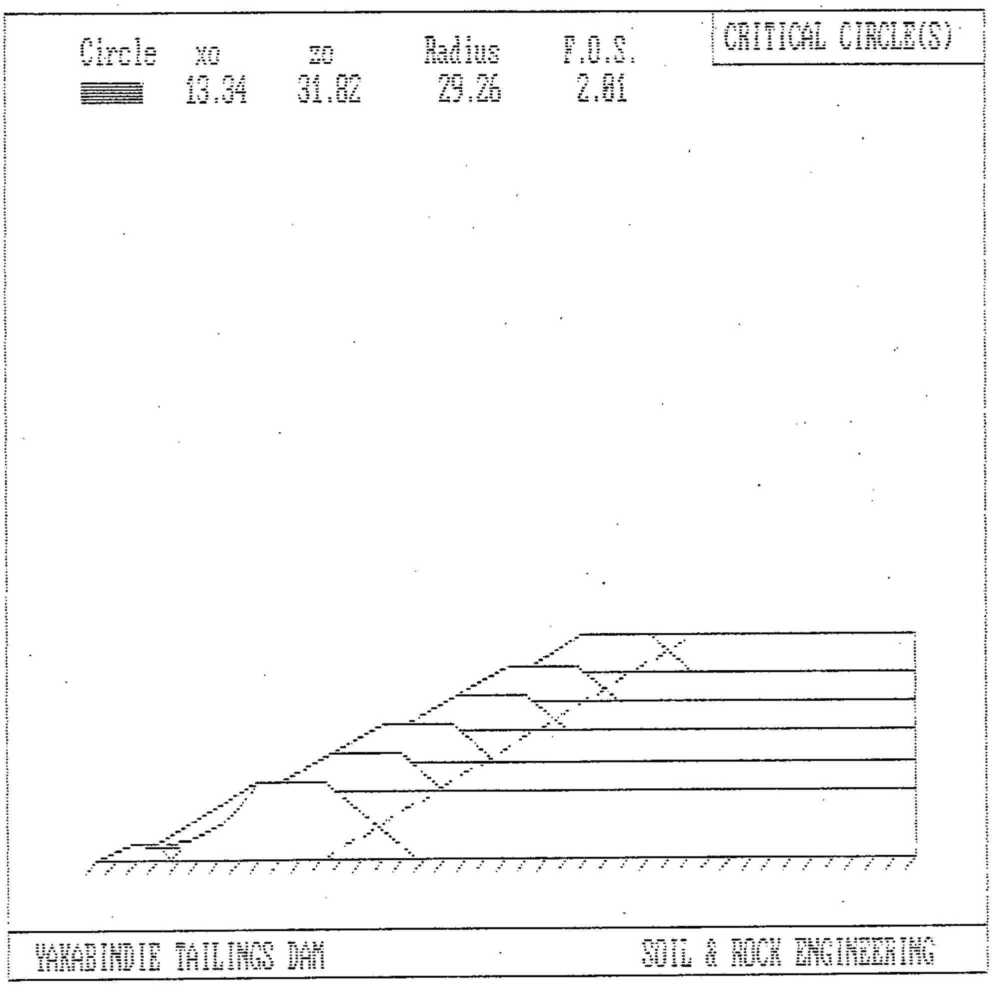
CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS: MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: SLOPE STABILITY ANALYSIS

---




Soil & Rock Engineering Pty. Ltd.

PLATE 8

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PROJECT YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

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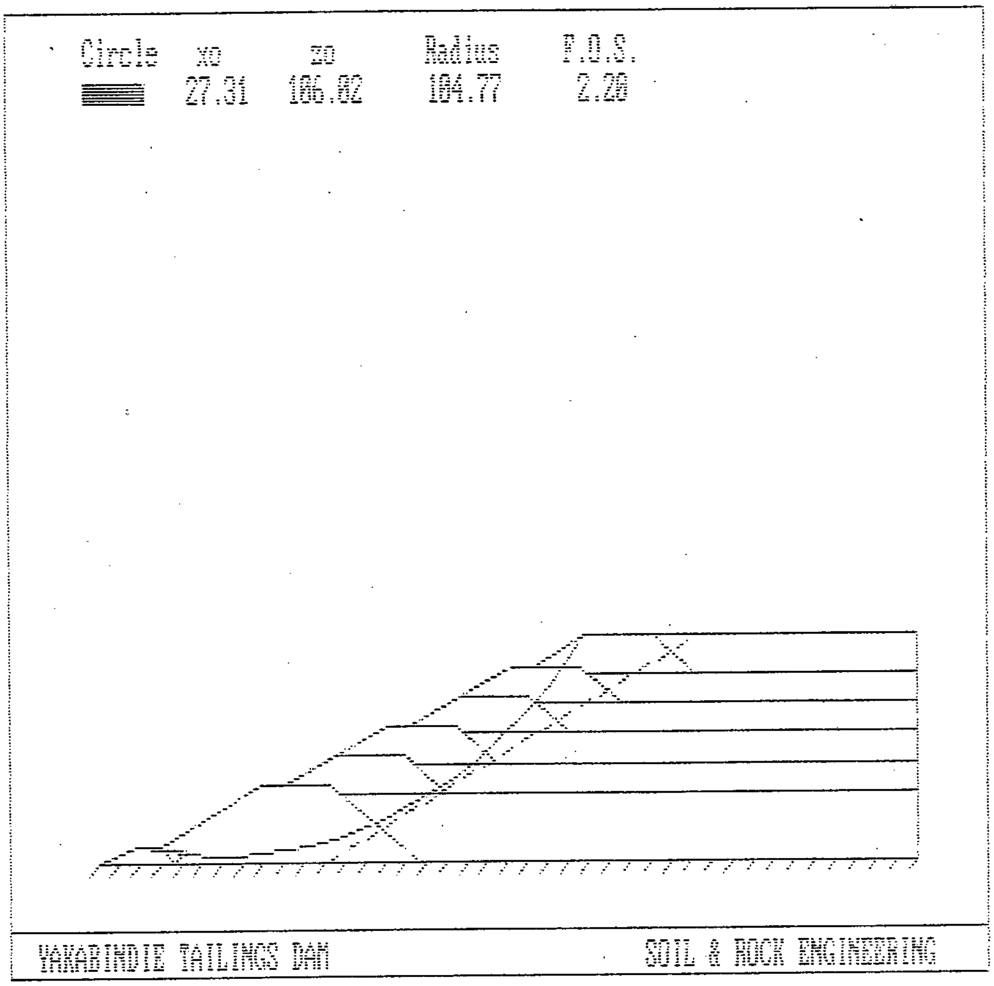
CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: SLOPE STABILITY ANALYSIS



Our ref: 2488/00/T/CL/jb
C2488T/LOG



PROJECT: YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

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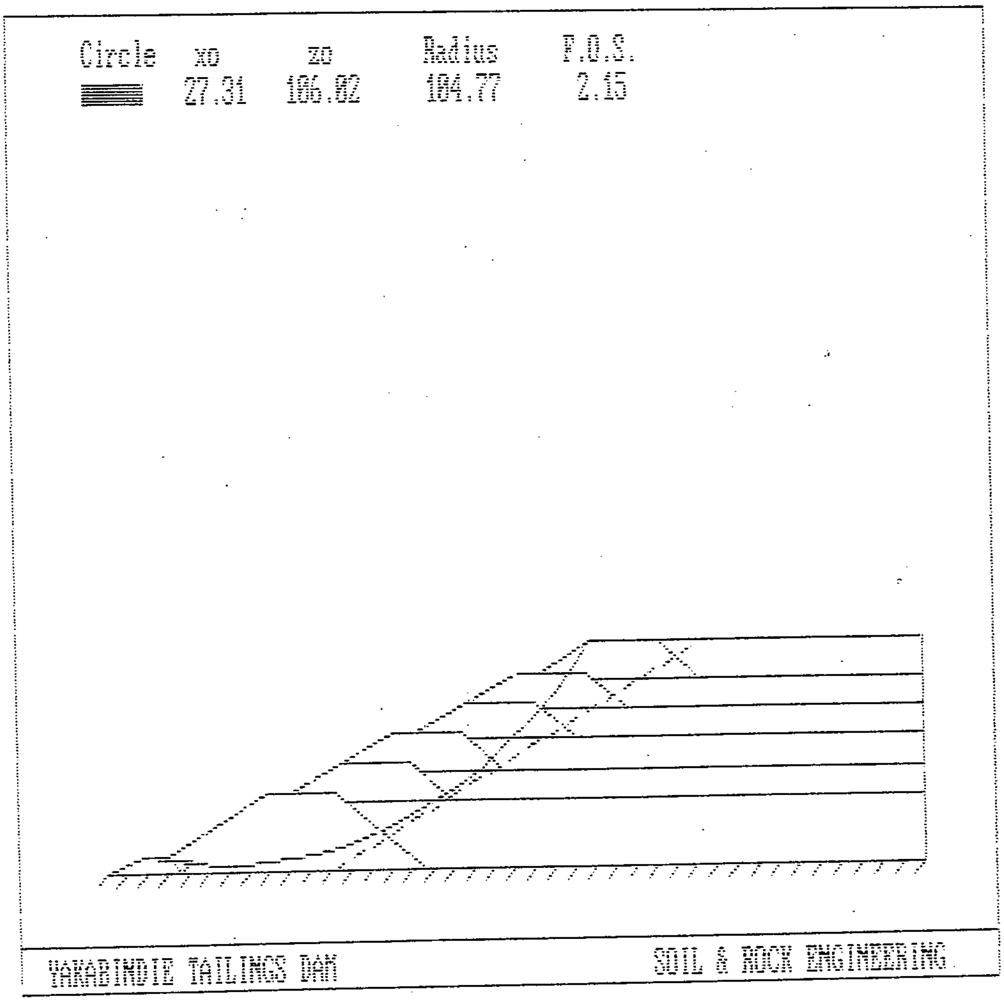
PRELIMINARY
Not Approved for Construction

CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS: MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: SLOPE STABILITY ANALYSIS




Soil & Rock Engineering Pty. Ltd.
PLATE 10

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C2488T/LOG



PROJECT YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: SLOPE STABILITY ANALYSIS

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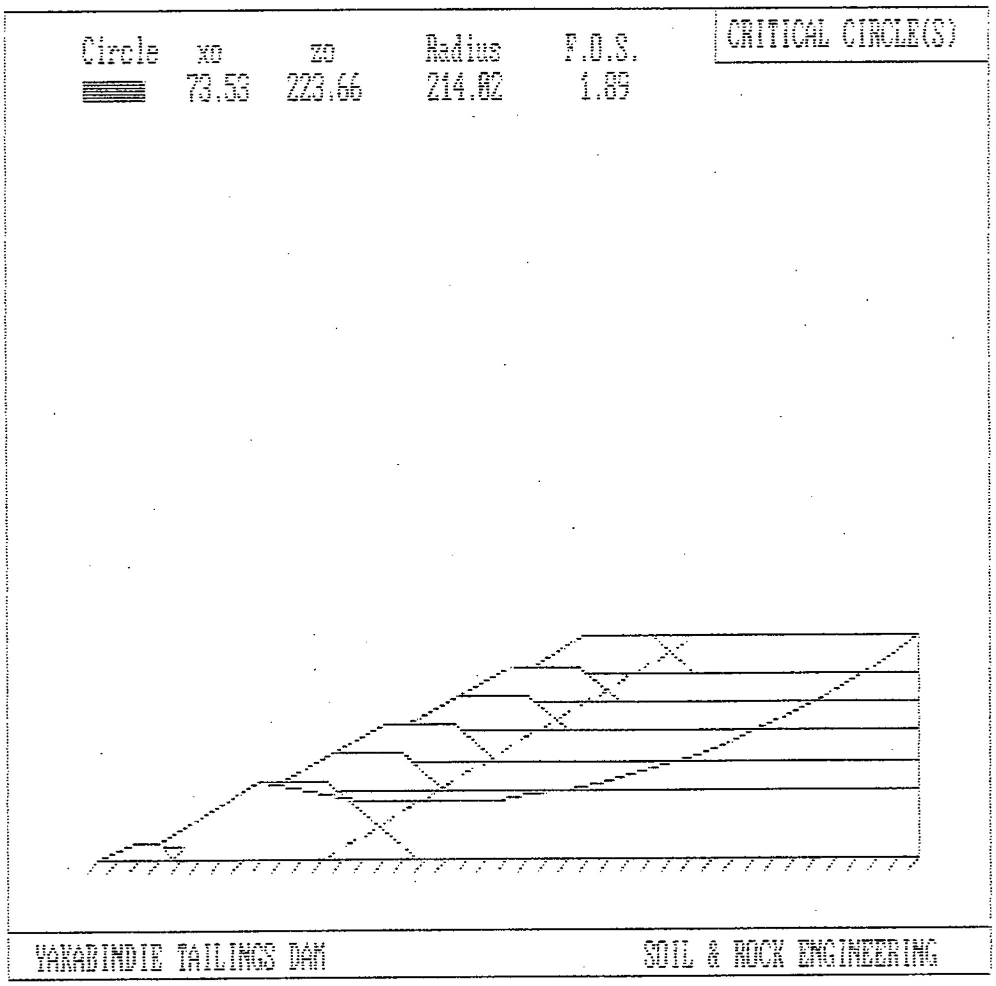


Soil & Rock Engineering Pty. Ltd.
PLATE 11

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# YAKABINDIE NICKEL PROJECT
# TAILINGS DAM
# CONSTRUCTION DOCUMENTATION

Report prepared for:

DOMINION MINING LIMITED
10 Richardson Street
WEST PERTH WA 6005

Report prepared by:

SOIL AND ROCK ENGINEERING PTY LTD
CONSULTING GEOTECHNICAL ENGINEERS
AND GEOLOGISTS
4TH FLOOR CENTREPOINT TOWER
123 COLIN STREET
WEST PERTH WA 6005

Ref: 2488T/0.2/CL/jb
Date: 20th April 1990

Soil & Rock Engineering Pty. Ltd.

## TABLE OF CONTENTS

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PRELIMINARY

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TABLE OF CONTENTS (contd)



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PRELIMINARY

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Our ref: 2488T/0.2/CL/jb
C2488B/SUM

20th April 1990

PROJECT: YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS: MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: CONSTRUCTION DOCUMENTATION
TAILINGS DAM EMBANKMENT CONSTRUCTION
STAGED CONSTRUCTION (I TO VI.)

---

## 1.0 INTRODUCTION

This specification covers all stages of construction for the tailings dam embankments and is to be read in conjunction with the drawings.

## 2.0 ATTACHMENTS

The following attachments complete this specification:

- Construction Drawings for Stage I

| | |
|---|---|
| W1292-00/C-002 | Plan - Stage I Earthworks |
| W1292-00/C-003A & 003B | Embankment Sections and Details |
| W1292-00/C-004 | Decant Details |
| W1292-00/C-005 | Upstream Toe Drain, Downstream Toe Drain, Return Water Sump and Silt Trap Details |
| W1292-00/C-006 | Plan Stages II to VI Earthworks |

## 3.0 GENERAL

### 3.1 Scope

The Contract shall include the provision of all necessary materials, labour, plant, equipment and cartage to complete the works shown on the drawings and described in this Specification. All works shown on the drawings but not referred to in this Specification, or referred to in this Specification but not shown on the drawings, shall be included. The majority of preparatory work will be completed under Stage I. Stages II to VI works will mainly involve bulk earthworks to extend and raise the embankments.

### 3.2 Code of Practice

Unless otherwise specified, or shown on the drawings, the Contractor is to provide all materials and carry out all the work in accordance with the latest revisions of the relevant Australian Standard Codes.

### 3.3 Site Inspection

The Contractor shall inspect the site and must allow for the following factors in his price:

(i) the nature and requirements of the work to be done;

(ii) all conditions on and adjacent to the site;

(iii) access to the site;

(iv) the types of soil and vegetation to be dealt with;

(v) the expected or known water table;

(vi) the nearest source of any suitable fill material which complies with this Specification; and

(vii) the nearest source of water for construction purposes.

## 3.4 Safety

The Contractor shall:

(i) carry out the works in a safe manner; and

(ii) conform to all relevant Acts or Statutes of Parliament, Regulations, By-Laws or Orders relating to the safety of persons and property on or about the site.

## 3.5 Site Description

The site is approximately 310 hectares in total area and is located adjacent to the proposed nickel plant of Dominion Mining Limited at Yakabindie.

The area has an overall fall to the east and is covered with sparse vegetation, the ground surface covered by rocks and soil.

## 4.0 SITE PREPARATION

### 4.1 Site Clearance

Remove all vegetable matter and scrub from beneath the embankment limits of the proposed tailings embankments. The area to be cleared shall extend approximately 2m past the toe of the embankment.

Remove all solid obstructions, tree stumps, roots and logs from beneath the area of the works. Water and compact the area prior to fill placement. Foundation preparation is detailed in clause 7.1.

### 4.2 Blasting

Some blasting is anticipated and hard ripping may be encountered.

Excavation for the return water sump is approximately 3.5m below existing ground level. If hard rock is encountered, it is suggested that the shape of the excavation be changed to maintain the same capacity rather than blast to the specified RL.

Excavation for the decant structures is approximately 1m for each decant. If hard rock is encountered, it is suggested that hydraulic or pneumatic rock breaking equipment is used, to minimise overexcavation and subsequent backfilling.

### 4.3 Dewatering

Allow for keeping water from excavations by pumping, dewatering, or other suitable means, and adequately dispose of it clear of the works.

## 4.4 Excavation - General

All excavations shall be to the minimum lines and grades shown on the drawings or as required by the Engineer as work progresses.

During the progress of the works, the Engineer may find it necessary to revise the lines, levels and grades of any part of the excavations because of the conditions revealed by the works.

The Contractor shall accept reasonable delays due to inspection and checking of any part of the excavations to determine grades and levels.

The Contractor shall not excavate beyond the lines and grades shown without the prior written approval of the Engineer.

Excess excavations shall be backfilled with approved material to the satisfaction of the Engineer.

## 4.5 Excavation - Trenches

The excavation of any trenches, especially those to take pipework shall be to a regular finish, with no sudden changes in direction. Excavation shall be to an even grade with no abrupt slope changes unless specified in the specification or on the drawings.

## 5.0 SURVEY

### 5.1 Setting Out

The Contractor shall be wholly responsible for the setting out of his works in accordance with the terms of the specification. Although the Engineer will cause such setting out to be checked from time to time, such checking will not relieve the Contractor of full responsibility for the accuracy of such setting out.

The Contractor shall be responsible for the protection of all permanent and temporary beacons or bench marks.

### 5.2 Measurement - General

The Contractor shall perform all ground surveys using conventional and agreed surveying techniques. The surveys shall be carried out prior to the commencement of the item of work and at the completion of the item of work. The Contractor shall submit his survey data and calculations to the Engineer.

The Engineer may undertake his own survey of any item, either in conjunction with the Contractor, or separately. The Contractor and Engineer shall agree on the results of measurement surveys that are carried out prior to any works being covered up or within seven (7) days of a survey being undertaken. Should agreement not be reached, the difference shall be documented such that the matter can be later decided without disruption to the Contractor's programme.

## 6.0 MATERIALS

### 6.1 General

All materials shall be stockpiled, transported and placed in such a manner as to minimise segregation.

### 6.2 Material Quality

All material used to construct the embankments of the tailings dam shall be impermeable, well graded overburden waste material. The Engineer will direct the Contractor to a suitable source of clayey material.

Sand for pipe bedding shall be clean free-draining material with a maximum size of 5mm or as otherwise specified by the Engineer.

## 7.0 DAM CONSTRUCTION

### 7.1 Foundation Preparation

Excavation of the foundation area of the tailings dam embankment shall be carried out such that the base of the embankment as shown on the drawings is embedded into the stratum by not less than 1000mm, or to refusal. All areas to receive fill shall be left in a clean and suitable condition to allow the easy placement of fill.

## 7.2 Fill Placement

All fill material shall be placed in approximately horizontal layers not exceeding 500mm loose lift thickness. Each lift shall be compacted by a minimum of 8 passes of a heavy duty roller. Placement should be continuous. If a break in fill placement allows the exposed surface to dry, it should be lightly tyned, watered and compacted prior to fill placement recommencing. No oversize rock is to be placed into the embankments. Largest size should be 150mm. Drawing Nos. W1292-00/C-003A and W1292-00/C-003B outline the grades and lines to which the embankments are to be constructed.

## 7.3 Tolerances

The maximum permissible horizontal deviation from the finished lines or zone boundaries shall be -0m to +0.5m.

Vertical deviation shall be -0m to +0.2m, provided no abrupt changes in slope or level are present on any finished surface.

## 7.4 Measurement, Excavation and Fill

Refer also to Section 5.2.

No payment shall be made for over-excavation unless prior written approval has been supplied and granted by the Engineer.

Measurement for payment of all embankment fill material shall be made for the volume in cubic metres of compacted material, measured in place and only to the lines and grades required.

Initial and/or final surveys must be undertaken and approved by the Engineer prior to the removal or placement of any material, especially where such action will destroy or cover the surface just surveyed.

All survey checks or quantity measurements must be supplied to the Engineer, suitable time must be given to the Engineer to allow such calculations to be checked and approved prior to the works being covered or removed.

## 8.0 COMPACTION CONTROL

### 8.1 Compaction Method

8.1.1 The moisture content of the embankment construction material, approved for use in embankment construction, shall be within 2% of the optimum moisture content as determined from laboratory test E1.1 of AS 1289 (1976).

8.1.2 The material should be placed in loose layer thicknesses not exceeding 500mm. Each layer shall be compacted with 8 passes of a CA35 or equivalent.

8.1.3 After the construction of the first metre of embankment, 6 test pits shall each be excavated to 500mm. Each pit shall be filled with water and the time shall be measured for the water to drain away.

8.1.4 A Geotechnical Engineer shall nominate locations of the pits and shall be present during the initial construction stages and during the percolation testing.

8.1.5 The appropriateness of the lift thicknesses and the compactive effort shall be progressively assessed during embankment construction.

Clean rockfill around the decant shall be carefully placed to avoid damage to the decant structure.

## 8.2 Inspection and Testing

Tests shall be carried out to such a degree as to satisfy the Engineer that the above criteria on material quality and compaction are met.

Permeability quality control shall be carried out by seepage testing with compaction quality control being undertaken as appropriate (a calibrated Clegg Hammer may be used).

# 9.0 PIPEWORK

## 9.1 General

Furnish all labour, materials, tools and equipment to place and construct all pipework.

## 9.2 Materials

Each decant outfall consists of 1 No. 300mm diameter uPVC Class 12 rubber ring joint pipe from the decant structures.

## 9.3 Construction

The decant pipes shall be laid at an even grade between the central decants and the return water sump. Pipes will be laid predominantly on the natural ground surface, which shall be free of all stumps, cobbles, boulders, rocks or any other irregularity, and laid to the appropriate manufacturers specification.

Where bedding is required adjacent to the decant structures, the pipes shall be laid on cement stabilised compacted sand complying with the requirements of Section 6.2

The pipes will be placed through the southern embankment, at two locations.

The trench through the southern embankment for the 1 No. 300mm decant pipes and 1 No. 150mm upstream toe drain pipe shall have an approximate width of 2000mm and shall be excavated when the fill levels are at RL 520m (Decants 1 to 4) and RL 523.3. (Decant 5 to 8). Material excavated from the trench shall be stockpiled for re-use in the construction of the dam wall.

Once excavated, clean sand shall then be placed in a compacted layer of 50mm and shaped to provide full support for the barrel of the pipe.

Prior to backfilling, the pipe shall be tested for leaks. Any such occurrence shall be rectified and then re-tested.

Prior to trench backfilling, a concrete cut-off is to be installed to reduce seepage losses through the trench. The cut-off is to be formed against and into either natural ground or well compacted fill.

Once the pipes are tested, and the concrete cut off installed backfilling with overburden waste shall be undertaken, with 100mm thick layers being hand tamped from the pipe invert level to 100mm above the top of the pipe around the pipe, and small plate compactors used in the area between the pipes and trench sides as appropriate.

The remainder of the trench shall be carefully backfilled with overburden waste to the surrounding ground level. Extreme care shall be taken to avoid any damage to the installed pipework when backfilling and compacting around and above the pipes.

Normal embankment construction can recommence once the trench has been backfilled to the surrounding construction level.

Any pipes which are not laid to line, level or grade, or are damaged or displaced during backfilling or other operations by the Contractor in the course of his work, shall be removed and replaced by the Contractor at his expense. The Contractor shall be responsible for any excavation of backfilling necessary for the removal and replacement of any pipe.

The contractor shall ensure that all other pipework is placed in accordance with the appropriate recommendations of the manufacturer.

On completion of pipe laying and testing, the decant lines shall either be individually staked and tied at each joint or covered with 1m of sandy soil which is free of cobbles, boulders or rocks. The valves near the return water sump should be closed and the decant pipes filled with water to prevent floating during initial tailings deposition.

## 10.0 RETURN WATER SUMP

Construct the return water sump in the location and to the details shown on the drawings. The shape of the sump may vary on site, as directed by the Engineer, so as to suit rock excavation. All surplus excavated material shall be removed to spoil.

The excavated slopes of the sump are to be left smooth and regular to allow placement of a clay or polyethylene liner as appropriate.

## 11.0 COMPLETION

Clean up all rubbish, remove all plant and supply materials, trim all banks neatly, spread all excavated material not specified to be removed from the site and leave the site in a clean and tidy condition.

## 12.0 ESTIMATE OF QUANTITIES

A preliminary estimate of quantities has been provided to allow material requirements to be gauged for Stage I Construction. The figures have not been calculated by a Quantity Surveyor and are provided as preliminary information only.

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# ESTIMATE OF QUANTITIES

## STAGE 1 CONSTRUCTION

## 1.0 EARTHWORKS

### 1.1 Embankment Construction

Borrow, Moisture Condition, Transport, Place and Compact Earthfill

| | |
|---|---|
| Main Embankments | 1,780,000$m^3$ |
| Central Accessway | 71,500$m^3$ |
| Decant Accessway | 200,000$m^3$ |
| Return Water Sump Bund | 3,000$m^3$ |
| Downstream Bund/Road | 17,000$m^3$ |
| (assume 6.0m width and 0.6m minimum height) | |

### 1.2 Excavate and remove to spoil

| | |
|---|---|
| Decant (5.5$m^3$) | 44$m^3$ |
| Return Water Sump | 10,000$m^3$ |
| Downstream Toe Drain (Vee Drain) (linear metres) | 4,565m |

## 2.0 PIPEWORK

### 2.1 Decant Outfall

| | |
|---|---|
| 300 NB uPVC Class 12 | 5,675m |
| Concrete Cut-off (2 No @ 1.40$m^3$ each) | 2.80$m^3$ |
| Excavate to place pipe through embankments to form concrete cut off | 700$m^3$ |
| Backfill around pipes through | 700$m^3$ |

## ESTIMATE OF QUANTITIES (contd)

## STAGE 1 CONSTRUCTION

### 2.2 Decant Structure

| | |
|---|---|
| Reinforced Concrete Base for 8 no Decants (5.2m$^3$ each) | 42m$^3$ |
| 1.8m NB Class x concrete pipe internal flush joints (Standard Decant Pipe with three rows of slots) | 27 No. |
| 300mm NB uPVC Lobster Back 90° Elbow male and female ends | 8 No. |
| 300mm NB uPVC Class 12 pipe straight section no sockets | 16m |
| 300mm NB FRC Decant Sleeves 150mm long | 200 No. |
| 300mm NB uPVC Class 6 solvent weld socket with 80mm holes as per Drawing No. W1292-00/C-004 | 29m |
| Locating Spider as per Drawing No W1292-00/C-004 | 8 No. |
| Clean Rock Fill around Decant Structures | 15,000m$^3$ |
| Concrete plugs in base of Decant (0.6m$^3$ each) | 5.0 m$^3$ |

### 2.3 Upstream Toe Drain

| | |
|---|---|
| Excavate Toe Drain (linear metres) | 4,750m |
| 150mm uPVC Class 6 Slotted Pipe | 4,750m |
| 150mm uPVC Class 6 Pipe | 200m |
| 150mm uPVC Class 6 Elbows | 6 No. |
| 150mm uPVC Class 6 Tee Pieces | 1 No. |
| Filter Sand and Gravel | 3,000m$^3$ |
| Filter Cloth (linear metres) | 15,000m$^2$ |

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# YAKABINDIE NICKEL PROJECT
# TAILINGS DAM
# OPERATIONS MANUAL

Report prepared for:

DOMINION MINING LIMITED
10 Richardson Street
WEST PERTH WA 6005

Report prepared by:

SOIL AND ROCK ENGINEERING PTY LTD
CONSULTING GEOTECHNICAL ENGINEERS
AND GEOLOGISTS
4TH FLOOR CENTREPOINT TOWER
123 COLIN STREET
WEST PERTH WA 6005

Ref: 2488T/0.3/CL/jb
Date: 20th April 1990

Soil & Rock Engineering Pty. Ltd.

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Our ref: 2488T/0.3/CL/jb
C2488C/SUM

20th April 1990

PROJECT YAKABINDIE NICKEL PROJECT
FEASIBILITY STUDY

CLIENT: DOMINION MINING LIMITED

PROJECT MANAGERS MINPROC JR JOINT VENTURE

LOCATION: YAKABINDIE VIA LEINSTER

SUBJECT: OPERATIONS MANUAL

## 1.0 INTRODUCTION

This operations manual has been prepared as a guide to plant staff in the operation and management of the tailings dam. Reference should be made to the report titled "Yakabindie Nickel Project Tailings Dam Design", reference 2488T/0.1/CL/jb, dated 20th April 1990 and to the associated drawings W1292-00/C-002 to W1292-00/C-006, to ensure that the design concepts and management requirements are fully understood in order to achieve the design objectives, which are:

(i) allow the tailings dam to function with minimal daily input, while maintaining stability of the tailings dam;

(ii) maximise water return from the tailings; and

(iii) maximise storage capacity of the tailings dam.

## 2.0 SUMMARY OF OPERATIONAL PROCEDURES

The following is a summary of operational procedures:

(i) The tailings will be deposited subaerially (exposed to air) and spirally around the dam in discrete layers. Each layer should not exceed 0.3m in thickness. The length of time between successive depositions (i.e. drying time) on any one area should be maximised.

(ii) Tailings should be discharged at a low velocity through numerous spigot locations and never from a single point discharge of high flow.

(iii) The free water pond should always be kept centrally located around the nearest decant structure. This is achieved by regularly altering the spigot locations around the perimeter of the dam.

(iv) Frequent inspections (on a daily basis) should be made of the spigots, tailings lines, water return lines, the position of the pond in relation to the decant and the dam walls. The return water sump and return lines should be checked regularly for quantity and quality.

Only by regular inspection and appropriate remedial action can the performance of the decant system be optimised and environmental and operational problems be avoided.

(v) Operation, safety and environmental aspects should be periodically reviewed during an inspection by an experienced Engineer. The inspection should be done every two years or when the dam has been raised 5m, whichever is the sooner.

## 3.0 TAILINGS DAM START UP

During the period of initial deposition into the tailings dam, a temporary mobile pump is recommended to collect surface water and discharge it into the return water sump. The level at which water can enter the first decant system in each area is approximately 4.5m and 6.2m higher than the lowest ground level of each storage area. It should be noted that although the upstream toe drain will function well during this early period, it is not possible to recover all free water through this system.

The temporary pump should therefore be positioned such that it will not be subjected to either water or tailings inundation as deposition continues and will allow routine maintenance to be undertaken without danger to service personnel.

All decant outfall pipes should be checked during this phase to ensure the pipe anchorage is adequate. To prevent decant pipe floatation, all decant pipes should remain full of water with control valves closed, unless the water recovered by the pump is being discharged into the decant.

It has been estimated that this arrangement will be required for a period of approximately 12 weeks from commencement of tailings deposition in the southern storage area before return water will enter decant no 1; (and a period of approximately 10 weeks from commencement of tailings deposition in the northern storage area before return water will enter decant no. 5).

Normal spigotting procedures, as detailed in Section 4.1.1, can be carried out during this initial deposition period.

## 4.0 COMPONENTS OF TAILINGS DAM OPERATIONS

Successful management of the tailings dam to achieve the design objectives requires a thorough understanding of three major components in the operation of the tailings dam. These components are:

(i) Deposition of tailings;

(ii) Control of the phreatic surface within the tailings; and

(iii) Poutine inspection and maintenance.

These components are described in detail below.

### 4.1 Deposition of Tailings

The following details are provided as a guide to an efficient tailings disposal system that will maximise water recovery and storage volume whilst reducing environmental and stability considerations:

(i) the tailings should be deposited subaerially and spirally (in a sequential manner around the dam perimeter) in layers not exceeding 0.3m. The tailings will then be allowed to drain and desiccate (dry) before being covered with the next layer;

(ii) at any one time tailings deposition into the storage should be from numerous adjacent spigot locations. This enables low velocity discharge of the tailings into the storage. **Low velocity discharge** promotes the deposition of the coarser fraction of the slurry adjacent to the discharge point, with finer material progressively deposited towards the centre of the storage area. The finest material is deposited when the flow meets the central water pond;

Tailings discharged at a high velocity, (ie. from one or two points), erodes both embankment material and previously deposited tailings by forming a channel as it flows to the centre of the storage;

(iii) initially the tailings will be discharged and dried in discrete layers from the perimeter of the dam until the tailings approach the level of the starter embankment, nominally within 500mm of the crest; and

(iv) the embankments around the perimeter of the dam and the access causeways should be raised, whilst simultaneously raising the decants. The decant structures will be raised progressively with the access way. Decant raising must always be kept in advance of the rising tailings and water level. Plate 1 shows the design concept.

### 4.1.1 Spigotting

This method is provided as a guide only.

The deposition of tailings into the storage is one of the controlling factors in achieving higher in situ densities and corresponding higher water returns.

Tailings should be deposited over the exposed beaches, at a low velocity. This is best achieved by discharging the tailings through numerous pipes (spigots). A typical discharge arrangement is shown on Plate 2. The most economical method would be the use of reducer tees, fitted with flexible mining hose (no valves) at 20m centres (nominally). Tailings should not be discharged so as to erode the soil embankments. During the initial start up period, conductor pipes (solid or slotted) into which the flexible hose must be inserted will be required to ensure the tailings are deposited at the toe of the embankment. Other forms of embankment protection are available (e.g. flexible hose laid on old conveyor mat).

These spigots are very easy to operate, and are opened and closed by unfolding the flexible pipe to open the spigot or folding the flexible pipe back on itself and tying it together to close the spigot (Plate 2). Consecutive groups of spigots are operated. New spigots are opened in succession around the dam to build up the tailings beaches to ensure the water pond is located around the nearest decant.

Some experimentation will be required during the early period of operation to determine the optimum number of spigots to be opened, to achieve low velocity discharge, whilst still maintaining sufficient pressure from the tailings pipeline to ensure the spigots are discharging uniformly.

## 4.2 Control of the Position of the Phreatic Surface

The position of the phreatic surface in the tailings dam will be governed by three main factors:

(i) the location and the size of the water pond;

(ii) the efficiency of the decant operation; and

(iii) the placing of tailings in thin discrete layers that are allowed to dry prior to inundation.

### 4.2.1 Decant

The location of the water pond will be largely governed by the spigotting sequence employed. The process of tailings deposition is aimed at ensuring that the pond is positioned around the nearest decant structure and that the pond is maintained in that position. The pond is positioned by altering, in a regular manner, the location of opened spigot points around the perimeter of the embankment.

The main feature of the decant system is that the decant pond is maintained at the smallest practical size, and most of the free water is recovered through the decant for recycling to the process plant. The size of the decant pond is the most important controlling influence on the water level and thus the phreatic surface within the body of the tailings, the smaller the decant pond, the higher the water recovery.

By adopting the approach of maintaining a small decant pond the stability of the dam should not be significantly reduced by the formation of a **temporary** "lake" caused by maintenance requirements or by storm flooding of the tailings beaches.

The size of the pond will be largely governed by the efficiency of the offtake or internal riser pipe in removing water from the tailings storage. Other controlling factors will be:

(i) evaporation from the surface of the pond;

(ii) the input of tailings water (percent solids);

(iii) the rainfall;

(iv) the difference in permeability between the tailings and the underlying soil types; and

(v) the ratio of horizontal to vertical permeability of the tailings.

Plate 3 shows a section of the central decant when operating.

A water balance for this tailings dam is attached. The water balance shows the potential water return as a percentage of inflow. Graphical presentations show the monthly water balance; the design storm event (based on the month with lowest evaporation, and a storm event with an average recurrence interval of more than 100 years); and water management (estimated average water return versus area of pool and running beaches).

## 4.3 Management, Inspection and Maintenance

### 4.3.1 Management

The active life of the tailings dam is advised to be at least 15 years.

During this time many changes can take place in the materials being placed which effect the stability of the embankment. The quantity and physical properties of the tailings placed in the dam may change over the years for many reasons. Such changes may alter the stability of an embankment, resulting in variations in the factor of safety.

#### 4.3.2 Quantity of Tailings

Increased tonnage from the mill without a commensurate increase in the area available to store tailings is one of the most common changes. This results in an increase in the annual rise of the tailings and reduces the factor of safety.

#### 4.3.3 Physical Properties of Tailings

A change in grind with an increase in the minus 75 micron fraction can cause a higher phreatic surface, a possible decrease in the efficiency of the drains, and increased seepage through the starter dam fill.

Any one or a combination of these changes can result in a reduced stability of the embankment. **It is therefore important that a continuous programme of inspection and maintenance of the embankment, the decant systems and return water sump be started at the beginning and maintained throughout the life and even after the abandonment of the storage.** The embankments should be thoroughly inspected by an experienced Engineer at least once every two years or for a 5m rise, whichever is the sooner, during the active life of the dam.

#### 4.3.4 Inspection

##### 4.3.4.1 Daily Inspections

Daily inspection should be made of the spigots, the position of the water pond in relation to the decant or the tailings area boundary, the decant system and return water sump and all pipelines. The quality and quantity of water returns should be checked daily.

### 4.3.4.2 Engineering Inspection

An inspection should be carried out every two years, or when the dam has been raised 5m, whichever is the sooner. The objectives of this inspection programme should be to answer the following questions:

(1) Are there any major changes in the foundation or the embankment that were not anticipated in the design, such as heaving of the foundation at the toe, longitudinal or transverse cracks in the crest, or excessive seepage ?

(2) Have the material characteristics changed ? and if so, how will these changes affect the stability ?

(3) Is the distribution of the material into the pond as called for in the design; and if not, how will it affect stability ?

(4) Is the slime and water pond where it should be in relation to the decants and perimeter embankment ?

(5) Is the dam construction rapid enough to keep the slimes and water well back from the dam wall ?

(6) Can the decants handle any storm runoff in addition to the reclaim water and how efficiently ?

(7) Is there seepage on the downstream face of the embankment wall ?

(8) Are the decant lines intact and free of cracks that could allow sand to pipe into the lines and cause a total failure ?

(9) Is the phreatic surface (within the dam) as planned ? or is there excess pore water pressure from within the foundation or perched water tables ?

(10) Have there been variations in the water levels or a sudden rise in the water level of the monitoring boreholes; the appearance of any new springs, or new seepage on the face of the embankments or foundation ?

(11) Has there been any embankment movement ?

(12) Is the embankment steeper than planned ?

(13) Is there evidence of borrow from the toe or any other area of the embankments that might affect stability?

All of the above points are critical for the stability of the structure and each item must be investigated closely and checked during the life of the structure. If problems are encountered, a thorough investigation must be made.

## 5.0 RAISING THE EMBANKMENTS

The design concept provides for the raising of the tailings dam embankment by upstream construction methods using waste rock from the pit.

The following procedure is therefore recommended:

## 5.1 Embankment Construction (Staged Construction)

Embankment raising must be planned so as not to disrupt the normal tailings depostition cycle.

Each lift will be 5m high (Plate 1).

Prior to construction commencing, tailings depostition lines must be removed from that section of the dam which is to be raised.

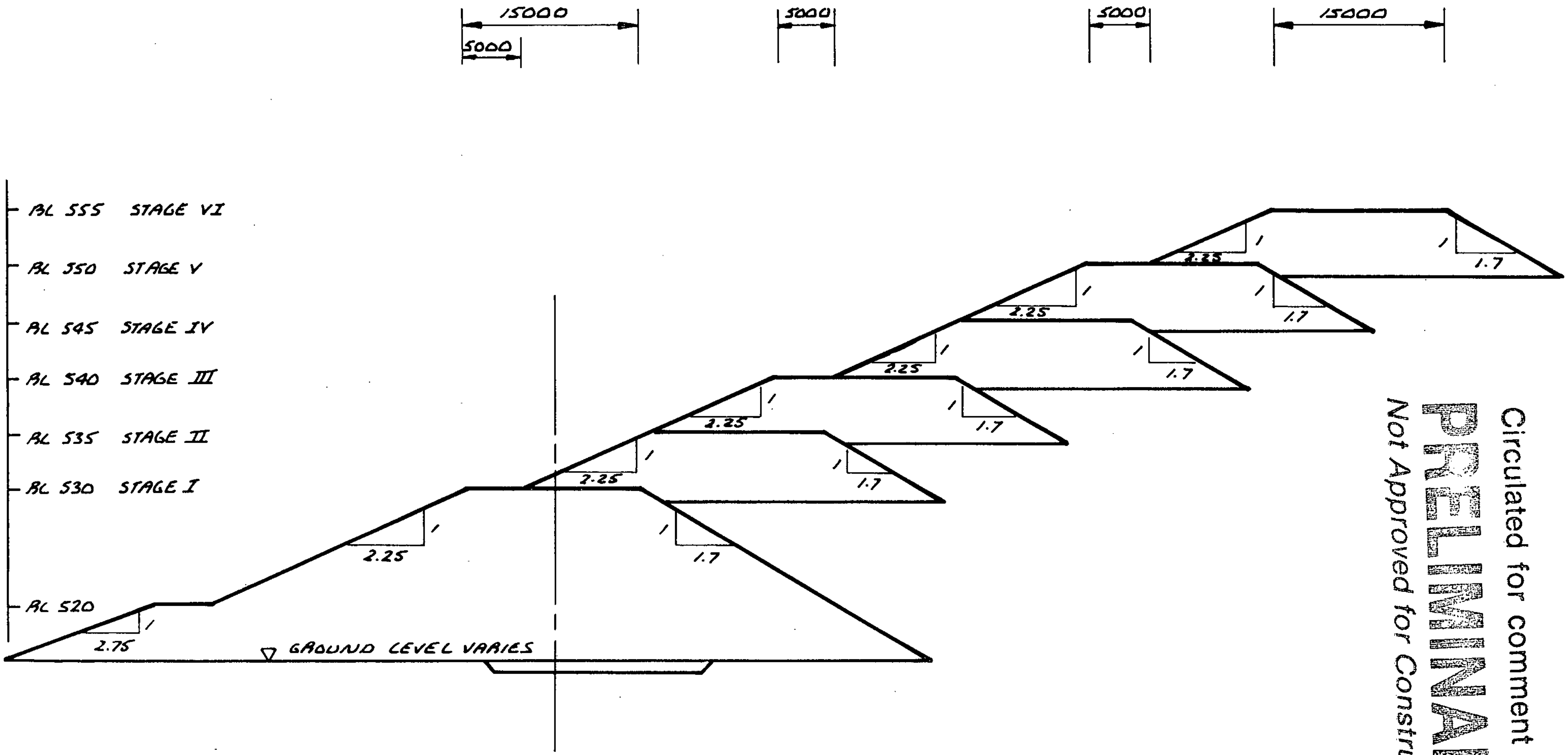
The construction materials (waste rock) shall be placed in horizontal layers not exceeding 500mm loose lift thickness. Each lift shall be compacted by a minimum of 8 passes with a heavy duty roller. No oversize rock is to be placed into the embankments. The largest size should be 150mm. Drawing No.s W1292-00/C-003A and 003B provide typical sections of embankment construction for each phase of the work.

The decant structure will also be progressively raised, simultaneously with the raising of the perimeter embankments. The concrete decant pipes will be raised approximately 5m, and the central access way will also be raised a similar height with run of mine waste rock, noting that only clean waste rock (free of excessive fines) be placed around the decant structure. (Plate 4)

Any external perimeter access road will be ramped up progressively to maintain grades levels with the central access way to allow easy access to the decant structure.

Plates 1 to 4 are attached, together with the water balance details, Plates 5 to 9.

*   *   *   *   *

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DESIGN CONCEPT
YAKABINDIE NICKEL PROJECT

Soil & Rock Engineering Pty. Ltd.

PLATE 1

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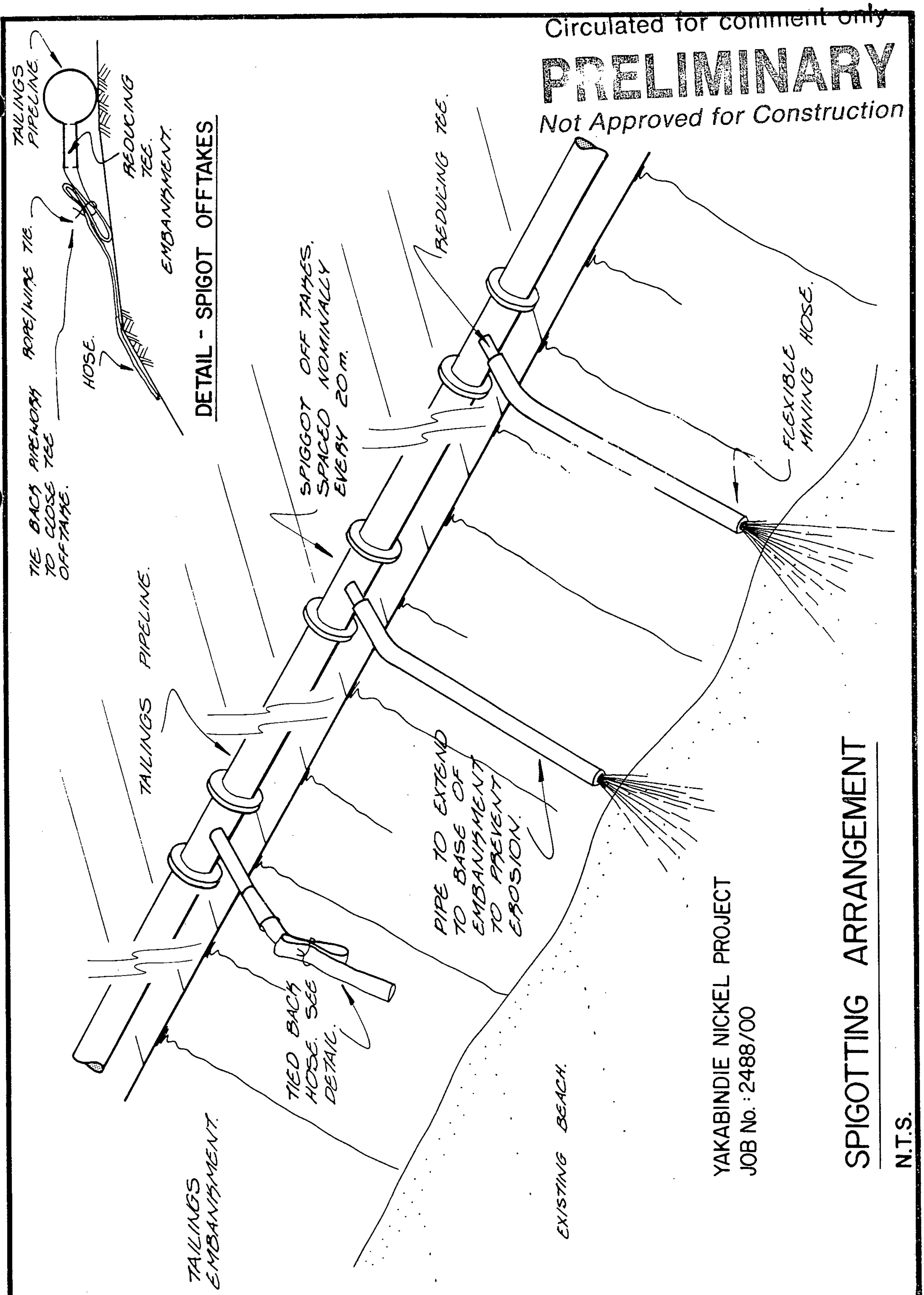


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PLATE 2

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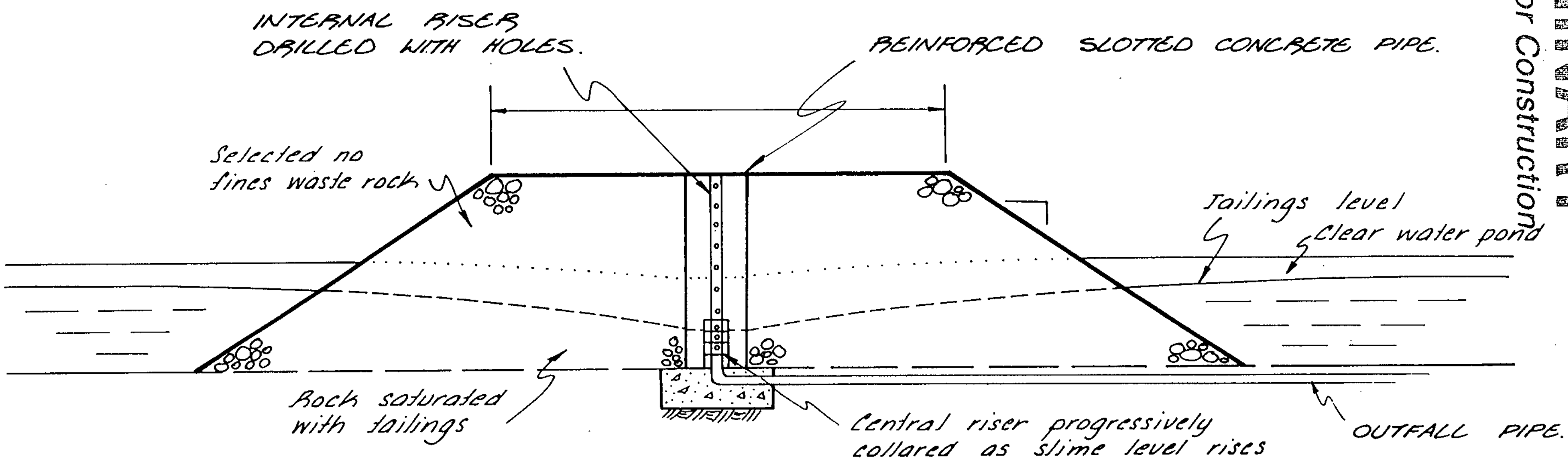


YAKABINDIE NICKEL PROJECT
JOB No. : 2488/00

# CENTRAL DECANT WHEN OPERATING

N.T.S.

Soil & Rock Engineering Pty. Ltd.

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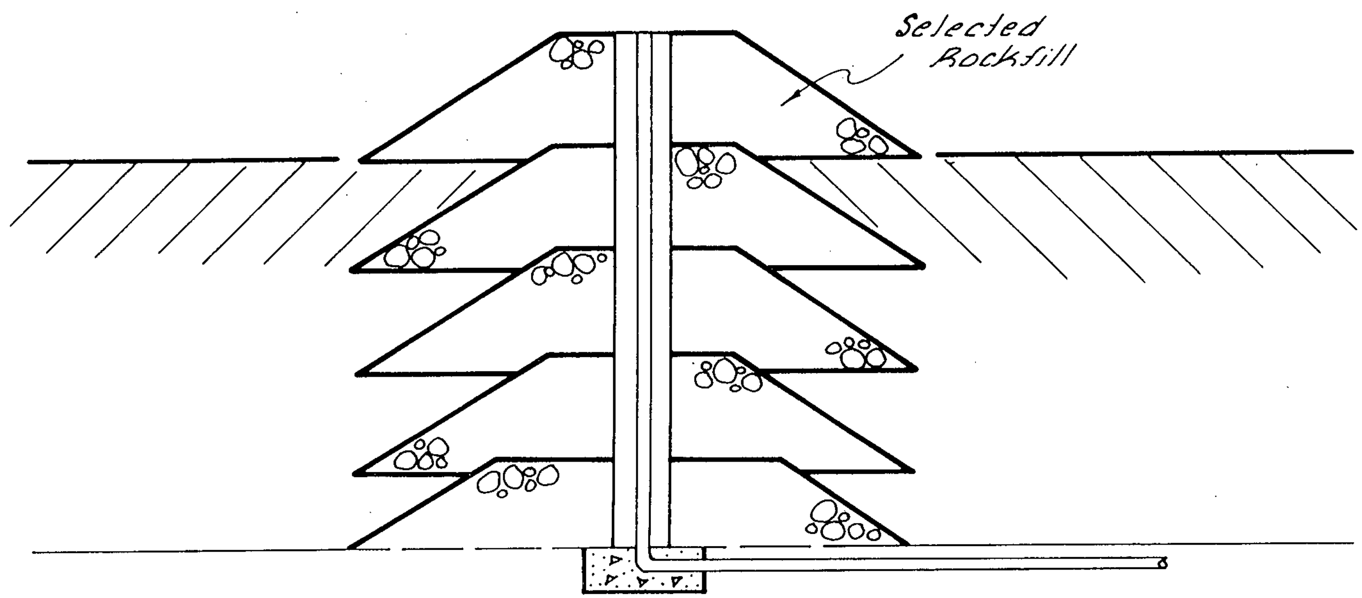


YAKABINDIE NICKEL PROJECT
JOB No. :2488/00

# CENTRAL DECANT MOUND RAISED USING CENTRELINE METHOD

CAUSEWAY ACCESS ROAD RAISED IN A SIMILAR FASHION.

N.T.S.

Soil & Rock Engineering Pty. Ltd.

PROJECT: YAKABINDIE NICKEL MINE

CLIENT: MINPROC ENGINEERS PTY LTD

LOCATION: YAKABINDIE, W.A.

JOB NO: 2488/00

DATE: 05-Apr-90

SUBJECT: MONTHLY WATER BALANCE
YAKABINDIE NICKEL MINE

TAILINGS DAM BALANCE

| INFLOW | JAN. | FEB. | MAR. | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINFALL | | | | | | | | | | | | |
| Monthly Rainfall (mm) | 28.5 | 29 | 32 | 22.5 | 25.5 | 24.5 | 16.5 | 13 | 7 | 3.5 | 10 | 17 |
| Average Daily Rainfall (mm) | 0.92 | 1.04 | 1.03 | 0.75 | 0.82 | 0.82 | 0.53 | 0.42 | 0.23 | 0.11 | 0.33 | 0.55 |
| Tailings Storage Area (m^2) | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 | 3300000 |
| Runoff Coefficient Tailings | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Catchment Area (m^2) | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 | 1000000 |
| Runoff Coefficient Catchment | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Pool Area (m^2) | 140000 | 140000 | 140000 | 140000 | 140000 | 140000 | 140000 | 140000 | 140000 | 140000 | 140000 | 140000 |
| Running Beaches (m^2) | 700000 | 700000 | 700000 | 700000 | 700000 | 700000 | 700000 | 700000 | 700000 | 700000 | 700000 | 700000 |
| STORM EVENT | | | | | | | | | | | | |
| Design Storm Intensity (mm/hour) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Design Storm Duration (hours) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daily Inflow Volume (m^3) | 2504 | 2821 | 2812 | 2043 | 2241 | 2225 | 1450 | 1142 | 636 | 308 | 908 | 1494 |
| SLURRY WATER | | | | | | | | | | | | |
| Tailings Output solids, (tpd) | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 |
| Volume of Water (m^3/day) | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 |
| %solids= 50 | | | | | | | | | | | | |
| PROCESS WATER | | | | | | | | | | | | |
| Pumped from river (m^3/day) | | | | | | | | | | | | |
| Process Water Requirement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Clean Water Requirement * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Requirement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL INFLOW | 19004 | 19321 | 19312 | 18543 | 18741 | 18725 | 17950 | 17642 | 17136 | 16808 | 17408 | 17994 |

* not included in inflow calculation

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PLATE 5

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OUTFLOW** | | | | | | | | | | | | |
| Return Water from Dam (m^3/day) | 5800 | 5800 | 5800 | 5800 | 5800 | 5800 | 5800 | 5800 | 5800 | 5800 | 5800 | 5800 |
| **EVAPORATION (from pond & running beaches)** | | | | | | | | | | | | |
| Monthly Pan Evaporation Rate (mm) | 550.0 | 460.0 | 419.0 | 263.0 | 180.0 | 119.0 | 130.0 | 170.0 | 240.0 | 360.0 | 425.0 | 525.0 |
| Pan Factor | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| Monthly Dam Evaporation Rate (mm) | 368.5 | 308.2 | 280.7 | 176.2 | 120.6 | 79.7 | 87.1 | 113.9 | 160.8 | 241.2 | 284.8 | 351.8 |
| Average Daily Evaporation Rate (mm) | 11.9 | 11.0 | 9.1 | 5.9 | 3.9 | 2.7 | 2.8 | 3.7 | 5.4 | 7.8 | 9.5 | 11.3 |
| Pool Area + Running Beaches (m^2) | 840000 | 840000 | 840000 | 840000 | 840000 | 840000 | 840000 | 840000 | 840000 | 840000 | 840000 | 840000 |
| Daily Evaporation Loss (m^3/day) | 9985 | 9246 | 7607 | 4934 | 3268 | 2232 | 2360 | 3086 | 4502 | 6536 | 7973 | 9531 |
| **EVAPO-TRANSPIRATION (from drying tailings)** | | | | | | | | | | | | |
| Monthly Pan Evaporation Rate (mm) | 550 | 460 | 419 | 263 | 180 | 119 | 130 | 170 | 240 | 360 | 425 | 525 |
| Evapotranspiration Rate (Pan/3) | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| Monthly Transpiration Rate (mm) | 123 | 103 | 94 | 59 | 40 | 27 | 29 | 38 | 54 | 80 | 95 | 117 |
| Average Daily Transpiration Rate (mm) | 4.0 | 3.7 | 3.0 | 2.0 | 1.3 | 0.9 | 0.9 | 1.2 | 1.8 | 2.6 | 3.2 | 3.8 |
| Area Transpiring (m^2) | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 | 1155000 |
| Daily Transpiration Loss (m^3/day) | 4577 | 4238 | 3486 | 2261 | 1498 | 1023 | 1082 | 1415 | 2064 | 2996 | 3654 | 4369 |
| **SEEPAGE** | | | | | | | | | | | | |
| Downstream Embankment (m^3/day) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Upstream Embankment (m^3/day) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dam floor (m^3/day) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| TOTAL SEEPAGE | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 |
| % INFLOW | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 7% | 6% | 6% |
| **RETENTION** | | | | | | | | | | | | |
| Tailings Output (tpd) | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 | 16500 |
| Volume Retained in Tailings (m^3/day) | 6600 | 6600 | 6600 | 6600 | 6600 | 6600 | 6600 | 6600 | 6600 | 6600 | 6600 | 6600 |
| assume wt water/soil= 0.4 | | | | | | | | | | | | |
| TOTAL OUTFLOW | 22262 | 21184 | 18793 | 14895 | 12466 | 10956 | 11142 | 12201 | 14266 | 17231 | 19327 | 21600 |
| BALANCE (INFLOW - OUTFLOW) (m^3/day) | -3257 | -1862 | 519 | 3648 | 6275 | 7769 | 6808 | 5441 | 2870 | -424 | -1919 | -3606 |

SUMMARY OF % RETURNS ON MONTHLY BASIS

| MONTH | JAN. | FEB. | MAR. | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potential Max. Water Return (m^3/day) | 2543 | 3938 | 6319 | 9448 | 12075 | 13569 | 12608 | 11241 | 8670 | 5376 | 3881 | 2194 |
| Potential Water Return (% inflow) (upper limit of 45%) | 15% | 24% | 38% | 45% | 45% | 45% | 45% | 45% | 45% | 33% | 24% | 13% |

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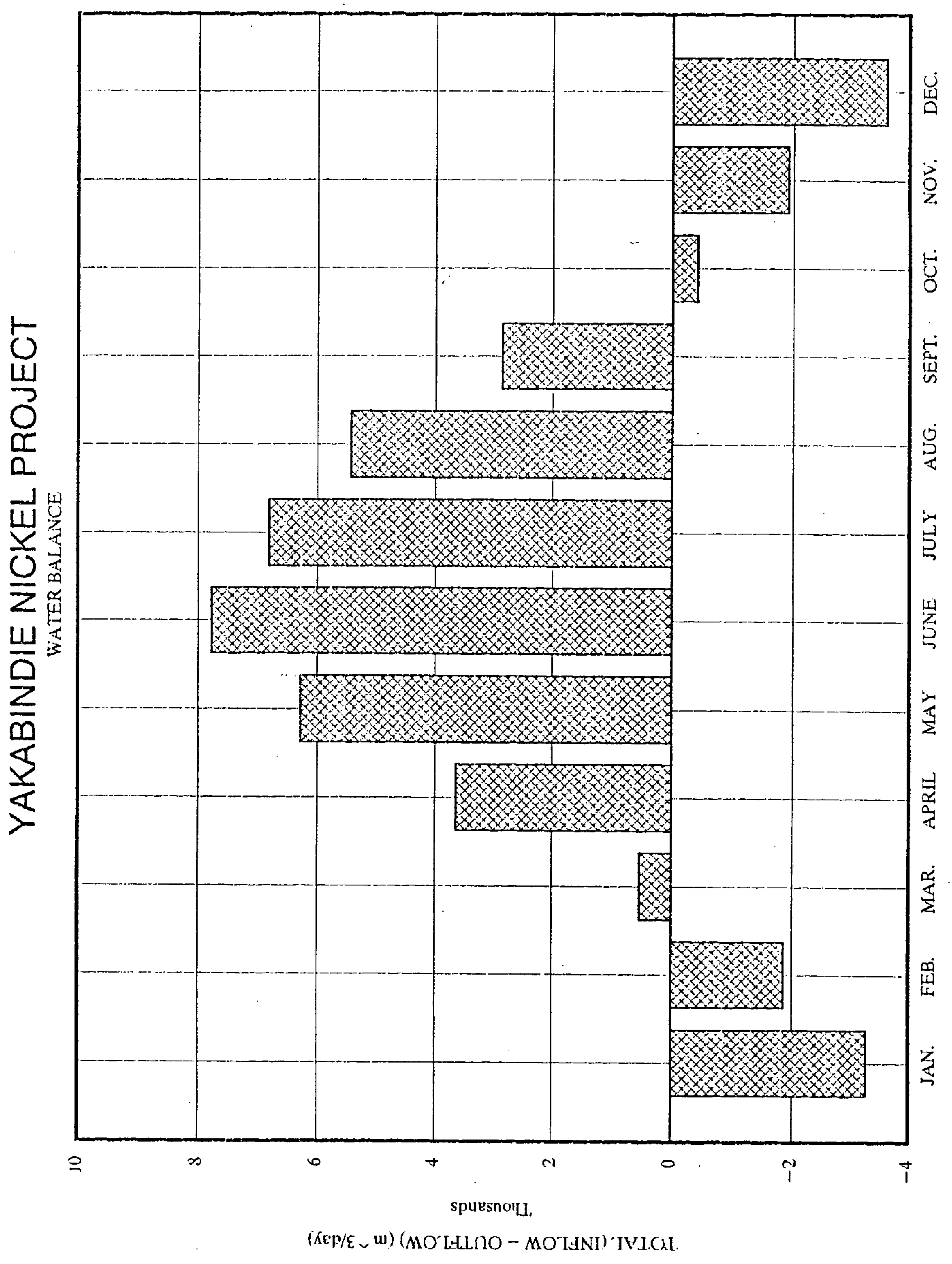


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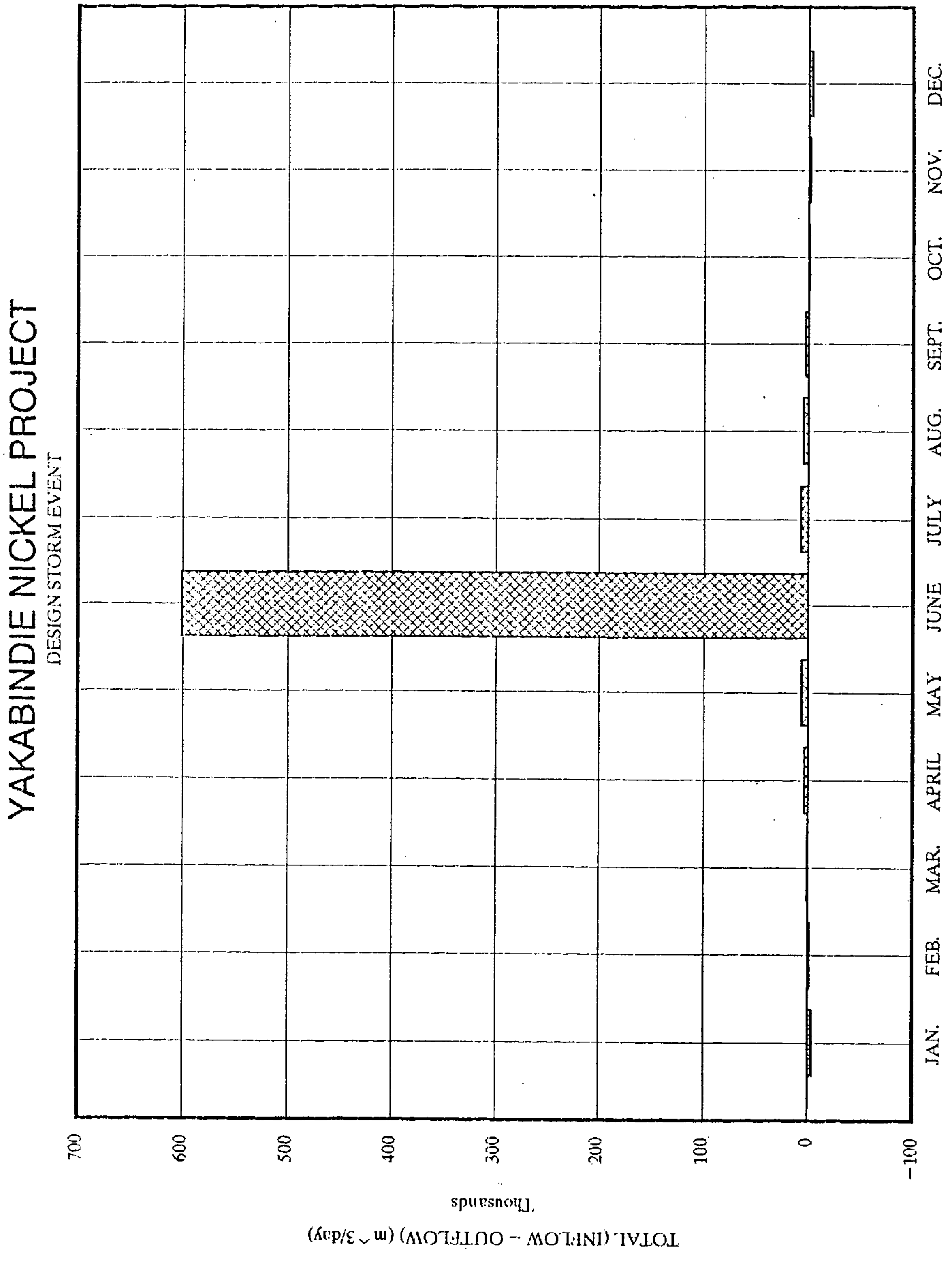
PLATE 7

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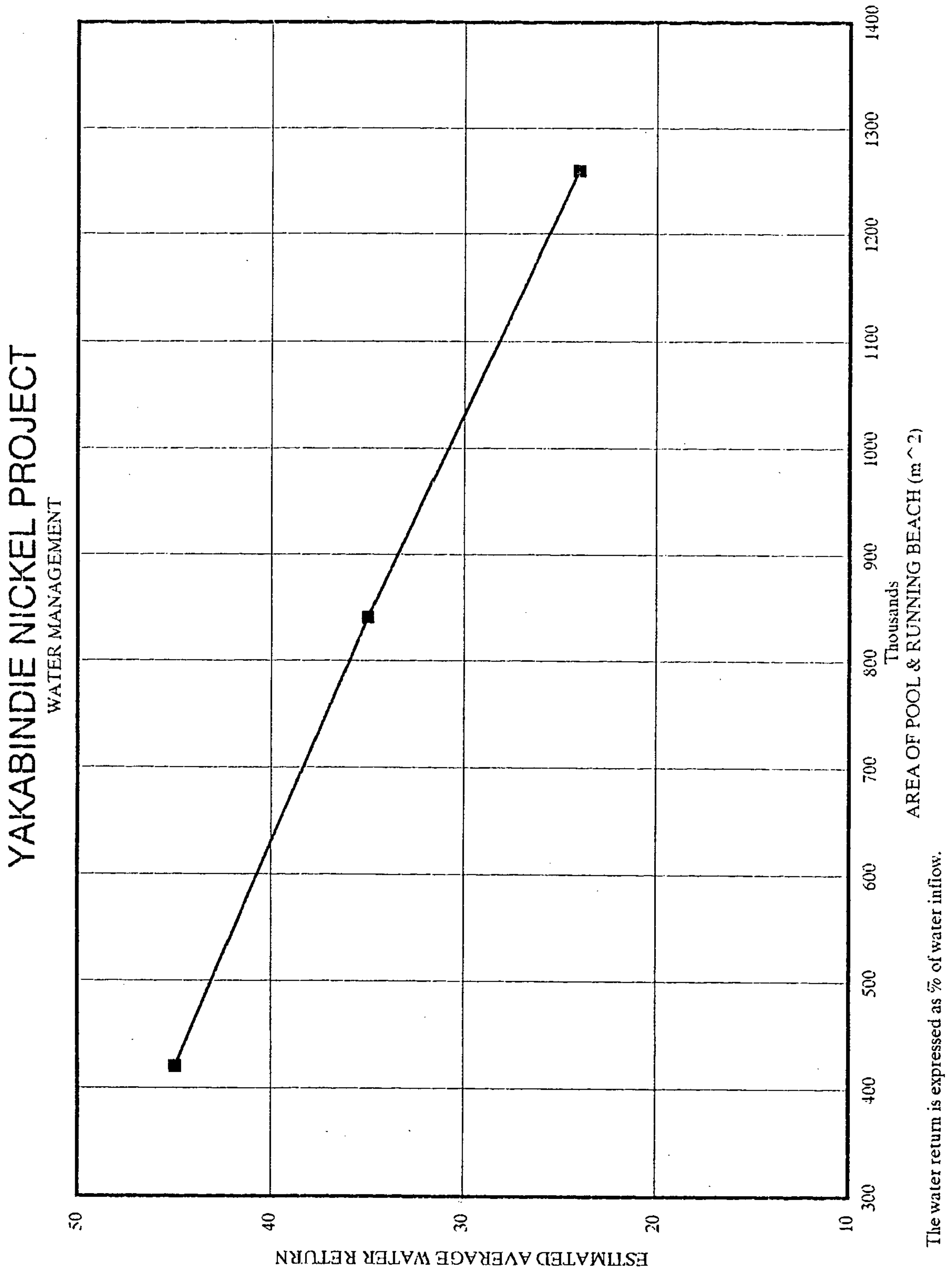
**Soil & Rock Engineering Pty. Ltd.**

PLATE 8

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Soil & Rock Engineering Pty. Ltd.
PLATE 9

## YAKABINDIE
## TAILINGS ACID NEUTRALISATION PERFORMANCE

A sample of tailings from the pilot plant testwork was assayed as follows:

The assay was as follows:

| | |
|---|---|
| Ni | 0.188% |
| Fe | 4.17% |
| Cu | 194 ppm |
| Pb | 10 ppm |
| Zn | 29 ppm |
| Cd | <1 ppm |
| As | <100 ppm |
| Se | 0.2 ppm |
| Te | <0.1 ppm |
| Ag | <0.005 ppm |
| S total | 0.489% |
| S as Sulphide | 0.416% |
| MgO | 39.1% |

(Ref. Ammtec facsimile 0800, 12/4/90)

The sulphide content of the tailings is of importance since this could potentially be converted to sulphuric acid by natural oxidation processes. Based on stoichiometry and assuming 100% conversion of sulphide sulphur, the maximum production of acid is 12.74 kg $H_2SO_4$/tonne of tailings.

A neutralisation test has been carried out by Ammtec (ref. fax of 30.3.90) to measure the neutralising capability of the tailings. This test indicated that the tailings has the ability to neutralise 14.3 kg $H_2SO_4$/tonne over a 24 hour period. This exceeds the maximum theoretical acid generating potential.

Further testwork is planned to determine the acid:base characterisation of tailings. This work will determine the actual conversion of sulphides to acid over a longer time period and the neutralisation potential.

# APPENDIX D3

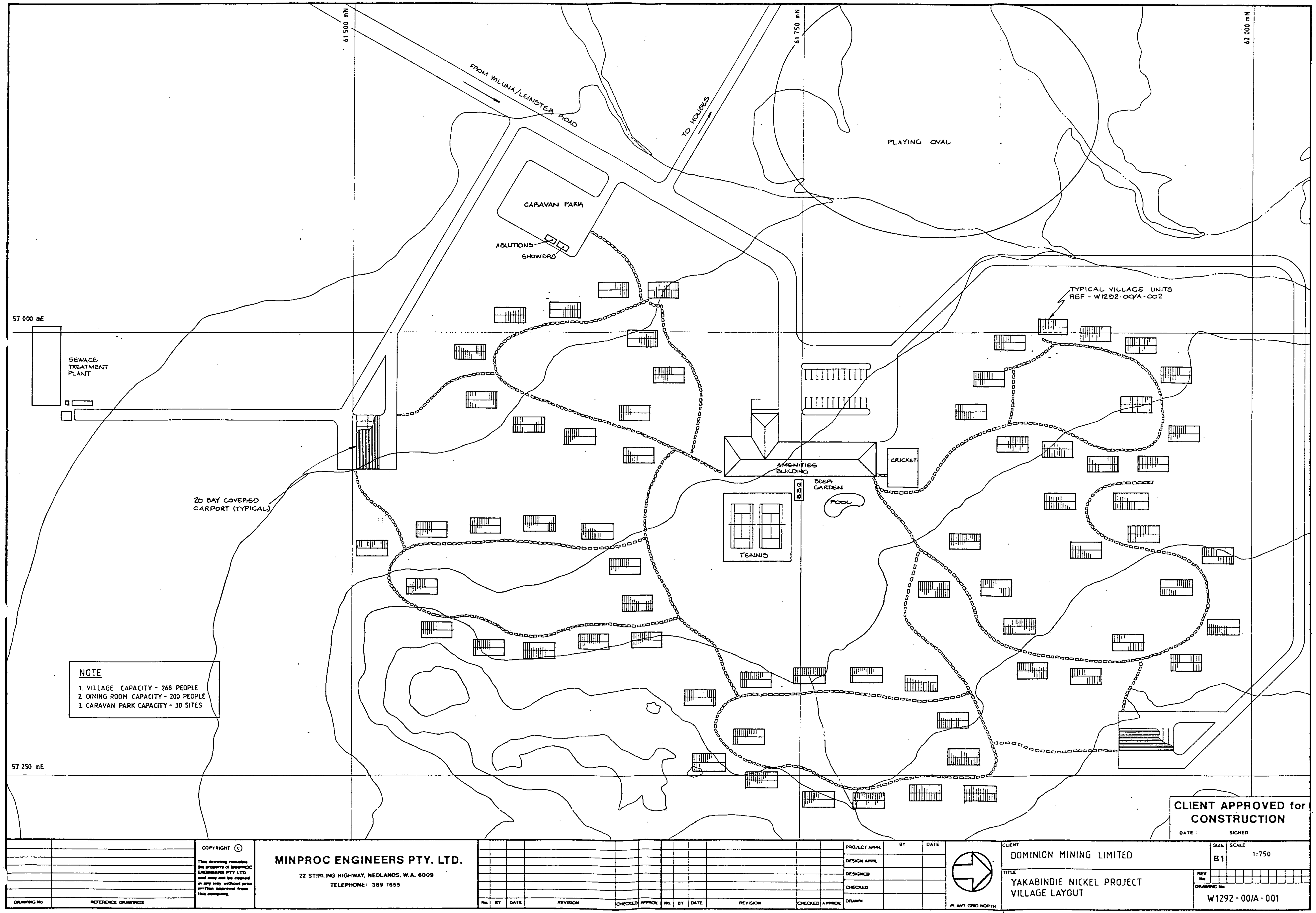
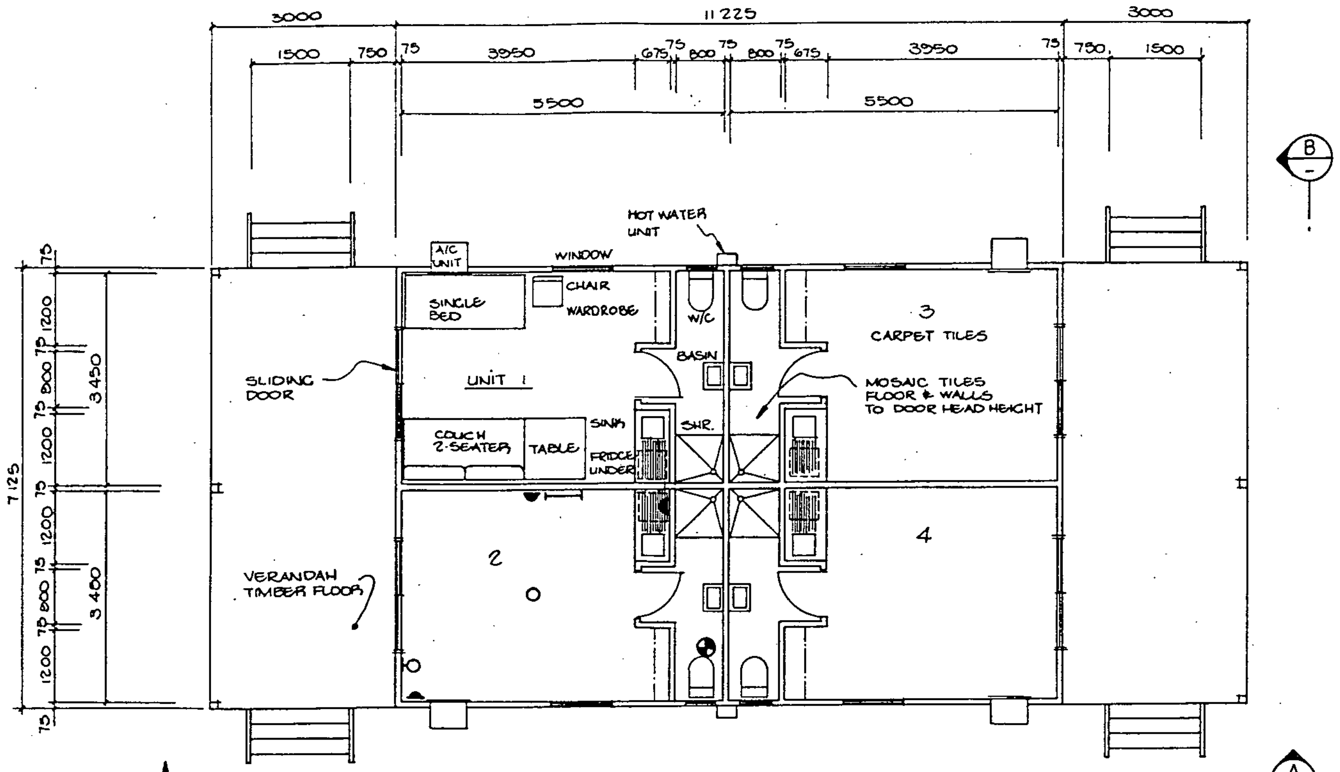
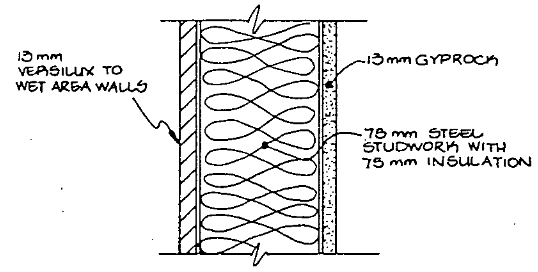

61 500 mN
61 750 mN
62 000 mN
FROM WILUNA/LEINSTER ROAD
TO HOUSES
PLAYING OVAL
CARAVAN PARK
ABLUTIONS
SHOWERS
57 000 mE
SEWAGE TREATMENT PLANT
TYPICAL VILLAGE UNITS REF - W1292-00/A-002
AMENITIES BUILDING
CRICKET
BEER GARDEN
POOL
TENNIS
20 BAY COVERED CARPORT (TYPICAL)
NOTE
1. VILLAGE CAPACITY - 268 PEOPLE
2. DINING ROOM CAPACITY - 200 PEOPLE
3. CARAVAN PARK CAPACITY - 30 SITES
57 250 mE
CLIENT APPROVED for CONSTRUCTION
DATE:
SIGNED
DRAWING No
REFERENCE DRAWINGS
COPYRIGHT ©
This drawing remains the property of MINPROC ENGINEERS PTY. LTD. and may not be copied in any way without prior written approval from this company.
MINPROC ENGINEERS PTY. LTD.
22 STIRLING HIGHWAY, NEDLANDS, W.A. 6009
TELEPHONE: 389 1655
No. BY DATE REVISION CHECKED APPROV.
PROJECT APPR.
DESIGN APPR.
DESIGNED
CHECKED
DRAWN
BY
DATE
PLANT GRID NORTH
CLIENT
DOMINION MINING LIMITED
TITLE
YAKABINDIE NICKEL PROJECT
VILLAGE LAYOUT
SIZE B1
SCALE 1:750
REV. No
DRAWING No
W1292-00/A-001

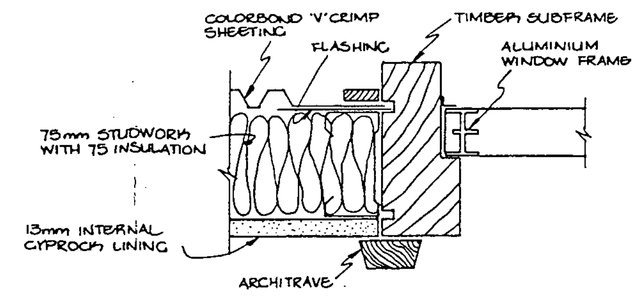
PLATE D17



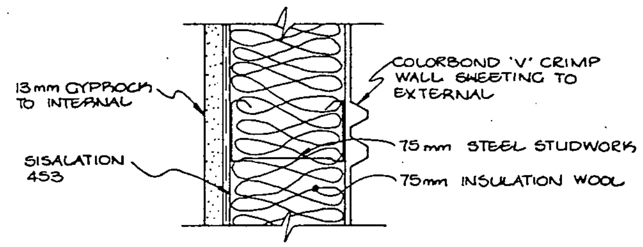

PLAN
1:50




TYPICAL INTERNAL WALL DETAIL



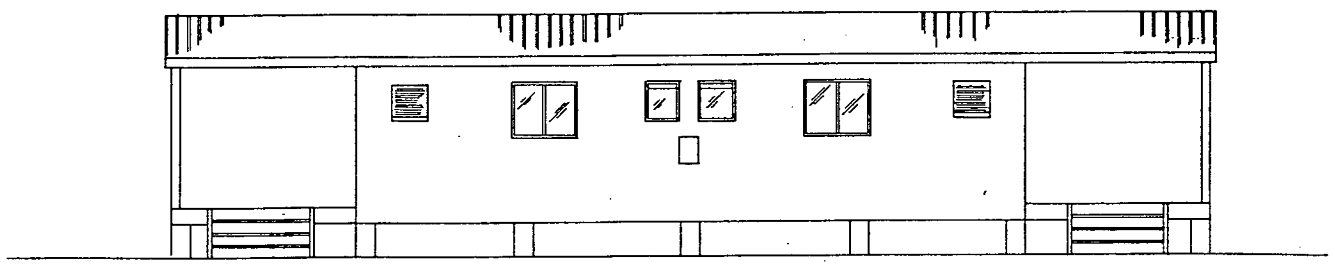

TYPICAL WINDOW/SUBFRAME LINING DETAIL



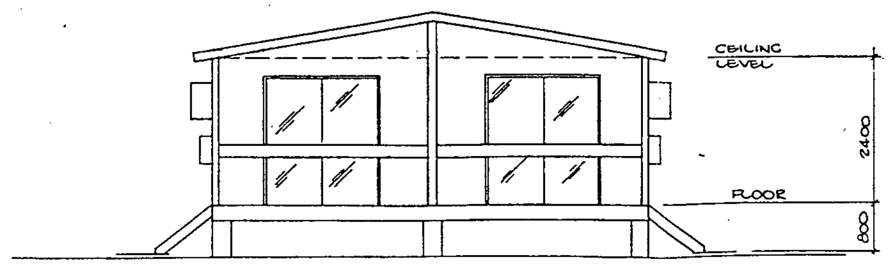

TYPICAL EXTERNAL WALL DETAIL

ELECTRICAL LEGEND

- 600 FLUORESCENT TUBE
- DOUBLE POWER POINT
- SINGLE POWER POINT
- WALL BRACKET LIGHT
- CEILING INCANDESCENT LIGHT
- EXHAUST FAN SWITCHED WITH LIGHT



ELEVATION A




ELEVATION B

CLIENT APPROVED for CONSTRUCTION

DATE: SIGNED

| DRAWING No | REFERENCE DRAWINGS |
|---|---|



**MINPROC ENGINEERS PTY. LTD.**

22 STIRLING HIGHWAY, NEDLANDS, W.A. 6009
TELEPHONE: 389 1655

| No. | BY | DATE | REVISION | CHECKED | APPROV. |
|---|---|---|---|---|---|

| | BY | DATE |
|---|---|---|
| PROJECT APPR. | | |
| DESIGN APPR. | | |
| DESIGNED | | |
| CHECKED | | |
| DRAWN | | |

PLANT GRID NORTH

CLIENT: DOMINION MINING LIMITED

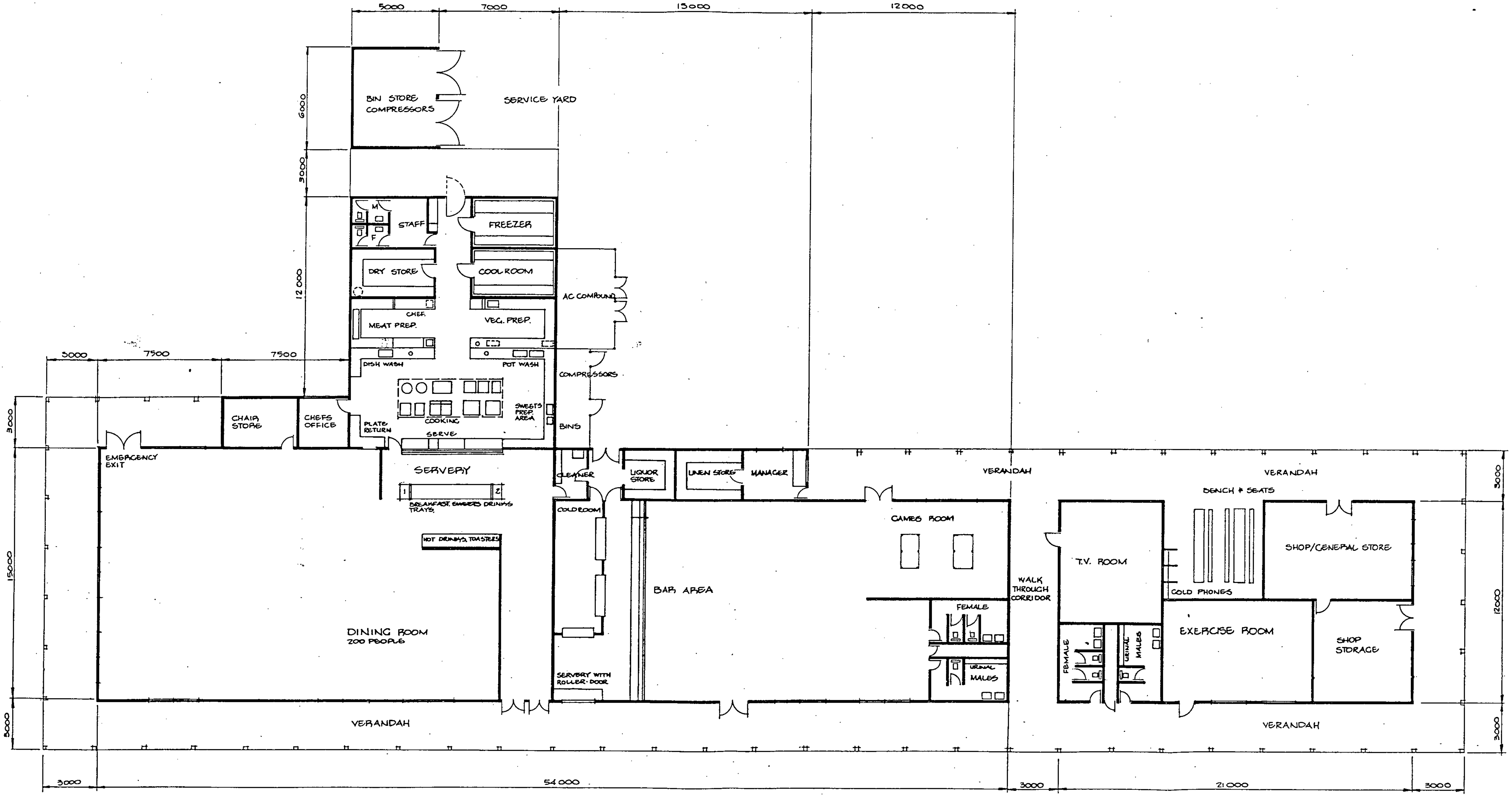
TITLE: YAKABINDIE NICKEL PROJECT VILLAGE UNITS

SIZE: B1 SCALE: 1:50

REV. No

DRAWING No: W1292 - 00/A - 002

PLATE D18

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PLANT GRID NORTH

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SIZE: B1 SCALE: 1:100

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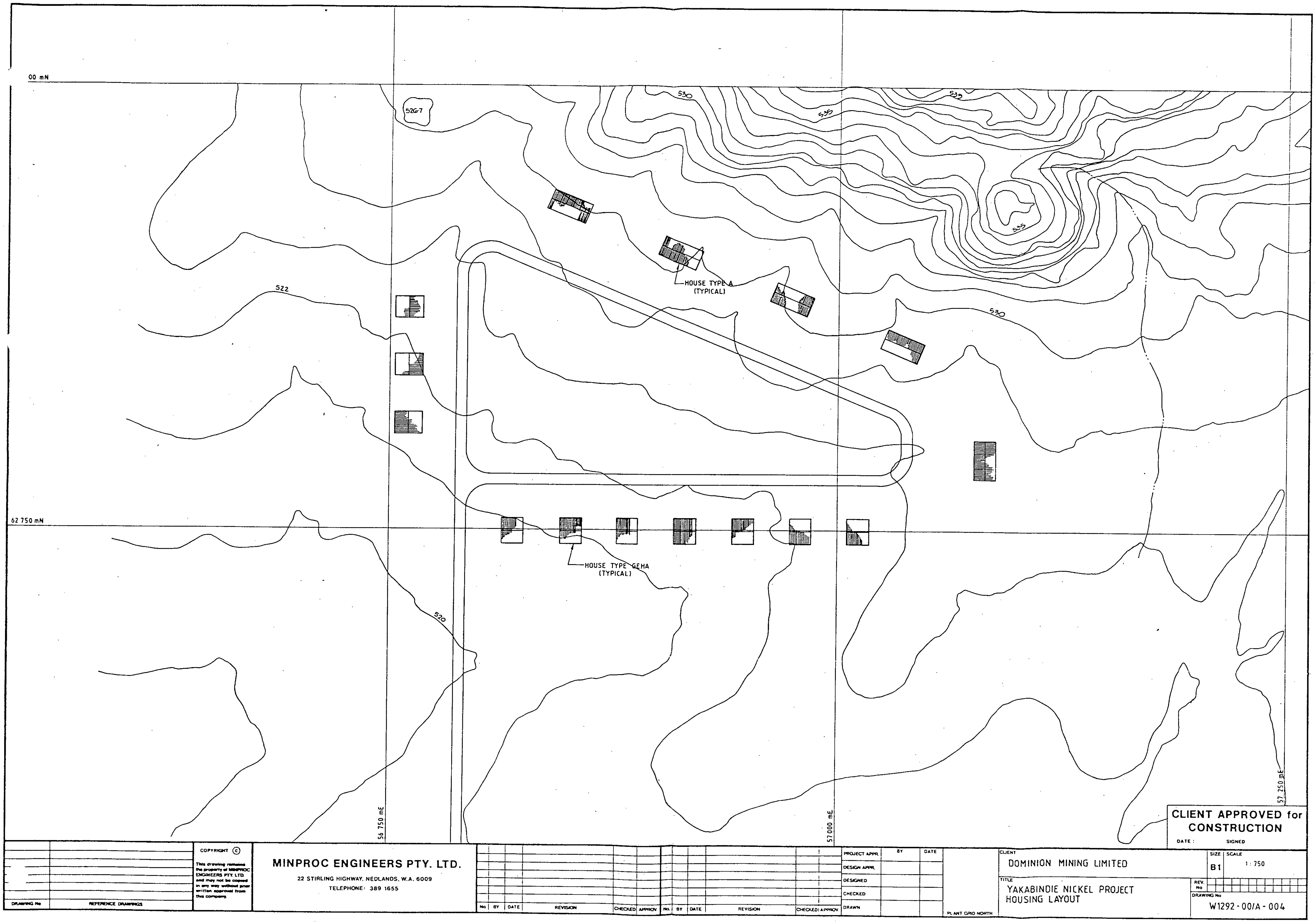
REV. No

DRAWING No: W1292-00/A-003

PLATE D19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CLIENT
DOMINION MINING LIMITED
SIZE B1
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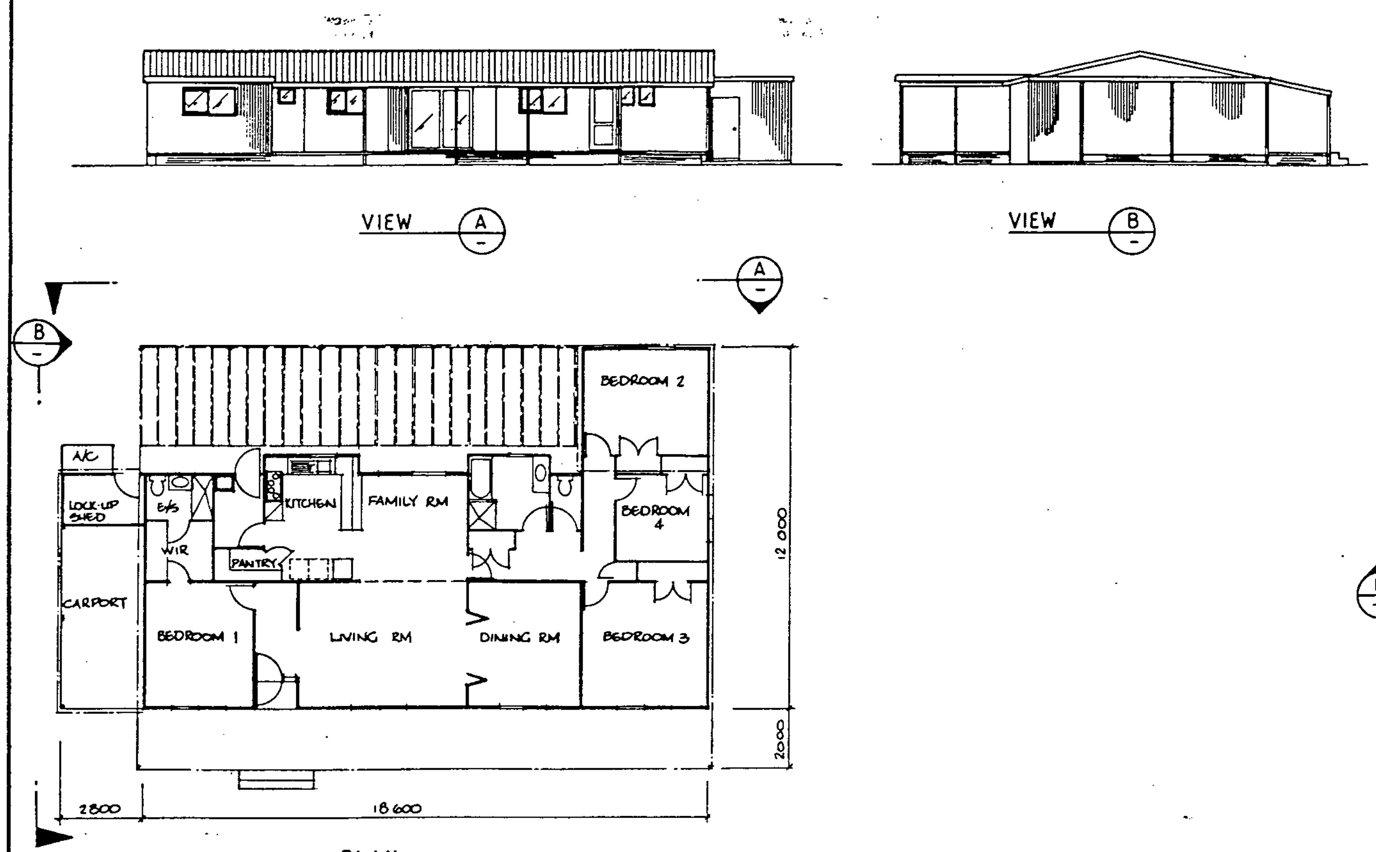
TITLE
YAKABINDIE NICKEL PROJECT
HOUSING LAYOUT
REV. No
DRAWING No
W1292-00/A-004

PLATE D20

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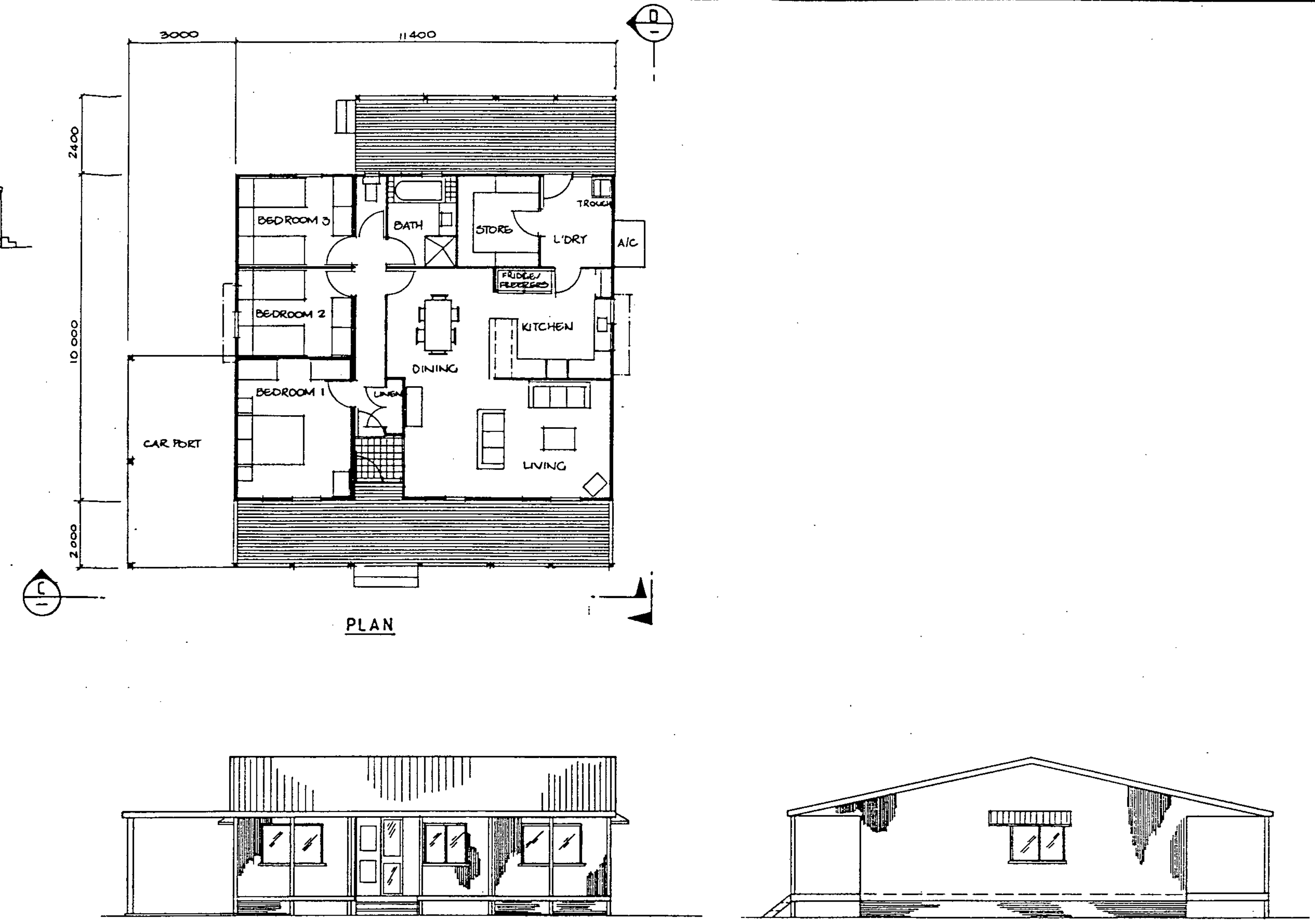


HOUSE TYPE 'B'
1:75

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PLANT GRID NORTH

CLIENT: DOMINION MINING LIMITED
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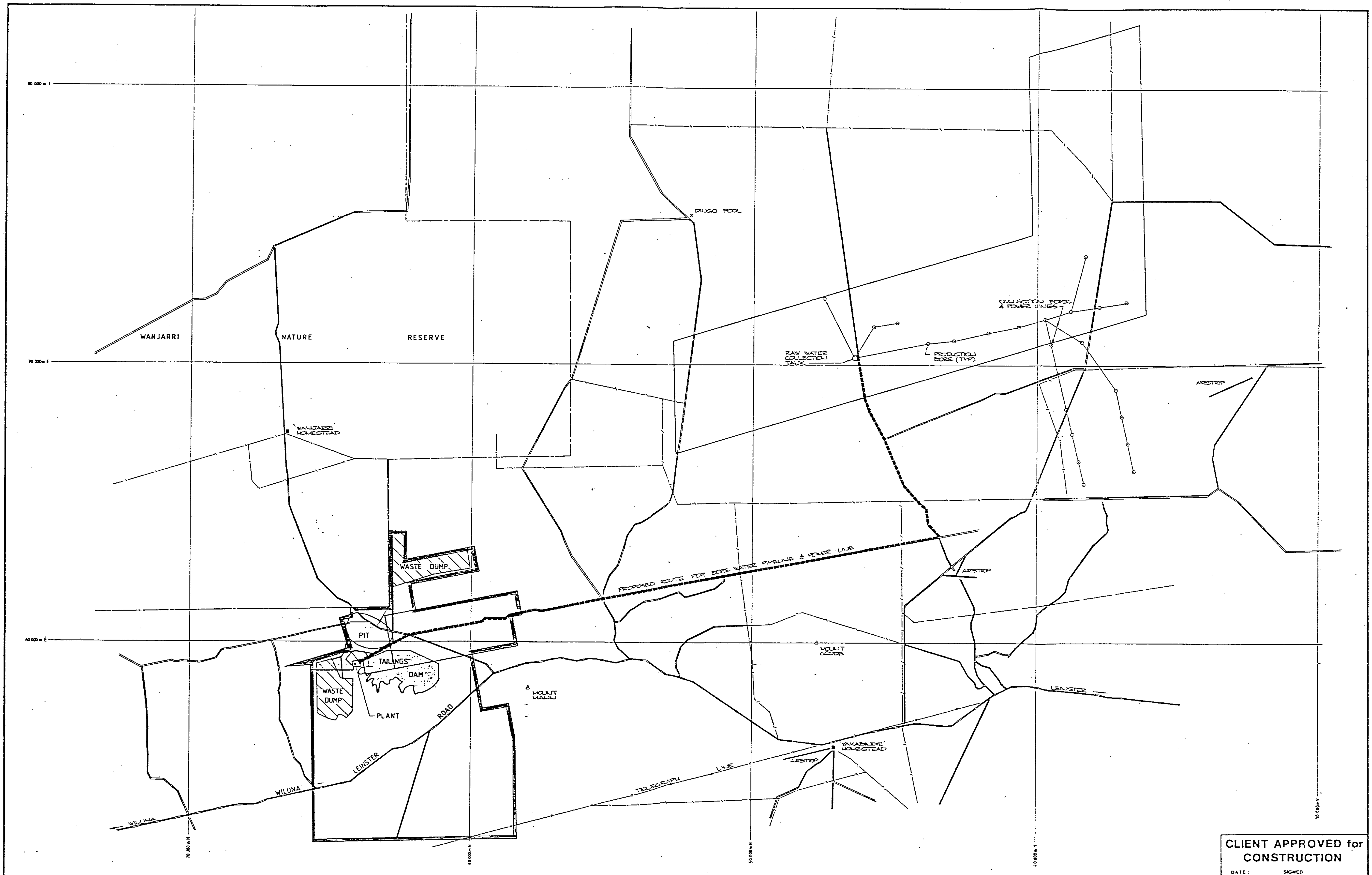
TITLE: YAKABINDIE NICKEL PROJECT HOUSE PLANS
REV. No
DRAWING No: W1292 - 00/A - 005

PLATE D21

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PLANT GRID NORTH

CLIENT: DOMINION MINING LIMITED

SIZE: B1 SCALE: 1 : 50000

TITLE: YAKABINDIE NICKEL PROJECT
BOREFIELD AND POWER LINE LAYOUT

REV. No

DRAWING No: W1292 – 00/ G – 005

PLATE D22

# APPENDIX D4

# PROPOSED MANNING SCHEDULE

## YAKABINDIE

### STAFF

i) Operations

| | | |
|---|---|---|
| Metallurgical Superintendent | 1 | |
| Mill Superintendent | 1 | |
| Metallurgists | 3 | |
| Clerical | 2 | |
| Supervisors | 4 | |
| Day/Plant Foremen | 2 | |
| Chief Chemist | 1 | |
| Analysts | 4 | |
| | | 18 |

ii) Maintenance

| | | |
|---|---|---|
| Maintenance Engineer | 1 | |
| Maintenance Planner | 1 | |
| Mechanical Foremen | 2 | |
| Electrical Foreman | 1 | |
| | | 5 |

AWARD

i) Plant Operators

Shift Workers:

| | |
|---|---|
| - Control Room | 4 |
| - Mills | 4 |
| - Flotation | 4 |
| - Thickening/Concentrate Handling | 4 |
| - Spare Operators | 4 |
| | 20 |

Day Workers:

| | |
|---|---|
| - Crusher | 3 |
| - Reagents/Steel | 2 |
| - Training | 4 |
| - Cleaning | 3 |
| - Sample Preparation | 5 |
| | 17 |

ii) Maintenance

| | |
|---|---|
| Electricians | 4 |
| Instrument Fitters | 2 |
| Fitter/Welders | 6 |
| Crane Drivers | 2 |
| Rubber Workers | 2 |
| Trade Assistants | 5 |
| | 21 |

| | |
|---|---|
| Shift Fitters | 4 |
| | 4 |

# APPENDIX E

# ABORIGINAL SITE SURVEY

# REPORT ON A SURVEY FOR ABORIGINAL SITES: YAKABINDIE FEASIBILITY STUDY

Prepared for Soil and Rock Engineering Pty. Ltd.
By Rory O'Connor and Gary Quartermaine
MARCH, 1990

# REPORT ON A SURVEY FOR ABORIGINAL SITES : YAKABINDIE FEASIBILITY STUDY

Prepared for Soil and Rock Engineering Pty Ltd

By Rory O'Connor and Gary Quartermaine

March, 1990

ABSTRACT

A survey for Aboriginal sites in the vicinity of the proposed mining development at Yakabindie Station, 65 kilometres north of Leinster, was commissioned by Soil and Rock Engineering Pty Ltd and executed in March, 1990. The survey incorporated ethnographic and archaeological components conducted by R. O'Connor and G. Quartermaine, which are reported upon in this document.

The Aboriginal people consulted in the course of the ethnographic component were satisfied that the proposed work would not impact any sites of significance.

As a result of the archaeological survey, four newly recorded sites, as well as four Isolated Finds, were located in the designated survey area. Two of these sites are likely to be affected by the proposed development. Recommendations are included in this report.

# PART ONE

# ETHNOGRAPHY

PART ONE - ETHNOGRAPHY

TABLE OF CONTENTS

## 1.0 INTRODUCTION

### 1.1 Background to Report

This report is based on a period of field research carried out in March 1990. The aim of the research was to identify and delineate any areas of Aboriginal significance in the vicinity of the proposed mining development at Yakabindie Station, 65 kilometres north of Leinster, and thus enable the developers, Dominion Mining Pty Ltd, to fulfil their obligations under the *Aboriginal Heritage Act (*1972-1980)

The proposed development is located near Six Mile Well, approximately seventeen kilometres (17 kms) north of Yakabindie Homestead (see Figure One for location of the survey area).

In the course of the survey, Aboriginal people who have long-term association with the survey region were consulted by the author. At the same time, in recognition of the possible archaeological significance of the area to be impacted by the proposed development, an archaeological survey was conducted by G. Quartermaine. The results of this latter survey are detailed in Part Two of this report.

### 1.2 Research Brief

The research brief required the author to conduct an Aboriginal site survey and produce a report which will enable the W.A. Museum to consider whether the proposed mining development at Yakabindie Station will affect any Aboriginal sites. The survey area is defined as the proposed open cut area in M 36/57 and P 36/973, together with the newly proposed waste dumps and tailings dam. In addition, the author was required to consider any sites of religious significance in the near vicinity of the survey area, to ensure accurate mapping and description.

### 1.3 Acknowledgements

The author gratefully acknowledges the assistance and advice given by Bill Wesley, Paddy Walker, Donald Stokes, Willy Hill, Harvey Willabone and Shirley Willabone.

## 1.4 Format of Report

The conduct of the field survey and format of this report are based upon:

(i) Guidelines for Developers and Consultants previously issued by the Department of Aboriginal Sites, Western Australian Museum;

(ii) discussions with senior officers of that Department;

(iii) research brief issued by the developer (see 1.2 above)

(iv) requirements of the W.A. *Aboriginal Heritage Act*;

(v) procedures standardised by the author in a large number of similar exercises, which have been acceptable to that Department in the past.

## 2.0 REGIONAL FRAMEWORK

### 2.1 Linguistic Groups

The area of the proposed development is located within the traditional lands of members of the "Western Desert social and cultural bloc" (Berndt, 1959:104), which stretches in a broad sweep from Oodnadatta in South Australia, through the Great Victoria, Gibson and Great Sandy Deserts to the Southern Kimberly. A high degree of cultural and linguistic homogeneity exists throughout this region, although dialectual variation occurs (Douglas, 1964; Wurm 1972; Yallop, 1982). The distribution of these linguistic groups in the survey region, as mapped by Tindale (1974), is reproduced in Figure 3 and, in the authors opinion, represents a reasonably accurate depiction of the pre-contact situation. These groups, it should be noted, were *speech communities* and not *political entities*. Rights to land and its spiritual associations, and other political loyalties were framed and expressed at a lower numerical level. However, the spread of these linguistic groups can be used to paint the political scene in broad brush strokes, and thus gain an overall view of the region's traditional political geography.

### 2.2 Post Contact History

Aboriginal history in the survey region, following European contact, has been described in O'Connor and Quartermaine (1984 and 1986a), O'Connor and Veth (1984a) and O'Connor and Christensen (1986). It can be summarised briefly as follows:

#### 2.2.1 Meekatharra/Wiluna Region

(i) Large population of gold miners move into the region in the late 1890's.

(ii) Indigenous people die out from violence and introduced diseases.

(iii) A process of Aboriginal migration from the north-east begins and the newcomers take over "custodianship" or "trusteeship" of local Aboriginal law, including protection of religious sites.

(iv) Many of these migrants intermarry and settle on the newly formed pastoral stations: older linguistic and other distinctions to dull and a population of "Wangkayis" a regional collective Aboriginal identity, begins to develop.

(v) Following adoption of the Pastoral Award for Aborigines in 1968, permanent residence and employment on the station becomes scarce and movement to central locations such as Wiluna accelerates.

(iv) These central areas become melting pots where "tribal" differences finally collapse through inter-marriage and new collectivities arise: collectivities of persons made up of many local descent groups, many hordes and usually a number of different linguistic groups. They see themselves, and are seen by others as having a common identity, expressed usually in terms of the mission or settlement where they live, although frequent movement between groups continues. In many cases, migrants to these "mobs" retain rights of ownership over sites in their ancestral estates, while exercising custodial roles in their new areas.

(vii) In 1956, Pastor Vaughan sets up a mission in Wiluna with the aid of grants from the Native Welfare Department and the Western Australia Conference of the Seventh Day Adventist Church.

(viii) Thus, the development of the Wiluna Mob led to the foundation of a Seventh Day Adventist Mission, which in turn has led to the incorporation of Ngangawili Community and the recent move to outstations such as Mangkilli Claypan.

(ix) Through all these developments, however, the sacred associations of land in this region have been retained.

2.2.2 Leonora/Laverton Region

(i) As with the Meekatharra/Wiluna region, the first contacts between Europeans and Aborigines occurred within the framework of the 1890-1910 goldrush years, a volatile period with large numbers of rootless single men converged on the goldfields.

(ii) Violent reaction to the "invasion" leads to violent reprisals.

(iii) Once again, as the pastoral industry develops, the scattered remnants of the local tribes settle on stations or on the fringes of the many mining areas.

(iv) Aboriginal migration from the north-east and east commences, following a traditional trade route though Tjirrkarli (N-W of Warburton), Pirlpirr (Minnie Creek near Yamarna) to Laverton. The attraction of introduced foodstuffs and tobacco was a magnetic force which radiated Eastwards into the sandhill country.

(v) In 1921, Willie Ross and Harry Axford take up Cosmo Newberry Station, which in due course becomes the site of a large Aboriginal camp.

(vi) In 1921 also, Roderick Schenk sets up an Aboriginal mission some six kilometres north of the then partially abandoned Mt Margaret Goldfield; a mission which spearheaded a sustained attack on traditional religion and traditional relationships with land.

(vii) These traditional relationships are retained, however, as a regular infusion of tradition - oriented people from the Desert continues.

(viii) In 1927, all Aboriginal ration stations in this region other than Cosmo Newberry and Mt Margaret are closed thus centralising Aborigines into these two settlements.

(ix) Today, therefore, traditional Aboriginal religion, including the specific associations of religious sites, has survived in both centres.

## 3.0 THE SURVEY

### 3.1 Methodology

The survey was comprised of four separate stages, as follows:

(1) examination of existing ethnographic data base;
(2) consultation with Aboriginal elders;
(3) visits to the study area with Aboriginal elders;
(4) report preparation.

### 3.2 Ethnographic Data Base

Among the more important published sources dealing with Aboriginal sacred and mundane associations with land in the general survey region are the following:

Berndt (1959; 1972; 1976; 1979), Layton (1983), Palmer(1983a,;1983b;1984), Stanton (1983; 1984), Tonkinson (1978), Elkin (1939-40), Sackett (1977), Douglas (1964), Kingsford (1982) and Tindale (1974).

In addition, numerous unpublished works now exist, including the extended discussions in : Muir and Pukungka (1985), Christensen (1983), O'Connor (1983), O'Connor and Veth (1984a;1984b;1984c), O'Connor and Quartermaine (1984; 1985; 1986a; 1986b; 1986c; 1987) and O'Connor and Christensen (1986).

Also, valuable information is available in local historical texts, including:Powell (1932), Bennett (1935), Vindin (1929), Topperwien (n.d.), Doughty (1977), Pinnock (1959), Reid (1933), Forrest (1875), Palmer (1985) and Gregory (1884).

Finally, a wealth of information is stored in scattered references and private papers held in the Battye Library of Western Australian History. Many of these have been consulted by the author, are mentioned in the texts cited above, and have been used to form the summarised statement in 2.2.1 and 2.2.2 above.

### 3.3 Newly Recorded Sites

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

### 3.4 Previously Recorded Sites

Two sites of religious significance have been previously recorded in the near vicinity of the proposed development. Details and new information regarding these sites are as follows.

#### 3.4.1 Tjulypu (W0911, 1:250,000 grid ref 325 595).

There are a number of errors in the official record regarding this site, which was recorded originally in 1976 by the then registrar of Aboriginal Sites. Its location is recorded as "in the vicinity of Mail Change Well". However, the site, whose name should be Tjulypunya, is actually Mail Change Well itself. This site is well constructed on a rockhole, which was an important water source for Aborigines in Pre-contact times. A further error arises from the fact that Mail Change Well is incorrectly mapped in the "Sir Samuel" 1:250,000 mapsheet. It is shown as being 2.6

kilometres to the north of the Six Mile Well turnoff, and 100 metres to the east of the Wiluna-Agnew Road. In fact, Mail Change Well is 5.1 kilometres north of this turnoff, and 200 metres to the east of the road (distances not surveyed, but calculated from odometer of rented vehicle). Its grid reference should therefore be TK556 641. Its location is shown in Figure Two. Its religious significance relates to its creation by Wanarmpi, the regional variant of mythic water snake, who also created the important site at Yandal Lagoon and the Lake Darlot and Lake Maitland systems.

3.4.2 Tjinkuna (W0510, 1:250,000 grid ref. 352 595).

This site is part of the dragon - fly dreaming, which passes through Yakabindie and Albion Downs (the local name for "dragon fly" is "Tjinkuna", also known in English to local Aborigines as "horse stinger"). All previous manifestations of this myth encountered by the author have been either hills or rocky outcrops; this site replicates that pattern. The hill, which is shown in Figure Two, is located to the east of Tjulypunya.

## 4.0 CONCLUSIONS

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

No further action is required of the developer with regard to the ethnographic component of this survey, as no sites of significance will be impacted by the proposed development. No specific recommendations for protection or management of Tjulypunya or Tjinkuna are incorporated into this report, as they are outside the area of proposed development.

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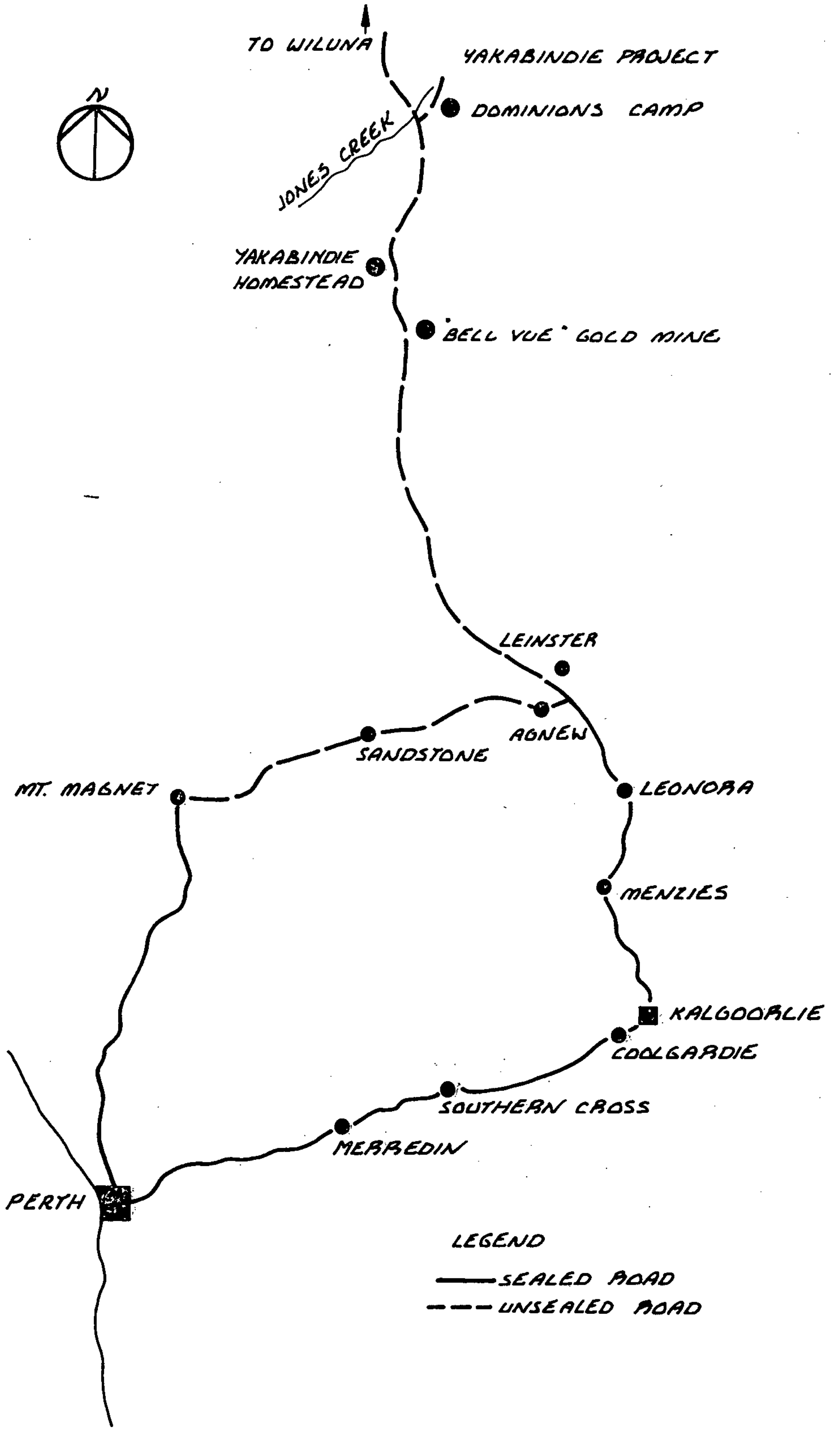


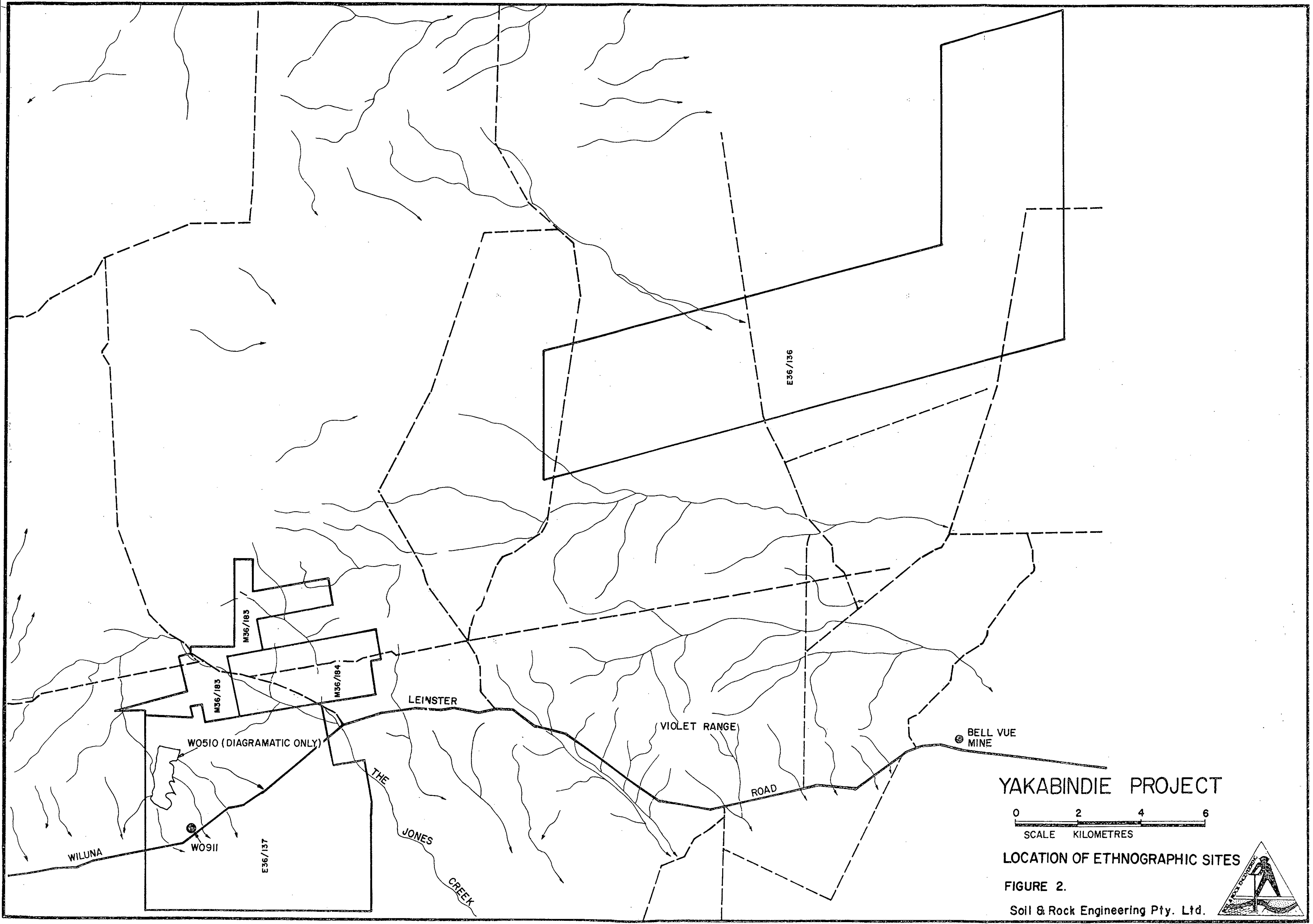

# YAKABINDIE PROJECT

NOT TO SCALE

**LOCATION PROJECT AREA**

**FIGURE I.**

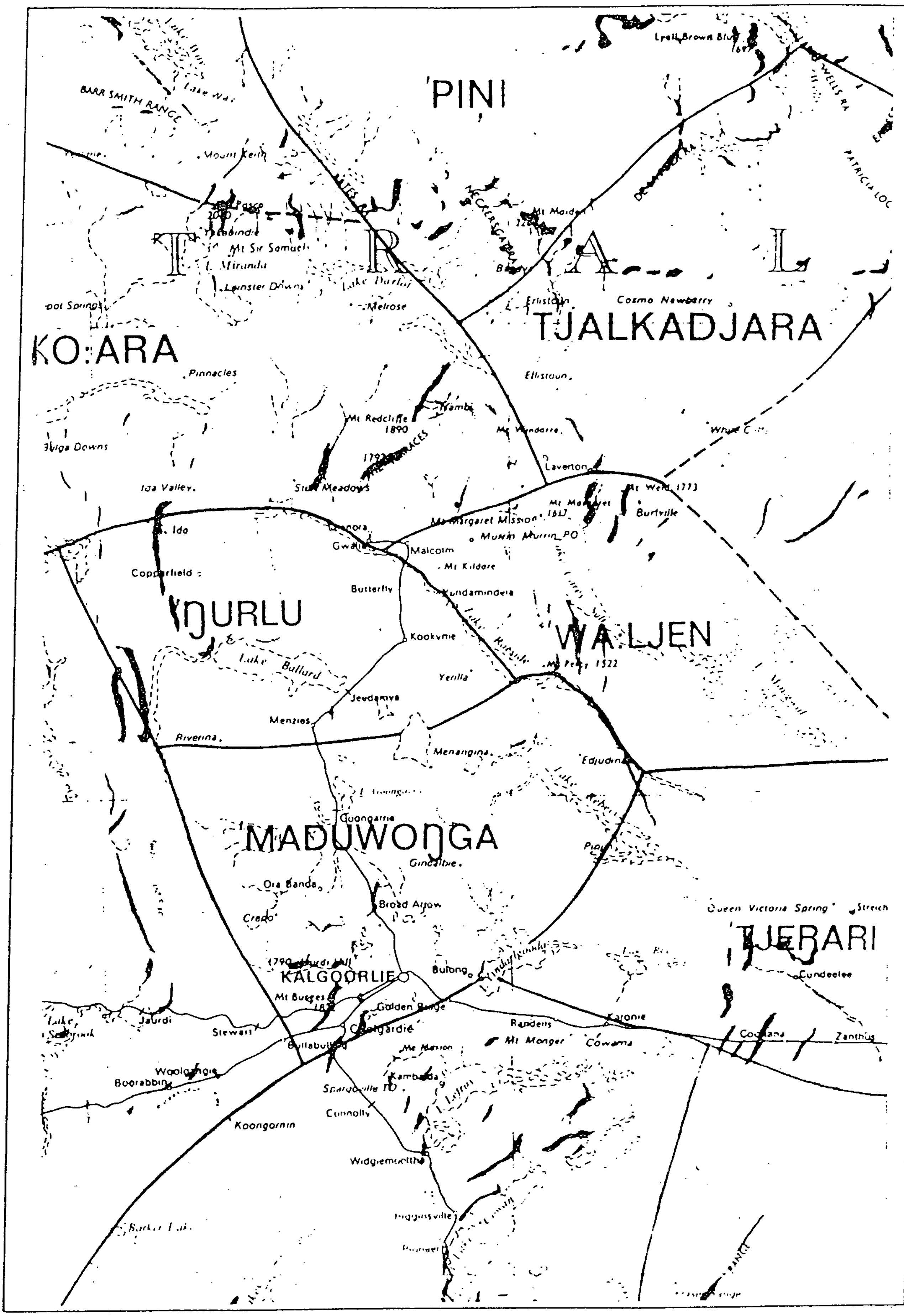
**Soil & Rock Engineering Pty. Ltd.**




LOCATION OF ETHNOGRAPHIC SITES

FIGURE 2.

Soil & Rock Engineering Pty. Ltd.




TRIBAL BOUNDARIES

Figure 3

(SOURCE: TINDALE, 1974)

# PART TWO

# ARCHAEOLOGY

PART TWO - ARCHAEOLOGY

TABLE OF CONTENTS

## 1.0 INTRODUCTION

### 1.1 Background to Survey

An Aboriginal site survey of a proposed mining development, near Yakabindie, 65 kilometres north of Leinster and 955km north-east of Perth by road, was commissioned by Soil and Rock Engineering Pty Ltd on behalf of Dominion Mining Limited and executed in March, 1990. Gary Quartermaine conducted the archaeological component of the survey in conjunction with Rory O'Connor, who undertook the ethnographic investigation.

The objectives of the archaeological survey were as follows:

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

2. A sample survey of the project area.

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

### 1.2 Location

The proposed mining development is situated 65 km north of Leinster and 955 km north-east of Perth by road (see Figure 1).The survey area is designated as an area of disturbance for a mine pit (1.4 sq km), waste dumps (1.5 and 1.9 sq kms) and tailings site (2.5 sq km - see Figure 2). The direct impact area, containing the proposed open-cut mine, waste dumps, and tailings site, takes up a total of approx. 7.3 sq. km in area.

### 1.3 Environment

The climate of the project area is classified as Desert, characterised by warm winters and hot summers. Mean annual rainfall is between 175 - 225 mm, and is unimodal (Bureau of Meteorology data).

The project area is part of the Archaean area, with granite and gneiss, and includes metamorphic rocks. It is gently undulating terrain with extensive mulga plains. There are low ranges of Archaean rocks and a few greenstone hills.

The chief soils are shallow acid or neutral red earths, each occurring with shallow earthy loams in intimate micro-association, with a scatter of surface gravel.

The vegetation is shrubby mulga (*Acacia aneura*) low woodland with mulga as almost the only tree. Occasionally, specimens of *A. quadrimaginea*, *A. grashyi* and *Hakea suberea* may be seen. On stoney ridges, the mulga is lower, more open and is joined by other species, mainly *Cassia and Eremophila* undershrubs (Beard, 1974).

## 1.4 Previous Archaeological Research

As a result of previous surveys and independent research, nine Aboriginal sites have been recorded and registered with the W.A. Museum in the general area of the project (see Table 1).

The nearest recorded archaeological site, W0048, is a stone arrangement and is situated ten kilometres to the east. Two ethnographic sites are recorded immediately west of the project area.

The other archaeological sites, previously recorded within 20 kilometres of the proposed development, are an engraving and artefact site (W0047) and artefact sites (W0478 and W0907).

The earliest occupation dates for inland Western Australia are in the order of 20,000 years ago and these were obtained from rockshelter deposits near Newman (Maynard, 1980; and Troilett. 1982). A 10,000 year old occupation of a rockshelter site, Puntutjarpa, near Warburton, has been described by Gould (1977), with continuous occupation into the present.

Prehistoric stone tool industries in the South-West have been classified into earlier and later phases (Dortch, 1977). The early phase industries have only been documented from a few well-dated sites. They include small thick flake scrapers, bipolar cores, notched-denticulated pieces, flakes from discoidal cores, and single and multi-platform cores. These artefacts have been manufactures from a range of lithic materials, including silicified sediments, quartz, chert, jasper, silcrete and chalcedony.

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

TABLE 1 : ABORIGINAL SITES IN THE VICINITY OF THE PROJECT AREA

| Site No. | SG51-13 250,000 Grid Ref. | Site Type | Site Name |
|---|---|---|---|
| W0511 | 33-.61- | ETH.ARC.C.M.S. | Yirltji |
| W0907 | 344.608 | ARC.M.A. | Tjiwal |
| W0482 | 346.569 | O. | Tjampuwa |
| W0509 | 34-.56- | O. | Yakamunti |
| W0510 | 352.595 | O. | Tjinkuna |
| W0911 | 352.595 | ARC.M.A. | Tjulypu |
| W0047 | 356.607 | ARC.E.A.O. | Wanjarri/Kathleen Valley |
| W0048 | 365.598 | ARC.S. | Wanjarri Station |
| W0478 | 369.584 | ARC.A.O. | Dingo Pool |

Eth = Ethnographic, Arc = Archaeological
M = Mythological, C = Ceremonial
S = Stone structure, A = Artefacts, E = Engravings, O = Other

## 2.0 METHODS

### 2.1 Obligations under the Act

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

The archaeological survey should identify the effects of the proposed disturbance of the physical environment on any Aboriginal archaeological sites. In recognition of the possible significance of this area to living Aboriginal people, consultations with Aboriginal people identified as having an interest in the area were conducted by Rory O'Connor, in conjunction with the archaeological survey.

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

### 2.2 Survey Design

The survey design involved the following stages of operation.

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

ii) Survey strategy - this consisted of a systematic sample survey of the designated survey areas.

The survey was completed using 1:50,00 aerial photos, and 1:5,000 and 1:20,000 plans of the development plus a 1:250,000 topographic map.

There has been considerable disturbance to the environment of the pit area. The other areas are relatively undisturbed. Surface visibility was good on the lateritic ground which had no ground cover vegetation between the trees and bushes. Access was possible to all parts of the survey area by use of a 4 wheel drive vehicle and on foot.

The field survey was completed on foot in a series of E/W and N/S transects from baseline tracks running N/S and E/W through the leases. These transects were spaced at 200m intervals using the extant grid system and a compass which provided an adequate degree of accuracy for the purpose of this survey. The pit area, which is already gridded, was surveyed in a more intensive pattern at 100 metre intervals. This allowed a sample of, at least, 25 % of each area surveyed.

## 2.3 Site Definitions

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

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

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

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

i) Site dimensions - extent and type:

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

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

iv) Stratigraphy - assessment of potential.

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

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

## 3.0 RESULTS

Four newly recorded archaeological sites and four Isolated Finds were located as a result of this investigation. The sites are all surface artefact scatters, three small and one medium in size. Details are as follows. See Appendix Three for data sheets and Figure 2 for locations.

### Field Site 1

1:250,000 Map Ref. SG 51-13 354.596

Description : This site is an artefact scatter/core reduction/ quarry area situated on the western margin of Jones Creek in the proposed pit area. The grid peg 19680N /9650E is near the site boundary. It is 200 metres north of a major creek junction and 50 metres west of the creek. The rocky laterite surface is open with sparse scattered shrub and denser and larger trees along the creek line (see Plate 1).

The site dimensions are 50 by 20 metres. Twelve artefacts were recorded as the total visible surface assemblage. These were mainly chert from a silica cap on the laterite at this location plus a quartzite and silcrete piece (see Plate 2). Two cores and ten flakes were recorded. There is only a very low potential for the presence of sub-surface archaeological material.

Discussion: This site is a minor site of low archaeological significance because of its small size, low number of artefacts and lack of stratigraphic potential. It is in the area of the proposed pit and will be affected if the development proceeds.

### Field Site 2

1:250,000 Map Ref. SG51-13 353.595

Description : This site is an extensive artefact scatter situated on the west side of Jones Creek. It is located 100 metres west of the creek and 300 metres south-west of Six Mile Well. There is little vegetation, apart from scattered mulga, on the flat laterite surface (see Plate 3).

The site dimensions are 150 by 100 metres. There is an estimated 2,000 stone artefacts present in this area based on a 10 by 10 metre sample square from which 14 artefacts were recorded. The artefacts were all flakes, including one retouched piece, made from chert, silcrete, quartzite, quartz and silicified sediment (see Plate 4 which also includes a retouched blade not in the sample). There is only a low potential for the presence of stratified archaeological material at this site.

Discussion: This site is considered to be of moderate significance because of its extensive area, number of artefacts and stratigraphic potential. It can be avoided by the present development since it is outside the tailings area.

Field Site 3

1:250,000 Map Ref. SG51-13 356.594

Description : This site is a small, low density artefact scatter situated on the east margin of a small ephemeral drainage area. It is located 2.5 kilometres east of Jones Creek and 400 metres east from the north-west corner of mining lease P36/976. There is some salt bush ground cover with moderate mulga scrub along the drainage (see Plate 5).

The site dimensions are five by five metres. Only four artefacts were located in this area. These were three flakes and a core made from chert, silcrete and silicified sediment (see Plate 6). There is only a very low possibility that sub-surface archaeological material may be present.

Discussion: This site is a minor site of low archaeological significance because of its small size, low number of artefacts and lack of stratigraphic potential. It is in the middle of one waste dump area and will be affected if the development proceeds.

Field Site 4

1:250,000 Map Ref. SG51-13 356.594

Description : This site is a small, low density surface artefact scatter, situated near a granite exposure to the north of a creek. It is located 300 metres west of the south-east corner of the P36/976 lease area and 100 metres north of the creek. Vegetation is sparse with occasional low trees on a flat, lateritic surface (see Plate 7).

The site dimensions are 20 by 10 metres. There were seven stone artefacts in the total visible surface assemblage. These were all flakes made from silcrete, chert, quartzite, silicified sediment and silicified mudstone (see Plate 8). There is only a low potential for stratified archaeological material at this site.

Discussion: This site is a minor site of low archaeological significance because of its small size, low number of artefacts and lack of stratigraphic potential. It will not be affected by the present development.

Details of Isolated Finds are as follows.

IF1 Mudstone flake, 48 x 27mm, creek margin.
IF2 Silicified sediment backed blade, 26 x 6mm, plain.
IF3 Chert flake, 42 x 27mm, creek margin.
IF4 Quartzite flake, 27 x 33mm, plain.

## 4.0 CONCLUSIONS

### 4.1 Discussion

The proposed development involves an open-cut mine, waste dump sites and tailings site. These encompass an area of approx. 7.3 square kilometres. The development is situated near Yakabindie, 65 km north of Leinster and 955km north east of Perth.

The archaeological field survey involved a systematic sample survey of the designated survey area. The terrain of the proposed area is mainly flat with a mulga low woodland vegetation on a lateritic soil with some low granite hills.

Access was possible to all parts of the survey area by the use of a 4WD vehicle. Surface visibility was good because of the absence of ground cover vegetation. However, there was considerable disturbance at the mine site due to previous mining activity.

As a result of the field survey, four newly recorded archaeological sites and four Isolated Finds were located. No other sites are expected in the development area based on the results of the survey.

The newly recorded sites were all surface artefact scatters situated in the vicinity of watersources, such as creeks and ephemeral drainages. Artefacts were made from a variety of lithic materials, including chert, banded ironstone, quartz, quartzite, silicified sediment and silicified mudstone, and silcrete. Artefact types recorded included a retouched flake, flakes and cores.

The most likely site locations, water courses, were where archaeological sites were recorded during this survey. This fits the pattern of site distribution in arid environments.

## 4.2 Recommendations

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

1. Field Site 1 is situated in the proposed pit area and Field Site 3 in a proposed waste dump area. Permission to disturb these sites is required under Section 18 of the W.A. *Aboriginal Heritage Act,* 1972-1980. This is obtained by written application to the Trustees of the WA Museum for permission to use the land under Section 18 of the Act. It is recommended that such permission be granted.

2. Field Sites 1 - 4 have been recorded, mapped and flagged in the field. If any of these sites is likely to be disturbed by future development, permission to disturb the site should be obtained from the W.A. Museum. Permission to disturb an Aboriginal site is required under Section 18 of the W.A. *Aboriginal Heritage Act,* 1972-1980. This is obtained by written application by the owner of the land to the Trustees of the WA Museum for permission to use the land under Section 18 of the Act.

3. Field Site 2 will not be affected by the proposed development. If this site is likely to be affected by any future disturbance, it is recommended that further archaeological recording be undertaken.

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

## Acknowledgements

The information and assistance provided by Dominion Mining staff at Yakabindie, Chris Lane, Emma Quartermaine and Caroline Heine is gratefully acknowledged.

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APPENDICES

APPENDIX 1

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

Report of Findings

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

Excavation of Aboriginal Sites

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

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

Offences Relating to Aboriginal Sites

"17. A person who-

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

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

Consent to Certain Uses

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

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

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

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

or

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

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

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

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

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

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

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

## APPENDIX 2

### Notes on the Recognition of Aboriginal Sites

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

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

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

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

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

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

### Habitation Sites

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

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

### Seed Grinding

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

## Habitation Structures

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

## Middens

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

## Stone Artefact Factory Sites

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

## Quarries

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

## Marked Trees

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

## Burials

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

Stone Structures

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

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

Paintings

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

Engravings

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

Caches

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

Ceremonial Grounds

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

## Mythological Sites

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

# APPENDIX THREE

# ARCHAEOLOGICAL SITE DETAILS

ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY Yakabindie DATE 5-3-90

FIELD SITE NO. FS1 GRID REF.

PHOTOS site from N 1:250,000 SG51-13 354.596
artefacts (last shot after FS4) 1:100,000
Other 19680/9650

ENVIRONMENT

landform:
geology :
vegetation: type...Mulga scrub..cover...sparse..........
species.....................................
water : type..ephemeral.......distance.....20 m..........
disturbance:type..grid line.....amount..moderate........

SITE DESCRIPTION

site type : artefact scatter
dimensions: NS.........50..........EW.......20 m............
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: stone artefacts

stratification: v. low potential
no. of artefacts: approx. total........12.................
density.........sparse.................
sample.........total visible..........

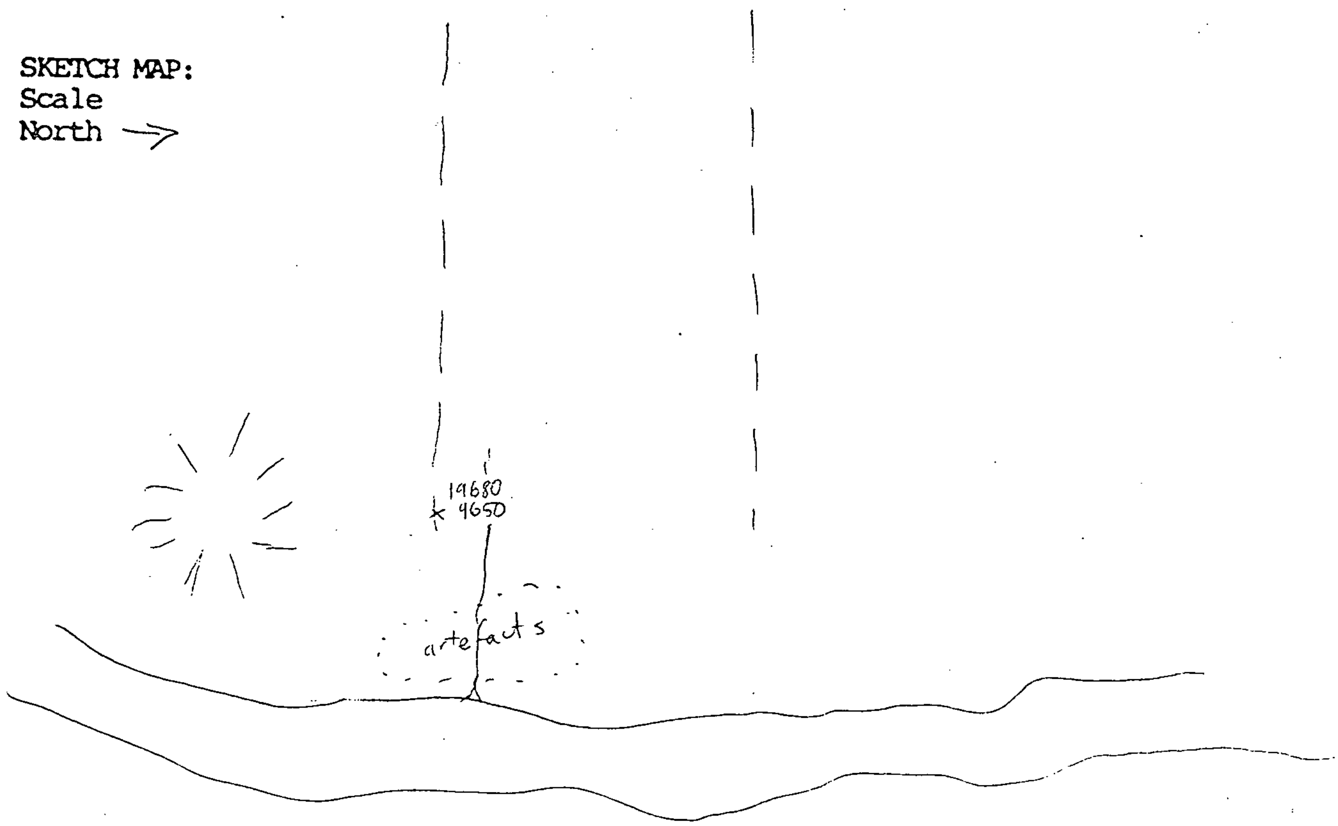
Recorded by : GSQ
Date : 5-3-90
Client : S & R

FIELD ID FS1

| ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE | ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| flake | chert | 46 | 34 | | | | | | | | |
| " | " | 77 | 45 | | | | | | | | |
| core | " | 75 | 58 | mp | | | | | | | |
| flake | qtzt | 28 | 22 | | | | | | | | |
| " | chert | 45 | 53 | | | | | | | | |
| " | " | 57 | 43 | | | | | | | | |
| " | " | 48 | 37 | | | | | | | | |
| " | silc | 25 | 26 | | | | | | | | |
| " | chert | 33 | 25 | | | | | | | | |
| " | " | 63 | 28 | | | | | | | | |
| " | " | 37 | 22 | | | | | | | | |
| core | " | 70 | 66 | sp | | | | | | | |

SITE LOCATION:

SKETCH MAP:
Scale
North →



ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY Yakabindi DATE 5-3-90

FIELD SITE NO. FS2 GRID REF.

PHOTOS site from N
artefacts

1:250,000 SG 51-13 353-595
1:100,000
Other

ENVIRONMENT

landform: floodplain
geology : weathered granite
vegetation: type..Mulga scrub...cover..sparse/medium.
species.......................................
water : type..ephemeral......distance.................
disturbance:type....-...........amount...................

SITE DESCRIPTION

site type : artefact scatter
dimensions: NS......150.........EW.........100 m...........
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: stone artefacts

stratification: low potential
no. of artefacts: approx. total..........2000...............
density..........sparse...............
sample..........10 x 10m sq.............

Recorded by : GSQ
Date : 5-3-90
Client : S & R

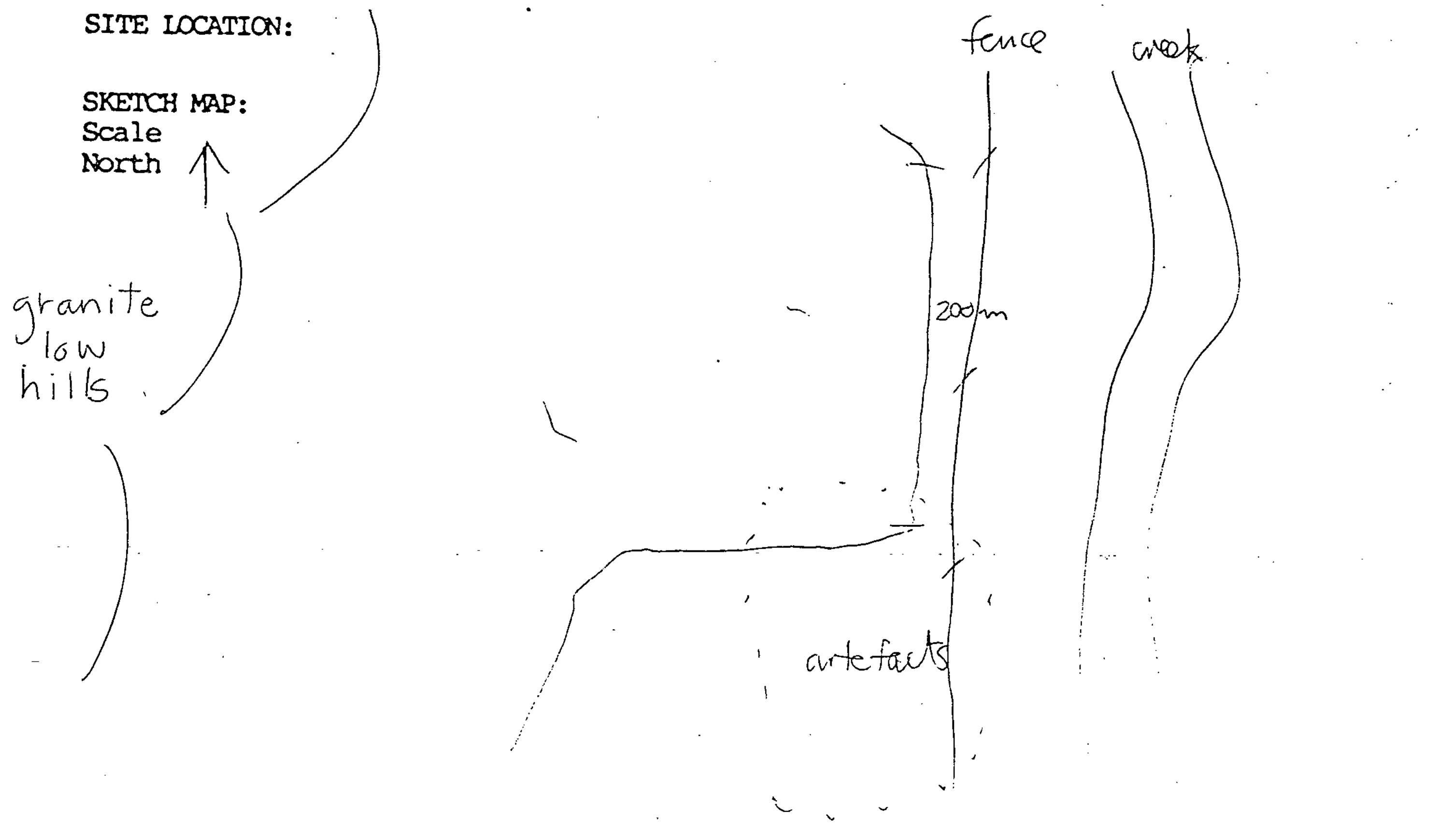
10 x 10 m sq

FIELD ID FS2

| ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE | ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| flake | chert | 27 | 15 | | | | | | | | |
| " | ss | 28 | 29 | | | | | | | | |
| " | silc | 39 | 25 | | | | | | | | |
| " | " | 36 | 44 | | | | | | | | |
| " | qtzt | 24 | 27 | | | | | | | | |
| " | ss | 29 | 24 | | | | | | | | |
| r " | chert | 39 | 25 | | | | | | | | |
| " | " | 38 | 32 | | | | | | | | |
| " | silc | 18 | 22 | | | | | | | | |
| " | qtzt | 19 | 28 | | | | | | | | |
| " | qtz | 27 | 16 | | | | | | | | |
| " | chert | 38 | 29 | | | | | | | | |
| r/u flake | ss | 29 | 31 | concave | step | | | | | | |
| flake | chert | 21 | 38 | | | | | | | | |

SITE LOCATION:

SKETCH MAP:
Scale
North



ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY Yakabindie DATE 6-3-90

FIELD SITE NO. FS 3 GRID REF.

PHOTOS Site from NE 1:250,000 SG 51-13 356.594
artefacts 1:100,000
Other

ENVIRONMENT

landform: Floodplain
geology : weathered laterite
vegetation: type..halophytes, scrub cover...sparse..........
species.....................................
water : type...ephemeral......distance...20m..........
disturbance:type...natural......amount....low..........

SITE DESCRIPTION

site type : artefact scatter
dimensions: NS.........5.......EW.........5 m............
boundaries: n~~atura~~l/artificial . discrete/~~diffus~~e
components: stone artefacts

stratification: v. low potential
no. of artefacts: approx. total.........4.................
density.............sparse...................
sample..........total visible........

Recorded by : GSQ
Date : 6-3-90
Client : S & R

FIELD ID ____________

| ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE | ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| flake | chert | 65 | 43 | | | | | | | | |
| core | SS | 43 | 37 | | | | | | | | |
| flake | silc | 44 | 34 | | | | | | | | |
| " | " | 34 | 23 | | | | | | | | |
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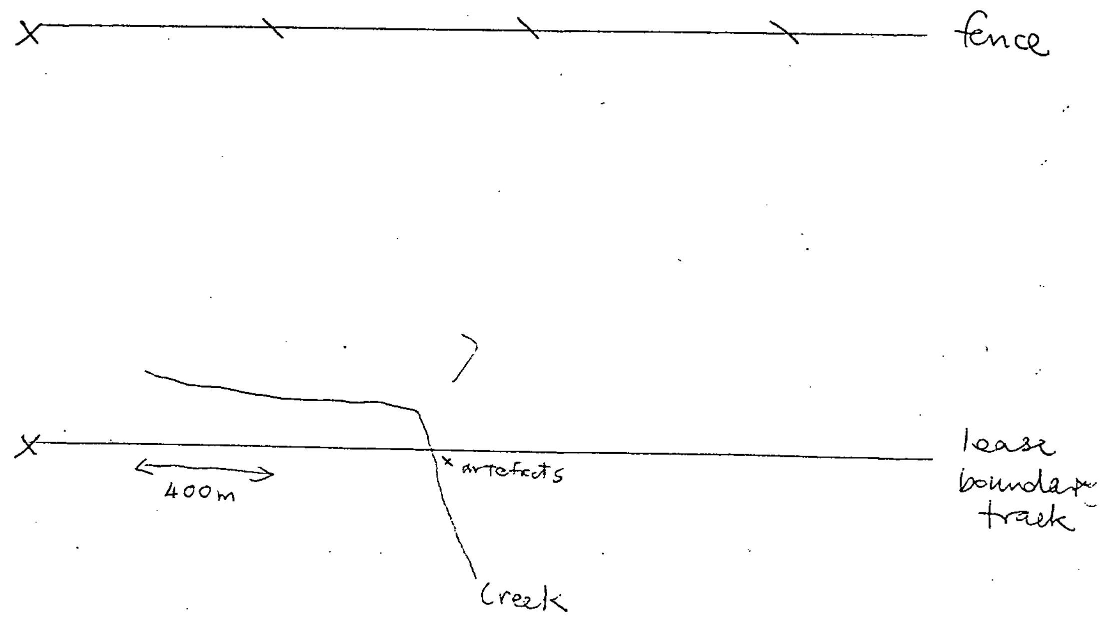
SITE LOCATION:

SKETCH MAP:
Scale
North ↑




X lease corner peg

ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY Yakabindie DATE 6-3-90

FIELD SITE NO. FS 4 GRID REF.

PHOTOS Site from E 1:250,000 SG 51-13 356.594
Artefacts 1:100,000
Other

ENVIRONMENT

landform: granite exposed on floodplain
geology :
vegetation: type....scrub........cover....sparse..........
species..........................................
water : type..ephemeral......distance.....100m........
disturbance:type..natural......amount....low............

SITE DESCRIPTION

site type : stone artefact scatter
dimensions: NS.........20........EW.......10 m..............
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: stone tools

stratification:
no. of artefacts: approx. total.......57.................
density...........sparse....................
sample.......total visible....................

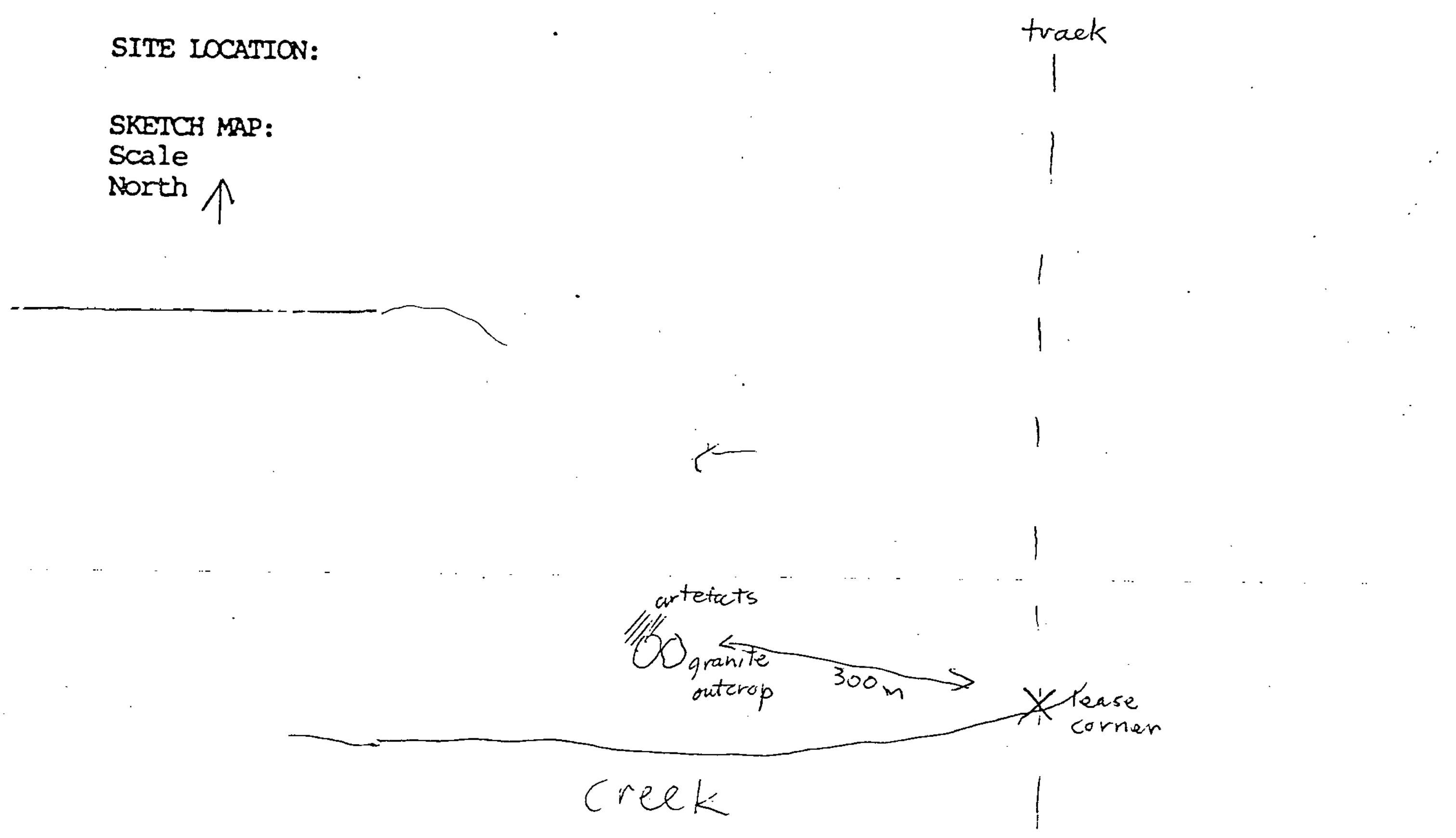
Recorded by : GSQ
Date : 6.3.90
Client : S&R

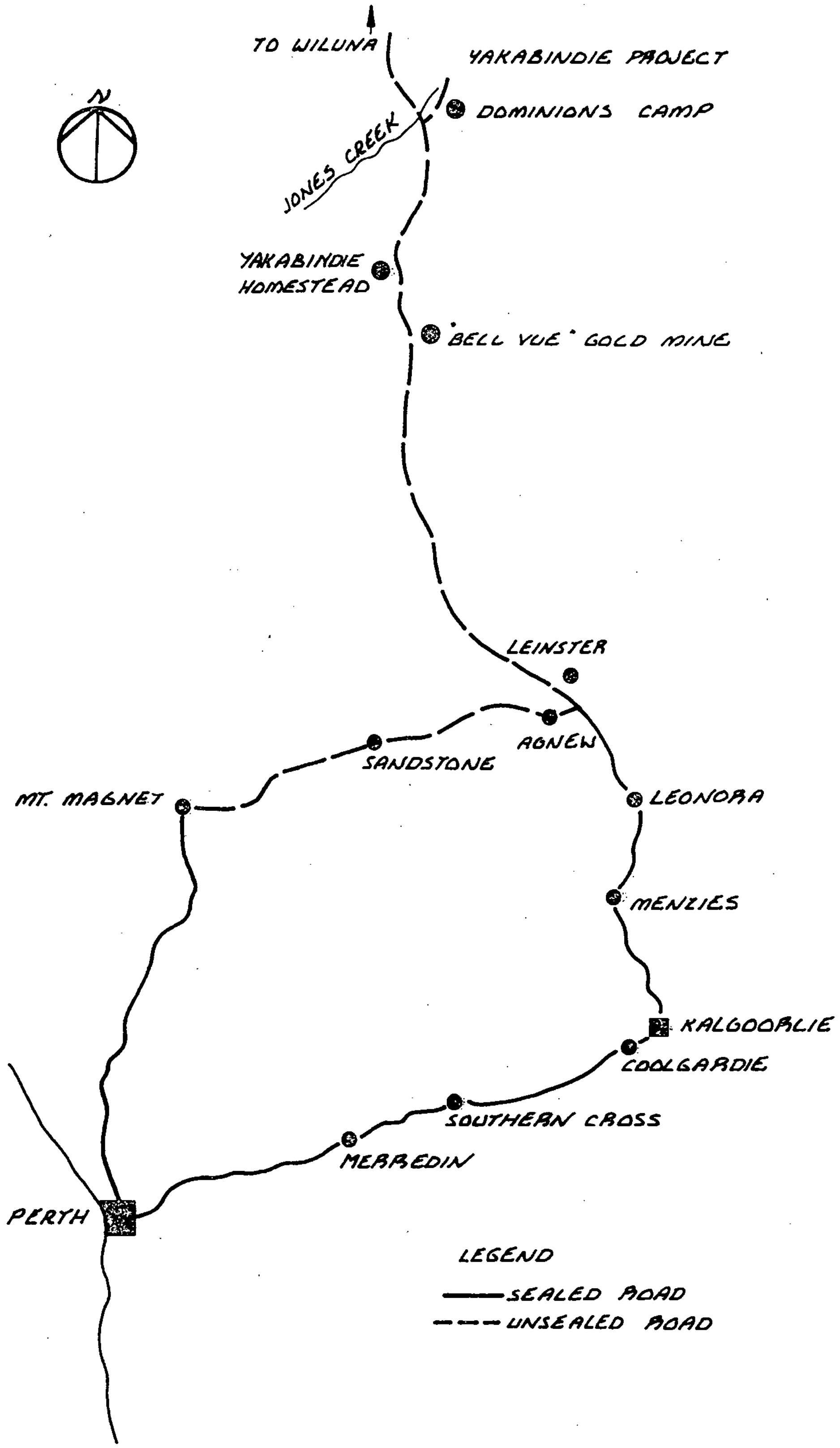
FIELD ID ________

| ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE | ARTEFACT TYPE | LITHIC | LENGTH | WIDTH | RETOUCH TYPE | EDGE SHAPE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| flake | silc | 41 | 52 | | | | | | | | |
| " | " | 34 | 28 | | | | | | | | |
| " | chert | 40 | 33 | | | | | | | | |
| " | smud | 44 | 30 | | | | | | | | |
| " | ss | 40 | 35 | | | | | | | | |
| " | qtzt | 30 | 35 | | | | | | | | |
| " | smud | 42 | 24 | | | | | | | | |

SITE LOCATION:

SKETCH MAP:
Scale
North ↑





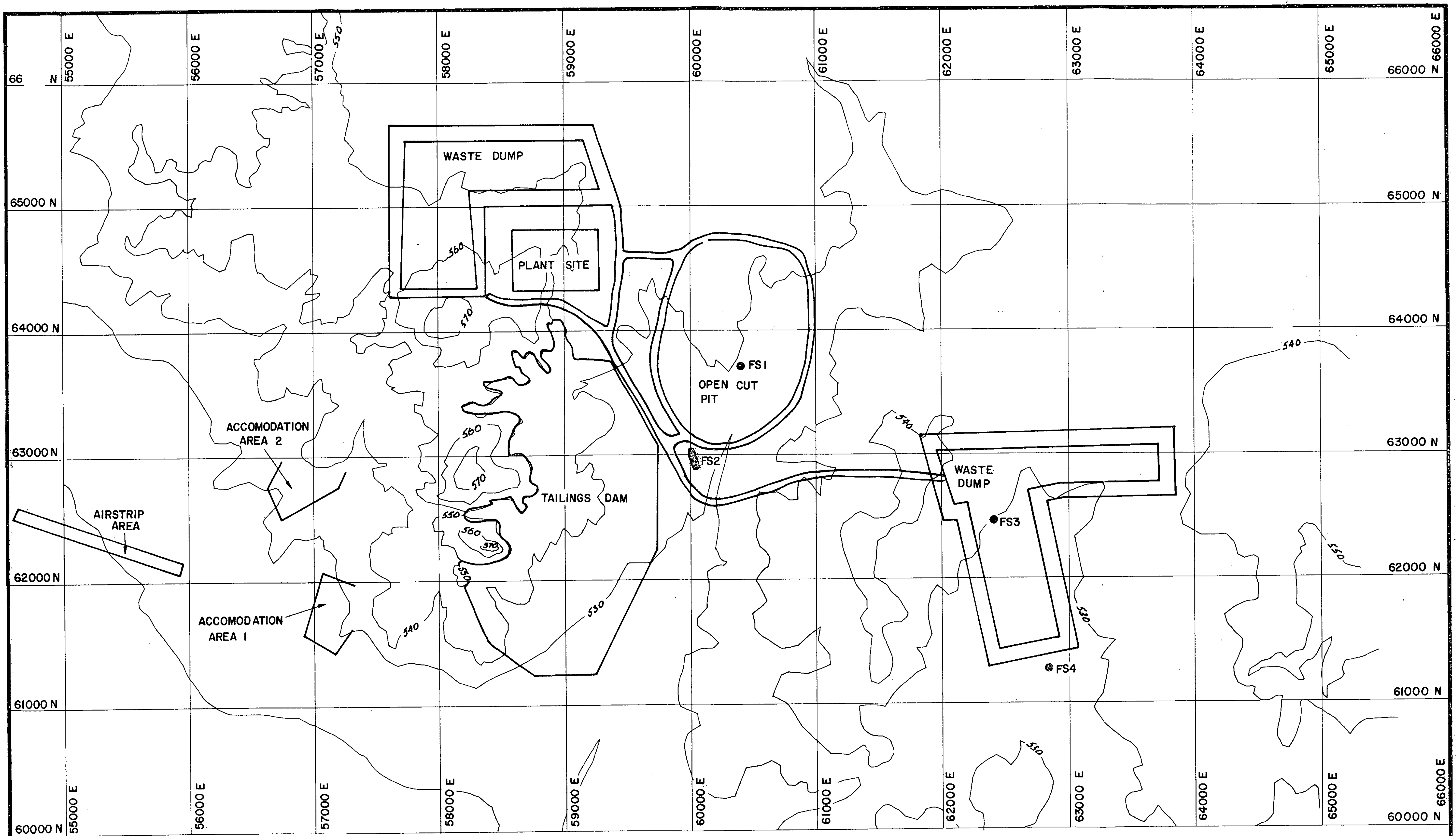

# YAKABINDIE PROJECT

NOT TO SCALE

LOCATION PROJECT AREA

FIGURE I.

Soil & Rock Engineering Pty. Ltd.




# YAKABINDIE PROJECT

200 0 200 400 600 800 METRES
SCALE 1:10000

LOCATION OF ABORIGINAL SITES
FIGURE 2.

Soil & Rock Engineering Pty. Ltd.

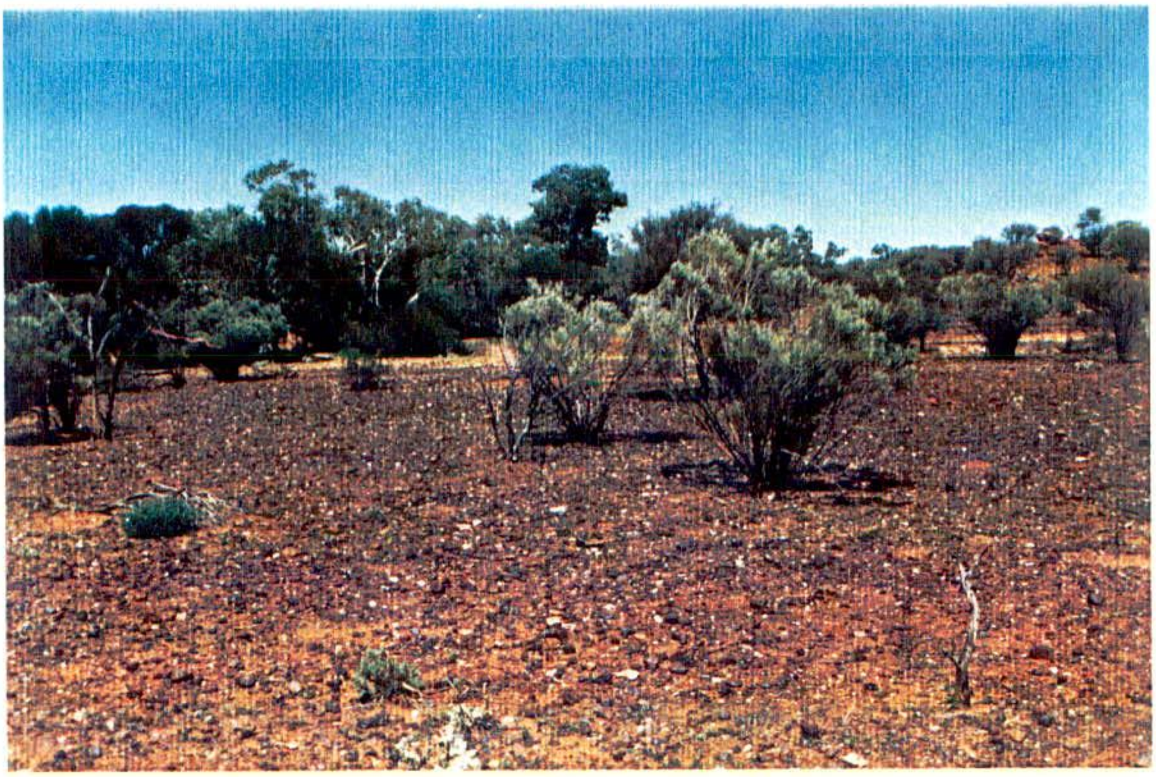


PLATE 1 : Field Site 1, from north - west

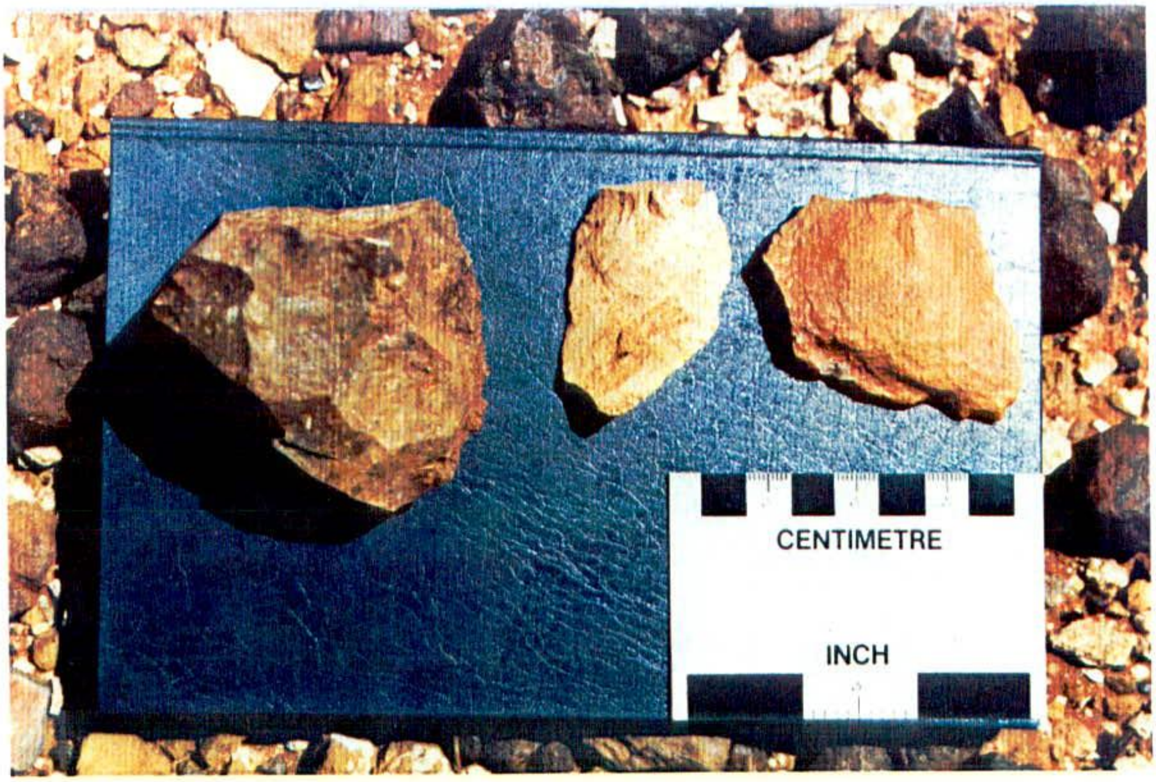



PLATE 2 : Field Site 1, artefacts

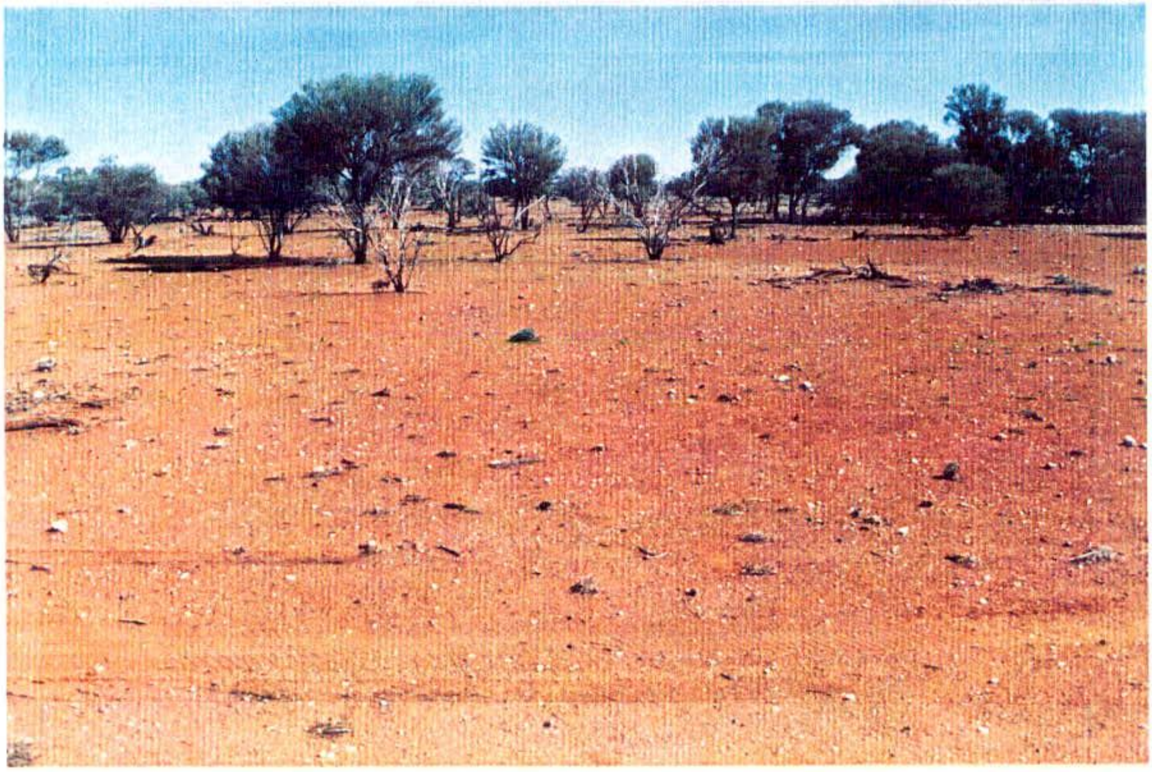


PLATE 3 : Field Site 2, from north - east

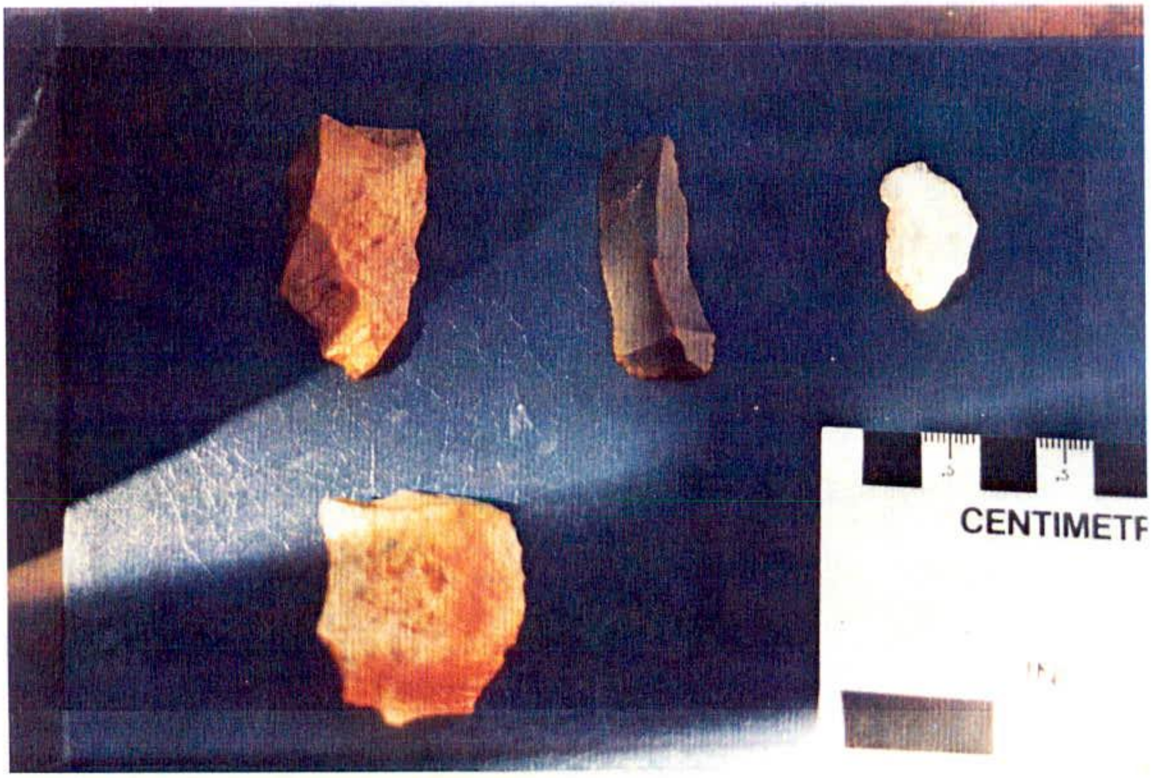



PLATE 4 : Field Site 2, artefacts

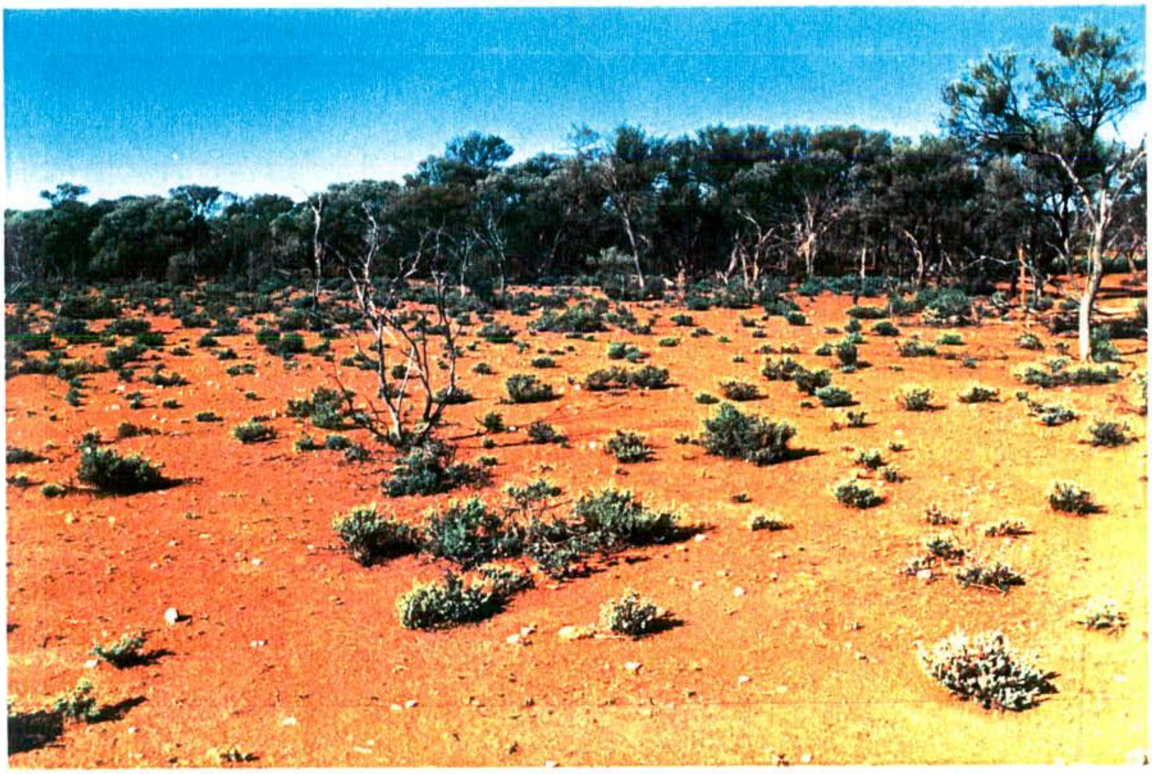


PLATE 5 : Field Site 3, from north - east


PLATE 6 : Field Site 3, artefacts

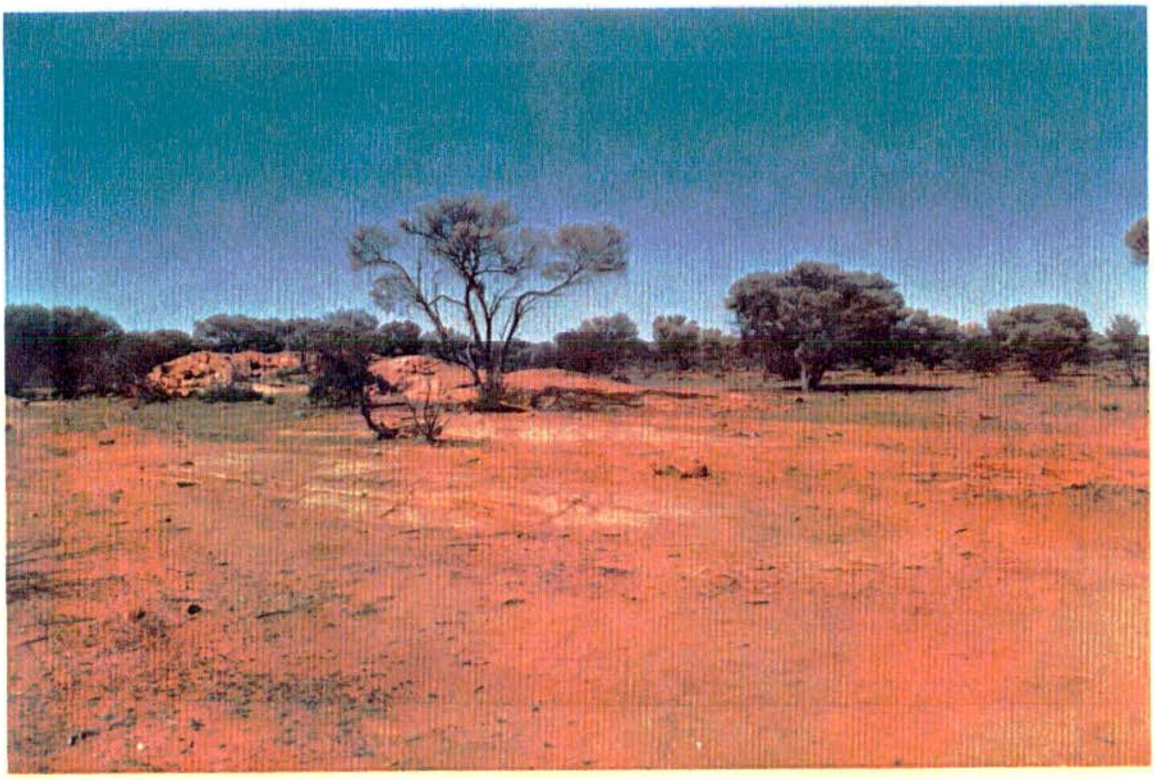


PLATE 7 : Field Site 4, from north - west


PLATE 8 : Field Site 4, artefacts