TIO2 CORPORATION NL
AND
KERR-McGEE CHEMICAL CORPORATION
JOINT VENTURE

RELOCATION OF PROPOSED DRY PROCESS PLANT, MUCHEA

NOTICE OF INTENT

Maunsell & Partners Pty Ltd
CONSULTING ENGINEERS & PLANNERS

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AND
KERR-McGEE CHEMICAL CORPORATION
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MAUNSELL & PARTNERS PTY LTD

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TABLE OF CONTENTS

TABLE OF CONTENTS (contd)

1. INTRODUCTION

TIO2 Corporation in conjunction with its prospective Joint Venture partners Kerr-McGee Chemical Corporation (KMCC), is proceeding with plans to establish a fully integrated mineral sands processing industry in Western Australia. Mineral sands will be mined at Cooljarloo, separation of the heavy minerals and ilmenite upgrading will follow at plants near Muchea and the upgraded ilmenite will be converted to titanium dioxide pigment at Kwinana. The final product will then be exported from Fremantle.

The various components of the proposal have been the subject of three environmental assessment reports as follows:

- Cooljarloo Mineral Sands Project Environmental Review & Management Programme (ERMP), covering the Cooljarloo minesite and the dry process plant at Muchea (Maunsell & Partners, 1987).

- Synthetic Rutile Plant Public Environmental Report covering extension of the Muchea to include upgrading of ilmenite (Maunsell & Partners, 1988a)

- Titanium Pigment Plant ERMP (Maunsell & Partners 1988b).

The Cooljarloo ERMP has been assessed by the Environmental Protection Authority (EPA) and found to be environmentally acceptable (EPA, 1988 Bulletin 330). However, the proposed dry process plant has subsequently been relocated to a new site largely at the request of local residents. This new site is described in the Synthetic Rutile Plant PER which is currently under review but the relocation of the dry process plant has not previously been presented formally to the EPA for separate evaluation. This Notice of Intent (NOI) meets that need. It provides a description of the new site and of the environmental implications of the relocation. Much of the material presented is also relevant to the synthetic rutile plant as the project will involve an integrated complex on the same site.

2. DISCUSSION OF THE ALTERNATIVE SITES

Selection of a site for the dry process plant is closely linked to the site of the synthetic rutile plant, because of the cost benefits in capital and operating expenditures, integrated management, operations and maintenance structure which will service both plants. The cost of transfer of feedstock from one plant to the other is also minimised.

It was proposed originally to locate the dry process plant at a site approximately 0.5km north-east of Muchea (Maunsell & Partners, 1987). This site was selected after a detailed consideration of alternative sites at Geraldton, Eneabba, Cooljarloo and Muchea itself. However, with the extension of the project to include a synthetic rutile plant, this original site (Site A) was re-evaluated.

The evaluation concluded that while an environmentally acceptable integrated complex could be established at Site A, relocation to a new site further away from Muchea would achieve a higher degree of local community support.

Various alternative sites in the Muchea area were then considered as described in Maunsell & Partners (1988a) and a new site some 4km north of the town was selected as the most appropriate (Site B). The relative merits of a summary of Sites A and B is given below.

Site A

The original site proposed for the dry process plant is relatively close to the township of Muchea and has the following advantages:

Positive features -

Economic:

- major services such as water, electricity and gas are readily available
- the site is well located to allow economic access to the railway and the Brand Highway access
- transport costs for ilmenite are negligible as the synthetic rutile plant will be on the same site
- transport of feed is made economical through the backloading of the waste from the synthetic rutile plant
- reduced costs because of the ability to share plant infrastructure with the neighbouring synthetic rutile plant

Social:

- within an area defined by the Shire of Chittering as intended for industrial land use
- the availability of a skilled and unskilled workforce within commuting distance

Environmental:

- the background noise levels of Muchea will be unaffected
- there is good access to the railway and the Brand Highway for easy transport of finished product and process materials

Disadvantages -

Economic:

- there are no pre-existing, engineering support industries such as machine shops etc

Environmental:

- none foreseen

Site B

Site B is located 4km to the north of Muchea but in a similar position with respect to the Brand Highway, railway line etc. as the original Site A.

Positive Features -

Economic:

- major services such as water, electricity and gas are readily available
- transport of ilmenite is negligible as the synthetic rutile plant will be on the same site
- transport of feed is made economical through the backloading of the waste from the synthetic rutile plant
- reduced costs because of the ability to share plant infrastructure with the neighbouring synthetic rutile plant

Social:

- the availability of a skilled and unskilled workforce within commuting distance

Environmental:

- the background noise levels of Muchea will be unaffected

Disadvantages -

Social:

- the site is not zoned for industrial use

Economic:

- there is not a pre-existing engineering support industry such as machine shops etc
- access to the Brand Highway and the railway will be impaired by Chandala Brook

Environmental:

- some vegetation loss on site due to plant construction, and road and rail access over Chandala Brook.

3. DESCRIPTION OF THE NEW SITE

3.1 LOCATION

The new site for the dry process plant is Swan Location M1261 approximately 4km north-east of Muchea and adjacent to the Brand Highway (Figure 1).

3.2 NATURAL ENVIRONMENT

3.2.1 Landscape

The landscape at Muchea is generally flat and low-lying. Inspection of the local topography reveals that the land traversed by the Brand Highway is a shallow depression bounded by the Gingin escarpment to the east and the extensive area of Bassendean Sand dune ridges to the west.

The Chandala Brook-Ellen Brook stream system flows north-south through the centre of this shallow depression, eventually connecting with the Swan River.

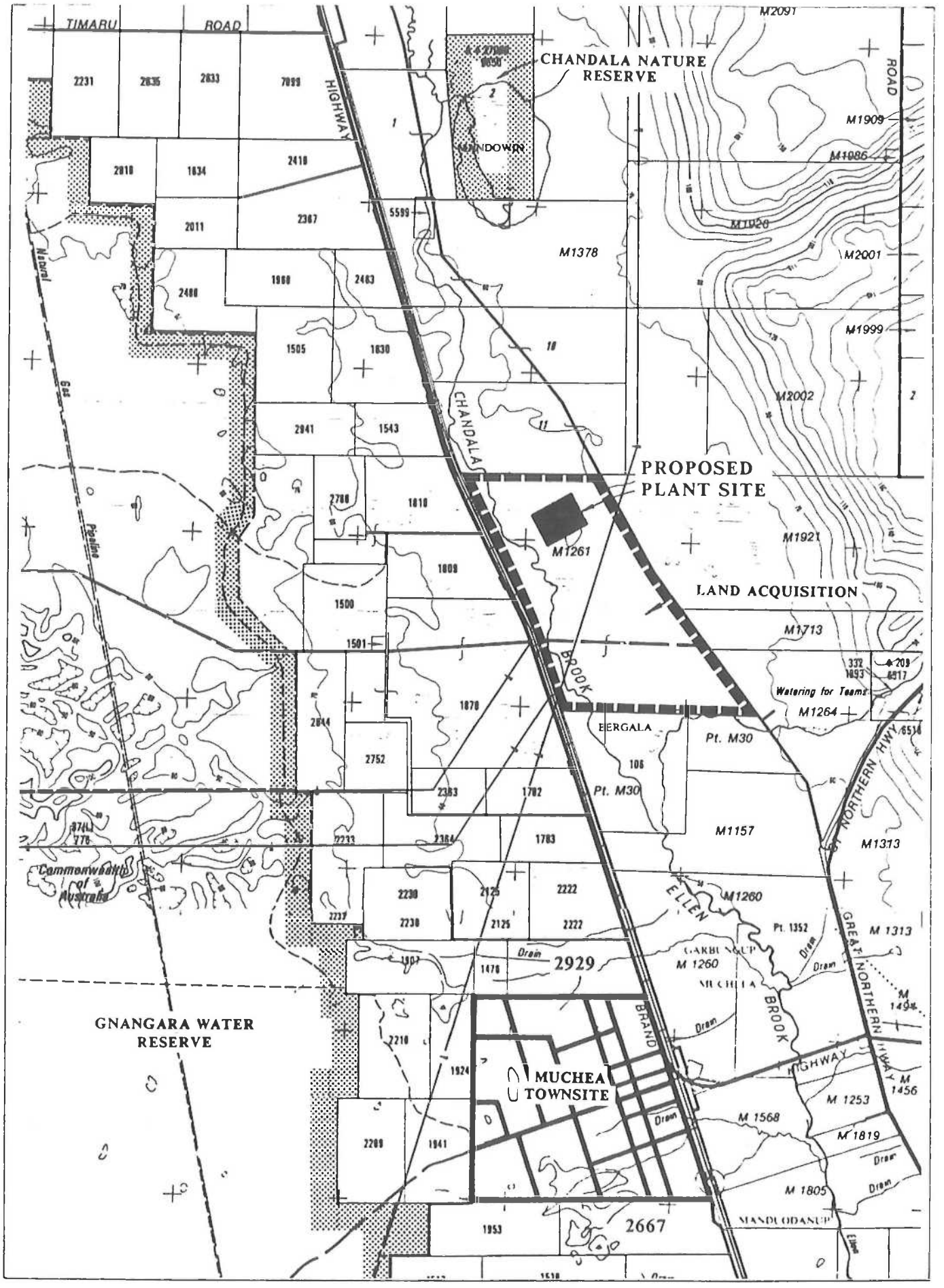
3.2.2 Climate

The climate of the Muchea area is warm Mediterranean characterised by dry summers and wet winters. The average annual rainfall is 698mm with an evaporation rate of 2,000mm. Average temperatures range from a low of $12^{o}C$ to a high of $25^{o}C$. Muchea has exhibited both diurnal and seasonal variations in air stability and mixing height. For details see Maunsell & Partners, 1988a

3.2.3 Ground and Surface Waters

The new site is on the eastern margin of the shallow groundwater system known as the Gnangara Mound. This aquifer comprises the Osborne Formation which is underlain by the poorer quality but larger yielding aquifers of the Leederville and Yarragadee Formations.

The site is also traversed from north to south by Chandala Brook, an upper tributary of Ellen Brook which eventually terminates in the Swan River.



LOCATION OF SYNTHETIC RUTILE AND DRY PROCESS PLANTS NEAR MUCHEA **FIGURE 1**

3.2.4 Vegetation

A report on the flora and vegetation at the proposed site has been prepared (Appendix 3). Essentially it comprises two basic types of vegetation; pastures and mixed Banksia/*Eucalyptus todtiana* woodland. The former is composed predominantly of pasture grasses and weed species but with scattered trees [Marri (*Eucalyptus calophylla*), Flooded Gum (*E. rudis* and Swamp Paperbark (*Melaleuca rhaphiophylla*]. The trees are relatively dense along the margins of Chandala Brook. The Banksia/*E. todtiana* woodland (*B. attenuata, B. menziesii, B. ilicifolia* occurs on the centre of the northern section of the site on slightly higher ground. The periphery of this formation is characterised by a dense shrub growth.

The site has been grazed throughout but stock damage is not as evident in the woodland.

3.2.5 Vertebrate Fauna

A preliminary survey of the fauna at the site has been conducted (Appendix 4). This concluded that the present fauna is decreased both in species number and population as a result of agricultural activities.

3.3 SOCIAL ENVIRONMENT

3.3.1 Aboriginal Sites

An ethnographic survey of the new site has indicated that there are no areas of significance to Aboriginal communities with traditional links to the area. However, concern has been expressed about the proposed road and rail crossings of Chandala Brook. Two archaeological sites were also located on the margins of the brook and have been registered with the WA Museum.

4. DESCRIPTION OF THE PLANT

4.1 PROCESS OVERVIEW

The process of extracting the valuable heavy minerals from the mined material and then of separating the various heavy minerals from each other and increasing their purity involves a complex series of treatments. The first of these will occur at the minesite where the bulk of the waste material (tailings and slimes) will be separated and disposed of and a wet concentrate with relatively high levels of heavy minerals will be produced. Further processing at the Muchea plant will involve the reduction of moisture content by drying, then a series of sequential treatments to separate the ilmenite, rutile, leucoxene, zircon, monazite and some other minor products from each other. The main treatment methods of concentration are:

- gravity separation
- electrostatic separation
- magnetic separation
- screening.

4.2 THE PROCESS

The dry mill or processing plant involves nine components as follows:

- feed preparation
- high tension separation of conductor minerals (ilmenite and rutile) from non-conductors (zircon and monazite)
- magnetic separation of ilmenite and rutile
- processing of rutile
- screening of the zircon rich feed
- separation of zircon and monazite
- final treatment of fine zircon
- final treatment of coarse zircon
- final treatment of monazite and xenotime
- disposal of reject material.

A schematic plant layout and process flow chart are shown in Figures 2 and 3 respectively.

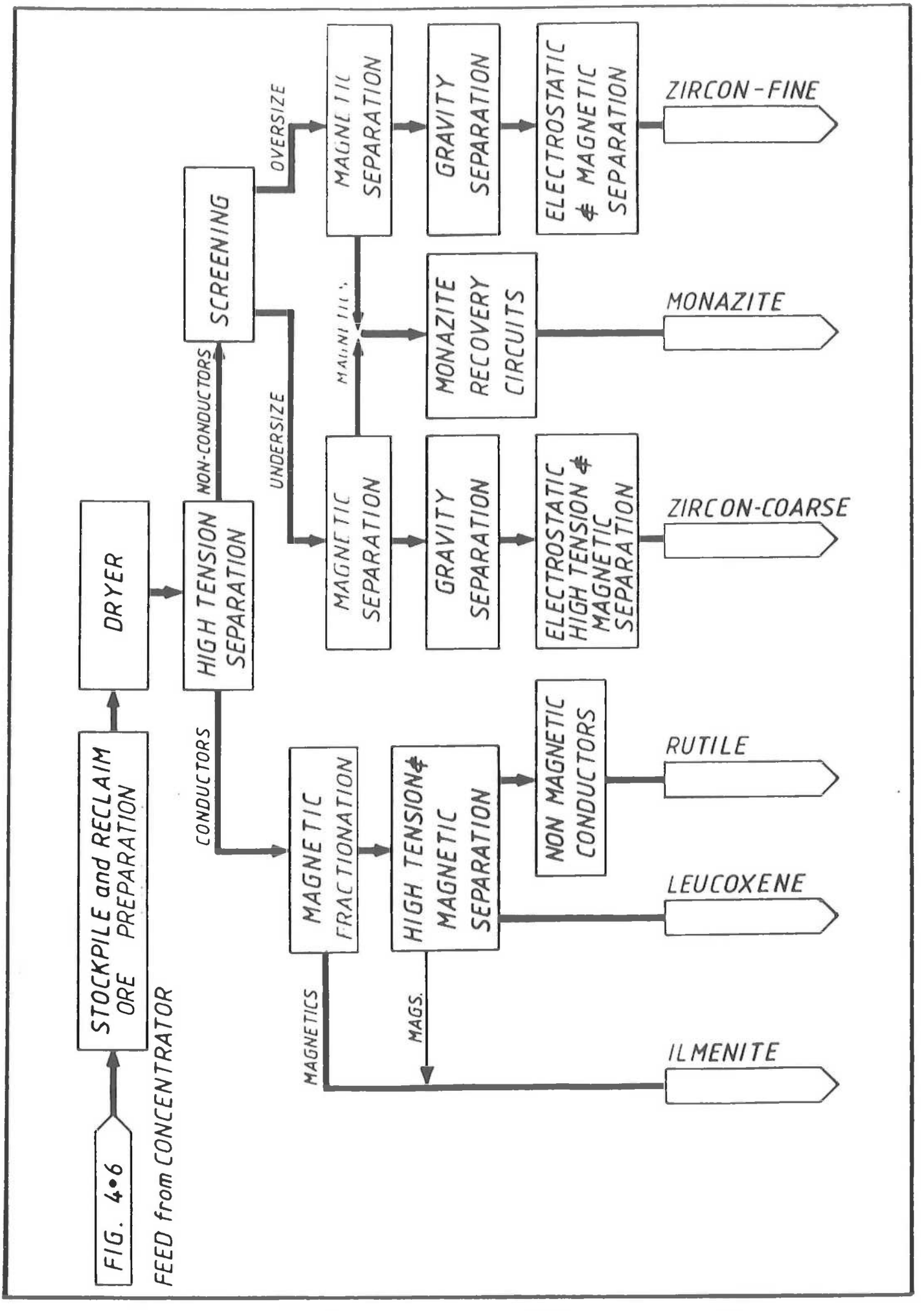
Incoming wet concentrates from Cooljarloo will be delivered to a covered stockpile and then transferred by a reclaiming system to the feed preparation cycle. This will involve attritioning screening to remove any contaminants, then removal of water by evaporation in a fluid bed dryer. The proposed dryer will have a capacity in the order of 30 tonnes per hour and will reduce the moisture content to less than 0.2%.

KEY

1 ADMINISTRATION BUILDING
2 FACILITY CAR PARK
3 SECURITY & WEIGHBRIDGE
4 NATURAL GAS METERING STATION
5 MAIN ELECTRICAL SUB-STATION
6 REMNANT BUSH
7 SECURITY FENCE
8 CONCENTRATE DUMP HOPPER
9 WORKSHOP & STORES WAREHOUSE
10 WORKSHOP 'LAYDOWN' AREA
11 ABLUTION, PLANT OFFICE, CRIB & FIRST AID
12 SUB-STATION
13 LABORATORY
14 EMERGENCY VEHICLE STATION
15 CONCENTRATE STORAGE SHED
16 CONCENTRATE RECLAIM SYSTEM
17 CONCENTRATE SCREENING STATION
18 OPEN SAND STORAGE AREA
19 BORE WATER TANK
20 POTABLE WATER TREATMENT PLANT
21 ADDITIVE MIXING & STORAGE
22 TAILINGS BACKLOADING AREA
23 PROCESS WATER TANK
24 THICKENER
25 CONCENTRATE DRYER
26 CONSTANT DENSITY HOPPER
27 DRY PLANT SUB-STATION
28 ILMENITE TRANSFER CONVEYOR
29 DRY SEPARATION PLANT
30 RAINWATER STORAGE POND
31 RAINWATER RECLAIM PUMP
32 RAIL LOADOUT
33 EVAPORATION PONDS - DRY PLANT
34 WATER RECLAIM PUMPS
35 LIME MIXING STATION
36 PIPE ROUTE
37 COAL STORAGE AREA
38 COAL FEED STATION
39 COOLER DISCHARGE TRANSFER POINT
40 SEPARATION BUILDING
41 ROTARY COOLER
42 WATER STORAGE
43 STORAGE SHED
44 BLOWER STATION
45 AERATION & ACID LEACH
46 PRODUCT DRYING
47 REDUCTION KILN
48 KILN WASTE GAS SYSTEM
49 ILMENITE FEED STATION
50 IRON OXIDE SETTLING PONDS
51 EVAPORATION PONDS - S.R. PLANT
52 ACID EFFLUENT STORAGE
53 RECYCLE WATER STORAGE
54 ENVIRONMENTAL BUFFER ZONE
55 REALIGNED DRAIN
56 RAINWATER POND SPILLWAY
57 BORE FIELD PIPE LINE
58 NATURAL GAS PIPE LINE
59 FLOOD CONTROL DRAIN
60 132KV POWER POLES @ 300 CTRS.
61 NEW TREE PLANTING
62 ACID NEUTRALISATION & pH CONTROL
63 PERSONNEL WALKWAY
64 KILN MAINTENANCE ACCESS RAMP
65 MAINTENANCE TRACK
66 TRUCK WASHDOWN LOOP

0 100 200 300
metres

SITE PLAN AND PLANT LAYOUT **FIGURE 2**



FLOW CHART FOR DRY CONCENTRATOR PLANT

FIGURE 3

The dry concentrate will then be screened to remove oversize material (larger than 500 microns) to a waste stockpile. The undersize fraction is then fed into the primary high tension circuit. This circuit will separate the conductors from the non-conductors. Ilmenite and rutile are electrical conductors while zircon and monazite are non-conductors.

The conductors will then be fed to magnetic separators which will separate (magnetic) ilmenite from a (non-magnetic) rutile rich fraction. The former will pass into a product silo while the latter will move on for further processing.

The further processing for rutile will firstly involve separation by screening into coarse (+212 microns) and fine fractions. The fine and coarse material will then be separately treated by further electrostatic and induced roll magnetic separation to produce a rutile product and other titaniferrous material (leucoxene).

Leucoxene may be separated in the processing circuit and stored in a concrete bunker. Further bunkers will be provided for wastes, and for titaniferrous middlings.

The non-conductors (the zircon and monazite rich fraction from primary high tension separation) will be screened at 180 microns. The fine stream will be magnetically fractionated for monazite removal. The coarse stream will be magnetically fractionated primarily for the removal of waste alumino-silicates such as staurolite.

Both coarse and fine streams will then be subjected to gravity concentration and the resultant heavy concentrates will receive further cleaning on electrostatic and magnetic separators to produce the final coarse and fine zircon products for storage in transhipment silos.

The monazite stream will also be further processed and the final product will then be stored in bins and bagged and containerised for transport. A description of radiation protection measures proposed for the handling of monazite was provided in the Cooljarloo Mineral Sands Project ERMP (Maunsell & Partners, 1987).

In full production, the total feed rate to the dry mill will be in the order of 748,000 (dry) tonnes per annum. The estimated production of saleable minerals from this feed is:

Ilmenite	400,000 tpa
Rutile	32,000
Leucoxene	9,000
Zircon	65,000
Monazite (and Xenotime)	2,000
Total	508,000

The ratio of products to waste will improve with metallurgical refinement of the circuit. The waste material will be stockpiled prior to return to the minesite or reprocessing. Wet waste material will be dewatered prior to transport back to Cooljarloo.

4.3 SERVICES

. Process Water

500kl/day of process water will be required for the dry process plant, which together with the synthetic rutile plant will result in an estimated demand of 2,000kl/day. This will be drawn from bores in the shallow aquifers of the Gnangara Mound resource 8-10km west of Muchea.

. Gas Supply

The natural gas, used for the initial drying of the wet concentrate, will be supplied from the Dampier to Perth pipeline located approximately 1.5km to the west of the site.

. Electricity

The dry process plant power will be supplied from the SECWA grid at the conventional level of 440 volts, 3 phase, 50 hertz. The synthetic rutile plant will require power at 132kV.

5. ENVIRONMENTAL IMPACT AND MANAGEMENT

5.1 NATURAL ENVIRONMENT

5.1.1 Site Preparation

Site preparation will involve clearing, levelling, drainage work, rail and road construction, and bridgeworks over Chandala Brook. The dry process plant, synthetic rutile plant, associated offices, amenities, workshop areas, storage facilities, railway sidings and roads, will all be built in the northern half of the property. The evaporation basins will be located in the southern part of the property.

5.1.2 Water and Site Drainage

The water supply for the plant will be drawn from the Gnangara Mound shallow aquifers located 8-10km west of Muchea. The bores will be sited so as to command maximum recharge which will result in minimising possible declines in water levels. The borefield development will be designed to be compatible with requirements of the Water Authority of Western Australia with respect to groundwater use and environmental protection.

Increased rainwater run-off from the buildings and vehicle areas will be partially absorbed by ornamental and screen plantings of trees and shrubs in the western section of the property. The balance of the surface run-off will be directed by surface drains to a stormwater basin.

In periods of extremely heavy and consistent rainfall, overflow from the stormwater basin would be discharged into Chandala Brook. As this creek would already have a high flow rate at such times due to catchment run-off, the extra discharge is expected to have no significant environmental impact on this watercourse.

5.1.3 Vegetation

The development of the site will incur impacts on the vegetation in the northern part of the property due to clearing for plant construction and access across Chandala Brook to the Brand Highway.

At this stage, the extent of these impacts cannot be assessed as the plant layout is only conceptual and there is some flexibility in the actual location of road and rail easements and plant components. This flexibility may provide some choice between alternatives with different degrees of site impact.

The company will provide the EPA with a report on site layout and environmental implications during the detailed design phase of the project.

The evaporation basins will be located in the southern part of the property on cleared land.

The vegetation along Chandala Brook will be protected during construction of road and rail access over the creek, and a significant buffer strip of vegetation retained between the plant and evaporation ponds.

A landscaping and planting programme will be undertaken to enhance the site and reduce the visual impact of the development.

Basic management activities will include:

- exclusion of uncontrolled stock access,
- some planting and seeding of indigenous plant species, and
- weed control activities compatible with the company's general site maintenance programme.

5.1.4 Vertebrate Fauna

The value of the present Muchea site to vertebrate fauna lies mainly in the vegetation along Chandala Brook and in the northern section of the property.

Landscape plantings are expected to compensate to some extent for loss of habitat due to site clearing.

There is the potential that waterfowl in the Muchea area may land on the large evaporation ponds. The analysis of effluent to be contained in these ponds (see Table 1) suggests that this will not pose a hazard to birds, especially as they are unlikely to ingest large quantities of liquid or to remain on the ponds for extended periods. Therefore, no preventative measures are considered to be necessary. However, the company will keep records of any incidents and incorporate this information in the general site monitoring reports which will be periodically supplied to the EPA.

TABLE 1

CHEMICAL ANALYSIS OF LIQUID WASTES IN IRON OXIDE ACID EFFLUENT STORAGE AND EVAPORATION BASINS

PARAMETER*	IRON OXIDE BASIN	ACID EFFLUENT STORAGE BASIN	EVAPORATION BASIN
pH	6.8	1.3	9.4
TDS	25540	21570	1855
Na	44.5	49.5	86
K	43.5	13	18
Cl	10760	68.2	72
HCO_3	48.8	<0.6	1
SO_4	51.4	9489	1569
NO_3	<0.05	39.3	<0.05
NH_3-N	5006	10.8	<0.05
Solids			40
As	<0.005	0.01	<0.005
Cd	<0.005	<0.005	<0.005
Pb	<0.05	<0.05	<0.01
Zn	0.05	1.95	<0.01
Cu	0.05	2.8	<0.05
Co	0.15	4.5	0.1
Ba	1.5	<0.25	<0.25
Cr	<0.05	5	<0.05
V	<0.25	1.25	<0.25
Ni	0.15	2.35	0.1
P (total)	<0.05	3.1	<0.05
Hg			<0.0005
Mo			0.12
Mn			<0.01
Ca			950
Mg			0.28
Fe			0.05
Ti	0.02		0.06

* All values in mg/l except pH.

5.2 SOCIAL ENVIRONMENT

5.2.1 Land Use

The TIO2 project will not affect the use of agricultural properties which surround the site.

These are used predominantly for the grazing of cattle and it is expected that this will continue during the operation and life of the plant.

5.2.2 Aboriginal Sites

An aboriginal survey was conducted on the northern half of the property where the location of the plant has been proposed. This survey has recorded two archaeological sites and three isolated finds. Though they are on the property the finds are not near the actual plant site and thus will not be affected. The two archaeological sites are located on the banks of Chandala Brook (one at the northern margin of the property and the other about 600m south of the northern boundary on the west bank of the brook). As it is an offence to interfere with aboriginal sites, appropriate personnel will be informed of their location and the need for protection.

5.2.3 Local Demography

The dry process plant and the administration centre are expected to hire 66 people directly. Assuming a conservative multiplier of 2.14 as an estimate for consequential employment (Dames & Moore, 1985) the resulting number of jobs that will be generated will be 141. This is the same figure as quoted in the Cooljarloo Mineral Sands ERMP (Maunsell & Partners, 1987).

It is anticipated that the plant workforce will commute to the plant from homes located within a 60km radius. This area includes the northern suburbs of the Perth Metropolitan Area. However, the majority of the workforce probably will choose to live closer to the plant within the Shires of Chittering, Gingin and Swan. A large number of residential lots are available in these Shires ranging from town allotments in Muchea and Bullsbrook to hobby farms and larger. The workforce and their families are not expected to concentrate their homes or to place strain on community facilities. Therefore, no special planning provisions are considered to be necessary to cater for the population increase.

The Shires of Chittering, Gingin, and Swan have all been notified of the project and are supportive of it due to the great employment opportunity it presents for residents. In particular the Shire of Swan sees this project as an opportunity to diversify its economic base of the town of Bullsbrook which at present is mainly dependent on the RAAF at Pearce.

5.2.4 Transportation

Vehicles will enter and exit the site via the Brand Highway which is the major highway route for heavy vehicles and cars from Perth to the North-West via Geraldton. The highway already has a substantial traffic volume averaging 2,100 vehicles per day.

Vehicles to the plant will comprise road trains delivering wet concentrate from the Cooljarloo minesite arriving from the north, and other vehicles (mainly employees cars) coming predominantly from the south and through the town of Muchea.

A road train will arrive with concentrate every 36 minutes 24 hours a day and will return to the minesite with waste material. This represents a total of 80 additional truck movements a day on the Brand Highway. Staff movements are estimated to involve a further 70 cars per day or 140 traffic movements. The total additional traffic generated by the dry process plant will therefore be

80 trucks + 140 cars = 220 vehicles,

representing about 11% increase in traffic on the highway. The increase in traffic through Muchea itself will be about 6%.

The proposed synthetic rutile plant would involve a further 70 arrivals and departures per day or 140 traffic movements. The total increase in traffic for the entire complex would then be 360 or 17%.

Most of the synthetic rutile plant traffic can be expected to pass by Muchea giving a total of about 280 additional vehicles per day by the town or 13%.

Delivery of the mineral sand products from the plant to Kwinana and Fremantle will also involve one train per day, although on occasion two trains will be required.

5.3 PLANT EMISSIONS

An analysis of potential noise emissions from the Muchea site has been prepared to include both the dry process and synthetic rutile plants (see Maunsell & Partners, 1988a). The predicted noise emissions from the plant are based on levels found in Westralian Sands' plant at Capel.

The analysis found, through modelling and assessment of potential noise sources, that with appropriate attenuation the new site could meet the required noise levels.

The management of radiation will be the same as that outlined in the Cooljarloo Mineral Sands ERMP (Maunsell & Partners, 1987). This will include:

- A comprehensive radiation level monitoring programme at both the plant and its environs and of the monazite transport units;
- Isolation of the monazite process circuit into a separate building;
- Comprehensive dust suppression measures; and
- Specific precautions in the handling, storage and transport of monazite products.

In the guidelines for the Cooljarloo Mineral Sands ERMP (Maunsell & Partners, 1987) atmospheric emission modelling was not required as plants of this nature do not generate problem amounts of atmospheric emissions. However, modelling was done for the synthetic rutile plant and can be found in the synthetic rutile PER (Maunsell & Partners, 1988a). Again, the findings indicate that with proposed pollution control devices the whole complex will meet generally accepted Australian Standards for air emissions.

Solid waste will be trucked back to the minesite for burial as part of the minesite rehabilitation programme.

Wastewater and sewage will be disposed of via septic tanks with lead drain systems as proposed in the Cooljarloo Mineral Sands ERMP (Maunsell & Partners, 1987). The volumes of sewage will be the same (5-6kl/day). As with the previous system any nutrients released from the drains would be largely diluted and dispersed such that insignificant levels of contaminants could be expected within a short distance of the point of discharge.

6. CONCLUSIONS

The new site for the proposed dry process plant is about 2.5km from the former site and accordingly the environmental implications of development are similar. However, the new site is further away from the town of Muchea and can be expected to have a reduced impact on the present lifestyle of the community as a result. Although the former site was environmentally acceptable for the dry process plant, features such as visibility and noise will be further reduced by the increased separation distance.

Development of the new site will potentially involve increased site impacts relative to the former site because it is more heavily vegetated. To minimise this potential, TIO2 Corporation NL will develop a site plan based on the principle of restricting disturbance due to vegetation removal especially along Chandala Brook and will implement site landscaping. The aboriginal sites on the property will also be protected. The site plan will be submitted to EPA for assessment prior to the commencement of major site works.

TIO2 Corporation NL is committed to building a technologically advanced process plant in which potential environmental problems are resolved in the engineering design phase. With this approach and the management commitments specified in this NOI and previous environmental assessments, the company is confident that the proposed development will have minimal impact on the existing natural and social environment.

7. REFERENCES

Dames & Moore, 1985
A Socio-Economic and Social Impact Assessment of the Proposed Kemerton Aluminium Smelter. WA Department of Resources Development.

Environmental Protection Authority, 1988 Bulletin 330.
Cooljarloo Mineral Sands Project
TIO2 Corporation NL
Report and Recommendations

Maunsell & Partners Pty Ltd, 1987
Cooljarloo Mineral Sand Project. Draft Environmental Impact Study/ Environmental Review and Management Programme

Maunsell & Partners Pty Ltd, 1988a
Synthetic Rutile Plant at Muchea. Public Environmental Report

Maunsell & Partners Pty Ltd, 1988b
Titanium Dioxide Pigment Plant at Kwinana. Environmental Review and Management Programme

APPENDIX 1

EPA GUIDELINES

GUIDELINES FOR THE NOTICE OF INTENT ON THE PROPOSAL BY THE T102 CORPORATION NL FOR A MINERAL SANDS DRY SEPARATION PLANT AT MUCHEA

In view of the fact that the plant has already been assessed by the EPA and found environmentally acceptable at a nearby location, the NOI need only address those issues which are site specific and those aspects of the plant which have changed from those described in the ERMP.

The NOI is to be made available to local residents. It should therefore use everyday language and relegate technical details to appendices.

SUMMARY

There should be a brief summary which lists the environmental issues addressed in the NOI and any associated new commitments.

Commitments from the previous assessment which are still relevant should also be reiterated.

1 PROPOSED LOCATION

The proposed location is to be described, including:

- cadastral, land use planning and zoning information;
- adjacent land uses, including;
  - the location of any nearby residences;
  - recreational land used;
  - reserves;
  - historical, archaeological or ethnographic sites;
- topography;
- meteorology, especially the prevailing winds;
- location of existing structures, and structures to be built on the site;

  and
- provision of services, including power, gas, telephone, road and rail access, water and drainage.

The location should be compared and contrasted with the previous location, and advantages of the proposed site should be listed.

2 DESCRIPTION OF THE PROPOSAL

The proposal need not be described in detail. Reference should be made to the ERMP where appropriate. However, the details of plant layout at the new site should be outlined as should any processes which differ from those outlined in the ERMP.

3 ENVIRONMENTAL IMPACT AND MANAGEMENT

Any site specific or changed environmental impacts should be fully addressed.

Reference to the ERMP should be made for detailed discussion of other impacts, but they should be listed briefly here along with proposals for their management.

An issue of concern at the new site is the crossing of the brook. It will be necessary to indicate how the integrity of the brook is to be maintained during both the construction and operational phases of the project. Plans for road and rail crossings should be included if available. Alternatively a commitment should be made to submit plans for approval before construction commences.

4 CONCLUSION

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

ADDITIONAL INFORMATION

- REFERENCES

  All references should be listed.

- GUIDELINES

  A copy of these guidelines should be included in the document.

- GLOSSARY

  A glossary should be provided in which all technical terms, and unfamiliar abbreviations and units of measurement are explained in simple language.

- APPENDICES

  Where detailed technical or supporting documentation is required, this should be placed in appendices.

- COMMITMENTS

  A list of all environmental management commitments should be given.

APPENDIX 2

COMMITMENTS

COMMITMENTS

TIO2 Corporation NL is committed to achieving EPA standards in construction and running of the proposed synthetic rutile plant. More specifically, the company's commitments are as follows:

- Report to the EPA during the detail design stage with a site layout and its environmental implications.

- Preserve as much as practically possible of the Chandala Brook vegetation during the construction of the road and rail access over the brook with a significant buffer strip.

- Implement a landscaping and planting programme to ensure the site blends in well with the surrounding area.

- Incorporated into the general site monitoring reports for the EPA, will be records of waterfowl usage of the ponds.

- Inform personnel of the locations of the two sites on the property, and the fact it is an offence to interfere with aboriginal sites.

- Comprehensive monitoring of radiation as outlined in the Cooljarloo Mineral Sands ERMP (Maunsell & Partners 1987).

APPENDIX 3
VEGETATION REPORT

REPORT ON THE VEGETATION

AT THE

TIO2 PROCESS PLANT SITE

MUCHEA, WESTERN AUSTRALIA

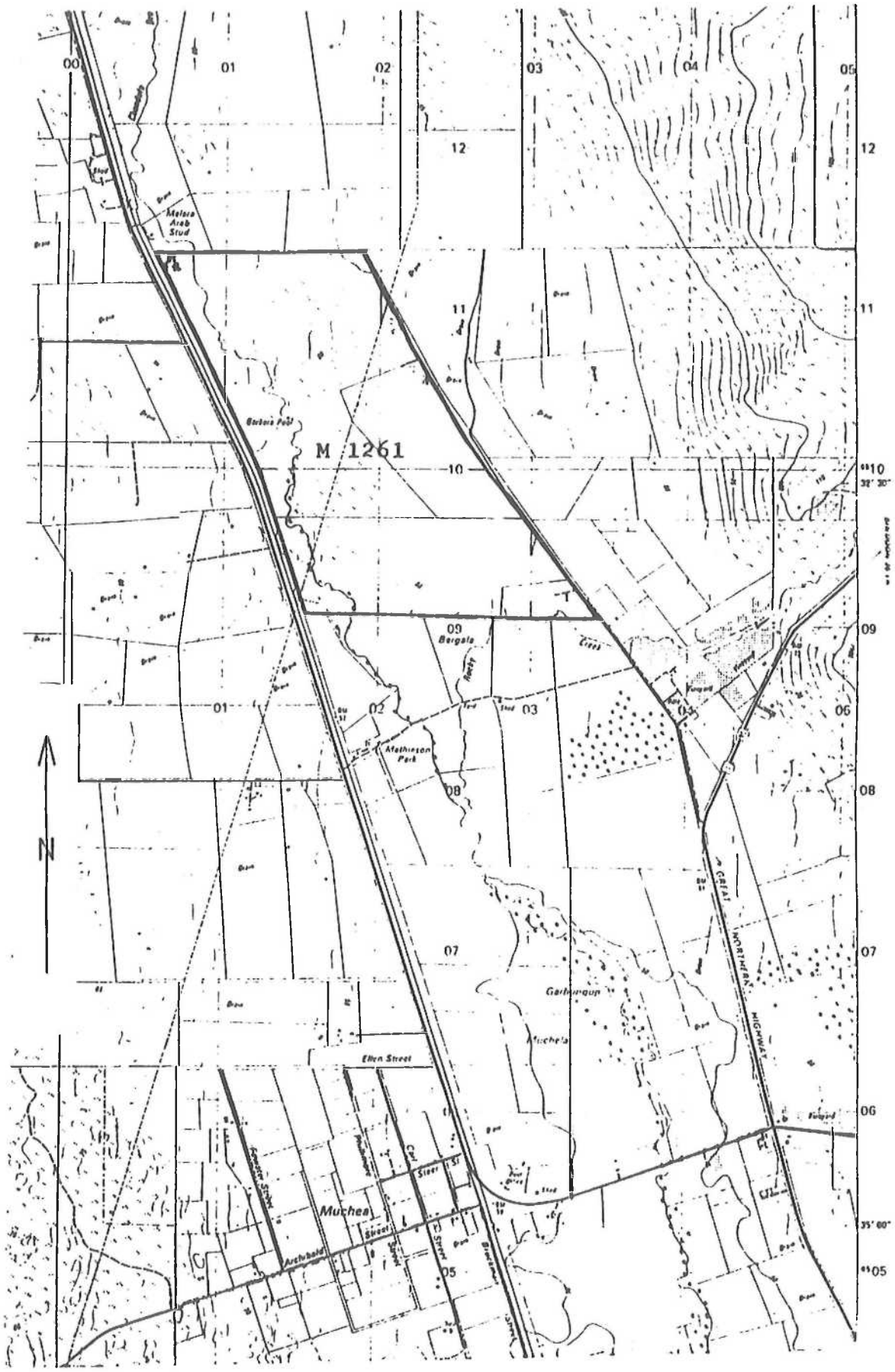
JULY 1988

by

Jane Elkington

Ekomin Pty Ltd
15 Dyson Street,
South Perth.

TABLE OF CONTENTS



Outline of M 1261

Scale 1 : 37000
(approximate)

Figure 1. Location of M 1261 at Muchea, Western Australia.

1.0 INTRODUCTION

TIO2 Corporation NL had requested that a vegetation survey be made on the northern half of their property at Muchea, W.A., prior to the establishment of a dry mineral sands processing plant and a synthetic rutile plant on the northern half of Location M 1261.

The property comprises 341 hectares lying approximately four kilometres north of Muchea on the eastern side of the Brand Highway (Figure 1).

One and a half days were spent walking over the site (July 7th and 8th, 1988). At this time the soils in the pastures over much of the area east of Chandala Brook were saturated.

2.0 VEGETATION

The area examined may be divided into three vegetation types:

1. Pastures, including the environs of Chandala Brook.

2. The periphery of the Banksia woodland.

3. The Banksia woodland.

2.1 Pastures, including the environs of Chandala Brook.

Approximately three quarters of the area comprise pasture lands. These are providing grazing for both sheep and cattle, and are composed predominantly of pasture grasses and weed species. The grasses were not flowering and could not be identified; weed species included capeweed (Arctotheca calendula), smooth cat's ear (Hypochaeris glabra), Guildford grass (Romulea rosea), lupins and clover, with patches of invading arum lilies (Zantedeschia aethiopica). Clumps of sedge are scattered along the drains.

Scattered throughout the pastures are specimens of the flooded gum (Eucalyptus rudis), the moonah (Melaleuca preissiana) and the marri (Eucalyptus calophylla). The latter species appears to prefer the areas which are slightly higher and less water logged, for example the low sandy rise along the western boundary.

Shrub species are not common. A few plants of Hakea prostrata are growing to a height of 3.5 metres along the western boundary of the property, and there are scattered clumps of Regelia ciliata to about one and a half metres tall and held in check by nibbling. Several small blackboys (Xanthorrhoea preissii) occur scattered throughout the pastures, but are much grazed by the stock and only one group was seen growing to a height of one and a half metres.

Chandala Brook runs in a south-south-easterly direction through the western section of the property. The banks are fringed by a denser distribution of flooded gums and Melaleucas: Melaleuca raphiophylla, the swamp paperbark, grows along and in the creek, and there are a few specimens of Melaleuca ?hamulosa.

There are no shrubs along the Brook, and the ground cover is similar to that found in the pastures, with larger patches of arum lilies and clumps of the reed Juncus pallidus.

It is unlikely that any rare or endangered species grow in these pastures. Both the clearing of the land for agriculture and the subsequent grazing have severely reduced the number of native species. The survival of rare or endangered species in this environment is highly improbable, and particularly so with regard to herbs and shrubs.

2.2 Periphery of the Banksia woodland.

The periphery of the Banksia woodland is in part characterised by a dense growth of Regelia ciliata (particularly on the western and south-eastern boundaries of the woodland), the shrubs forming a hedge-like thicket of variable width. Where these plants abut the pastures they are much nibbled, but where allowed to grow unhindered the shrubs reach to two metres in height.

The shrub, Actinostrobus pyramidalis, is also common and grows densely along parts of the woodland periphery. Again, this species is stunted where the plants are adjacent to the pastures, but grows to two metres where protected from the stock. These two species and the density of their growth here may be related to spring lines issuing from the edges of the adjacent Banksia woodland.

Other shrub species growing in this peripheral zone are those found in the Banksia woodland. Most of them are small specimens, much grazed, and include Hibbertia hypericoides, H. subvaginata, Jacksonia spinosa, Acacia huegelii and Melaleuca spp. There are scattered blackboys, Christmas trees (Nuytsia floribunda), Banksias and one small patch of Melaleuca uncinata, growing to two metres.

Pasture grasses and weeds are present in the ground layer, and the scarlet runner, Kennedia prostrata, may be found occasionally where protected from the reach of stock.

No rare or endangered species were found.

2.3 Banksia woodland.

The Banksia woodland occupies an area of slightly higher sandier soils within the centre of the area examined. The trees form a low woodland associated with a limited number of shrub species and a discontinuous ground layer.

Banksia species present are B. attenuata, B. menziesii, and B. ilicifolia, the trees growing to five and six metres. Eucalyptus todtiana is also found, and there are scattered specimens of Nuytsia floribunda (growing to eight metres).

Shrubs include Acacia pulchella, Calytrix spp, Hibbertia hypericoides, Leucopogon conostephioides, Melaleuca spp, and Petrophile linearis. There are occasional Macrozamias and blackboys. The low species density in the shrub layer may be attributed to the activities of the stock, the relatively small area occupied by the woodland and its isolation within the surrounding pasturelands.

The ground layer is discontinuous. Plants include Dasypogon bromeliifolius, Drosera erythrorhiza, Leptocarpus tenax, Patersonia occidentalis, Schoenus curvifolius and Stylidium repens.

While the inner woodland has not been so severely grazed as its periphery, stock damage is still evident; some of the Macrozamias have been stripped so badly they have died.

No rare or endangered species were found. The entire woodland area was not examined but it seems unlikely that any plants in this category are surviving in this small relict of Banksia woodland with its continuing grazing pressures.

3.0 FUTURE STATUS OF THE VEGETATION

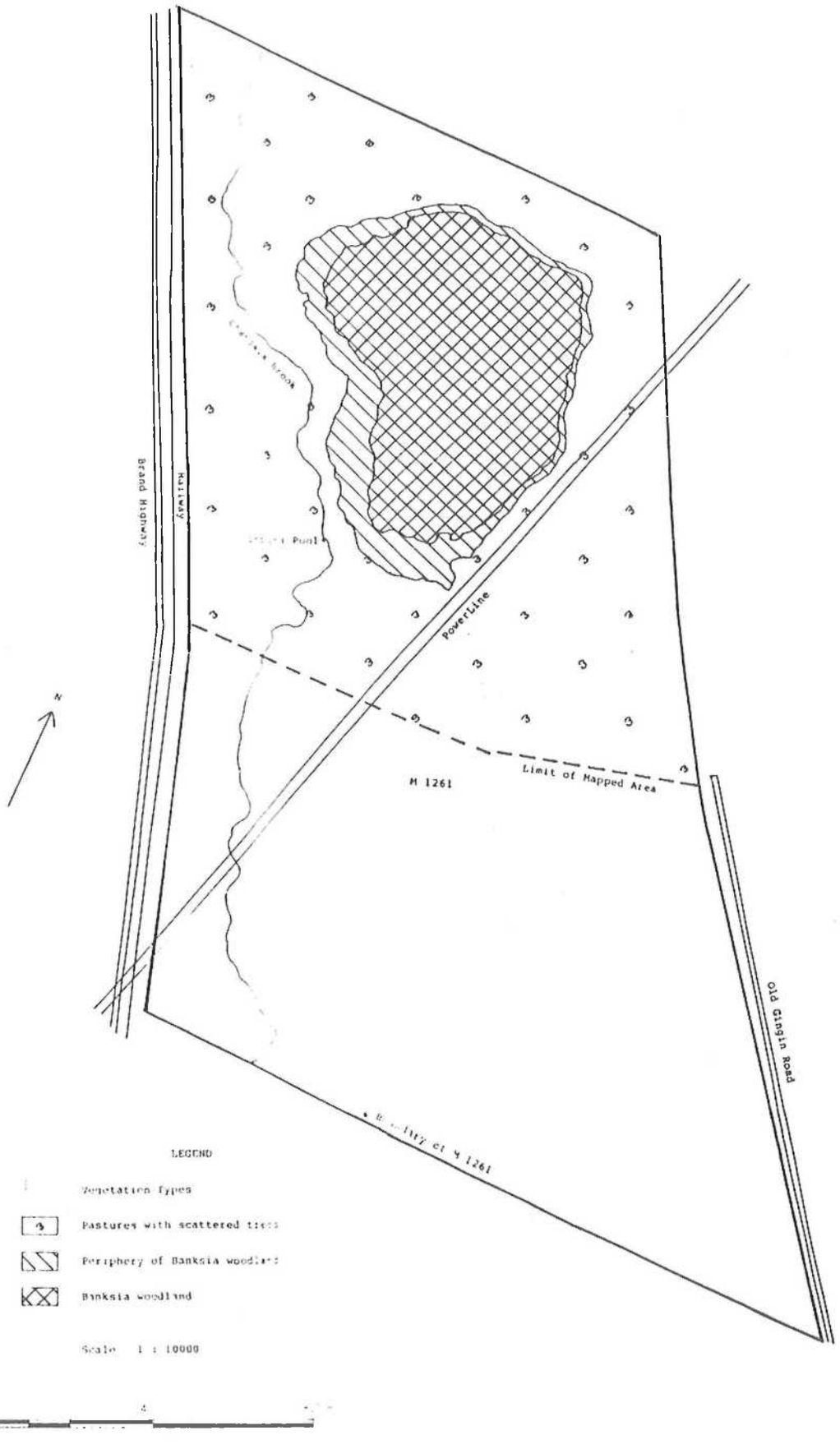
The central and eastern sections of the northern half of the Muchea site will be cleared for the industrial plant area and settling and evaporation ponds. Part of the southern Banksia woodland and periphery will be retained as uncleared bush, with restricted access, and will abut the environs of Chandala Brook on its western edge. Although comparatively few species are present, compared with ungrazed natural woodland, part of this woodland is worth preserving. This block of woodland will require careful management, because of its relatively small size. The periphery will be subject to human and industrial impact, and weed intrusion, but the status of the woodland will improve with the exclusion of stock.

Chandala Brook and its immediate environment and the entire area to the west, bordered by the Brand Highway, will remain to form a buffer zone between the industrial plant and the Highway. The trees along the Brook will provide an excellent screen, so that the industrial plant will be barely visible from the road. With stock excluded from the pastures and the Brook environment the density and size of those native species already present may be expected to increase, and species diversity to improve. A short investigation of the railway reserve adjacent to the western fenceline of the property revealed several species growing there which could be expected to increase their range into the former pastures. These species include an Acacia shrub growing to two metres, Banksia menziesii, Actinostrobus pyramidalis, Jacksonia spinosa, and Stirlingia latifolia.

In the ground layer are Burchardia umbellata, Conostylis sp, Corynotheca micrantha, and Opercularia vaginata, all appearing to compete successfully with the grass species present on the reserve. A similar situation occurs along the Old Gingin Road on the eastern boundary of the property, where Actinostrobus pyramidalis is common and there are stands of Melaleuca uncinata.

Management techniques should include the introduction of additional wetland species to Chandala Brook and its associated flood plain. Propagules may be available from Lake Mandowin Reserve (37060/9560) which is situated approximately four kilometres north of the site, and possibly other reserves in the vicinity. The aim would be to restore progressively the species richness which has been lost through grazing.

Re-establishment of a vigorous native flora along Chandala Brook and its flood plain will alter the hydrograph and lead to higher peak flood water levels at the upstream end due to increases in channel roughness in the flood plain and temporary storage of water. The engineering impacts of this should be estimated to determine what effects may occur. (Possible effects are upstream flooding, siltation on site and downstream erosion). The Public Works Department should have hydrographs for Chandala Brook and for well vegetated channels in the Darling ranges, from which changes in the hydrograph could be estimated.



Map 1. Distribution of vegetation types on M 1261 at Muchea, Western Australia.

Appendix 1.

List of Species Found

on

M 1261

at Muchea, Western Australia

July 1988

Species	Pastures	Periphery of Banksia Woodland	Banksia Woodland
Acacia huegelii Benth.		P	P
Acacia pulchella R.Br		P	P
Actinostrobus pyramidalis Miq.		P	
Anigozanthos humilis Lindley			P
Arctotheca calendula (L.) Levyns *	P		
Banksia attenuata R.Br		P	P
Banksia ilicifolia R.Br	P	P	
Banksia menziesii R.Br		P	P
Borya nitida Labill.			P
Bossiaea eriocarpa Bent.			P
Burchardia umbellata R.Br.			P
Calytrix ?flavescens Cunn.		P	P
Calytrix ?fraseri Cunn.			P
Cassytha glabella R.Br.		P	P
Dasypogon bromeliifolius R.Br.			P
Drosera erythrorhiza Lindley			P
Drosera sp 5		P	P
Eremaea pauciflora (Endl.) Druce			P
Eucalyptus calophylla Lindley	P	P	
Eucalyptus rudis Endl.	P		
Eucalyptus todtiana F.Muell.		P	P
Hakea prostrata R.Br.	P		
Hibbertia hypericoides (DC.) Benth.		P	P
Hibbertia subvaginata (Steudel) F.Muell.		P	P
Hypochaeris glabra L. *	P	P	P
Jacksonia floribunda Endl.			P
Jacksonia spinosa (Labill.) R.Br.		P	P
Juncus pallidus R.Br.	P		
Kennedia prostrata R.Br.		P	
Leptocarpus tenax (Labill.) R.Br.			P
Leucopogon conostephioides DC.		P	P
Lupinus sp 6 *	P		
Macrozamia reidlei (Fischer ex Gaudich.) C.Gardner		P	P
Melaleuca ?hamulosa Turcz.	P		
Melaleuca preissiana Schauer	P		
Melaleuca raphiophylla Schauer	P		
Melaleuca uncinata R.Br.		P	
Melaleuca sp 1		P	P
Melaleuca sp 2		P	P
Nuytsia floribunda (Labill.) R.Br. ex Fenzl		P	P
Patersonia occidentalis R.Br.		P	P
Pericalymma ellipticum (Endl.) Schauer		P	
Petrophile linearis R.Br.		P	P
Regelia ciliata Schauer	P	P	P
Romulea rosea (L.) Ecklon *	P		
Schoenus curvifolius (R.Br.) Benth.			P
Stylidium repens R.Br.			P
Stylidium sp 7			P
Trifolium sp 8 *	P		
Ursinia anthemoides (L.) Poiret *	P	P	P
Verticordia densiflora Lindley		P	
Xanthorrhoea preissii Endl.	P	P	P
Zantedeschia aethiopica (L.) Sprengel *	P		
Unidentified species no 9	P	P	
Unidentified grass species	P	P	P

* Species marked with an asterisk indicate naturalised plants, not native to W.A.

Appendix 1. List of Species Found on M1261 at Muchea, Western Australia during July 1988.

APPENDIX 4

FAUNA REPORT

A Preliminary Survey of the Fauna at a Site near Muchea for Ti02

July, 1988

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Capel, WA, 6271

A preliminary survey of the fauna at a site near Muchea for Ti02.

INTRODUCTION

The aim of this study was to provide a preliminary assessment of the present and potential importance of the site for fauna. Field work was carried out for two days and involved a thorough inspection of the northern half of the site and of the nearby Lake Chandala Reserve. Previous work in similar environments aided in providing a basis for deciding the fauna species that could be present.

THE GENERAL ENVIRONMENT

All of the site was subject to grazing by cattle and sheep, and some of it had been cleared for this purpose. There were, however, some areas of natural vegetation. Five environmental categories or types were recognized within the study area. These were:

1. Watercourses, including Chandala Brook and drains.
2. Ephemeral wetlands.
3. Farmland, consisting of pasture with scattered, remnant trees.
4. Shrub-thickets.
5. Banksia woodland.

The distribution of these environments is illustrated on Figure 1.

At the time of the survey (09-10 July), Chandala Brook was a fast-flowing stream approximately 5 m wide and 0.5 m deep. The

banks were lined with mature trees including Eucalyptus rudis and Melaleuca raphiophylla, but other fringing vegetation, such as reeds and sedges, was absent. There were no young trees and the banks were generally steep and in some places a metre high and badly eroded. Some trees had been undermined and had fallen into the stream. The drain that runs across the property is smaller than Chandala Brook and has no fringing vegetation. The poor condition of Chandala Brook is attributable to the cattle that are allowed to graze around and through it.

Ephemeral wetlands ranged from shallow pools only a few centimetres deep and a few metres across, to a small lake up to 30 cm deep and 50 m across. All ephemeral wetlands were located on farmland, the lake to the north-east of the hill and shallower wetlands to the west and south of the hill. The vegetation on these wetlands included flooded pasture plants, E.rudis and Melaleuca priessiana. The water in the wetlands between the hill and Chandala Brook was slightly saline and was fed by a seepage from the base of the hill. This salinity was probably the cause of death of several M.priessiana in the area.

The ephemeral wetlands were similar to the fringing wetlands of Lake Chandala in the Lake Chandala Reserve. The main lake in the reserve was very different from any environment in the site, however. Lake Chandala was several hundred metres across, up to a metre deep and heavily vegetated with species such as Melaleuca raphiophylla, Melaleuca teretifolia and Melaleuca laterita. Vegetation in the reserve was subject to some pressure from cattle, sheep and feral goats, but the density of the vegetation seemed to protect the bulk of the environment.

The farmland occupied the low-lying areas of the property, most of which are probably subject to flooding on occasions.

Remnant trees included Eucalyptus calophylla, E.rudis and M.priessiana.

The shrub-thicket consisted of very dense vegetation mostly less than 3 m high, and it formed a distinct zone on the western edge of the hill. Prominent species were a native conifer and a species of Regelia. Little grazing or damage from cattle was evident in this vegetation.

Banksia woodland occupied the sandy soils of the hill. It appeared typical in floristics and structure of much of the banksia woodland that is found on the sandy soils of the coastal plain north and south of Perth. Unlike the shrub-thicket, there was considerable evidence of damage by stock from both grazing and trampling. The understorey was open, the soil surface was broken by tracks in many places, there were unusually large numbers of dead trees and there were very few young banksias.

INVERTEBRATE FAUNA

Grazing and trampling by cattle had probably adversely affected invertebrates in the banksia woodland. Termites were noticeably abundant, reflecting the high number of dead trees in the woodland. Invertebrate life in the ephemeral wetlands was abundant but was scarce in Chandala Brook. A single specimen of a freshwater crayfish, probably a koonac, was found in Chandala Brook.

VERTEBRATE FAUNA

Fish

The introduced Gambusia affinis was observed in Chandala Brook. The only possible native species is the Swan River Goby Pseudogobius olorum.

Amphibians

Three species of frogs were recorded around the ephemeral wetlands. These were: Crinia (Ranidella) pseudinsignifera, Heleioporus eyrei and Pseudophryne guentherii. Larvae of all these species were present in the wetlands.

In the fringing wetlands around Lake Chandala, seven species of frogs were recorded. These included two of the above species but not P.guentherii, which is very cryptic and was probably missed in the brief visit made to the reserve. The four additional species were: Crinia (Ranidella) glauerti, Crinia (Ranidella) insignifera, Crinia georgiana and Litoria adelaidensis.

At the time of year when work was carried out, it is relatively easy to determine the frog species present in an area, as most are calling and have distinctive calls. Therefore, it is probable that the study area is deficient in frog species, although the species not recorded may be present in small numbers. This deficiency has almost certainly resulted from grazing that has removed emergent and fringing vegetation from the ephemeral wetlands and the watercourses.

One additional frog species may be present in the study area. This is Myobatrachus gouldii, which is a terrestrial-breeding frog that is common in banksia woodland and heathlands on the coastal sandplain.

Reptiles

Reptiles are active mainly in the warmer months of the year, so this study was carried out at an unfortunate time for them. The banksia woodland was the most suitable environment for

reptiles in the study area, and searching through leaf-litter and under logs and loose bark was carried out. This yielded only two species, the scincid lizard Cryptoblepharus plagiocephalus and the elapid snake Rhinoplocephalus gouldii, while the burrow of a third species, the varanid lizard Varanus gouldii, was found. This was an unexpectedly poor result despite the time of year, as banksia woodland is rich in reptile species. In a long-term study conducted by the consultant in banksia woodland east of Gingin, 34 reptile species were recorded. These included two species, the scincid lizard Lerista christinae and the elapid snake Vermicella calonotus, which are classed as rare and endangered by the Department of Conservation and Land Management.

All of the species recorded near Gingin may once have occurred in the study area, but only a programme of trapping will determine their presence and level of abundance. Because of the damage to the banksia woodland caused by livestock, it is probable that these species would be less abundant than in undisturbed woodland, and some may have disappeared.

Searching was carried out in the other environments in the study area, but no other reptile species were found. C. plagiocephalus, which is arboreal and often occurs on the trunks of trees, was ubiquitous.

Two additional reptile species were recorded near to the study area. The scincid lizard Leiolopisma trilineatum, which associates with low, riparian vegetation, was observed in rank growth around ephemeral wetlands in the railway reserve along the western boundary of the study area. Suitable vegetation is rare in the study area because of grazing pressure. The aquatic tortoise Chelodina oblonga was observed in Lake Chandala. The

ephemeral wetlands in the study area were probably too short-lived for it, while Chandala Brook was too fast-flowing. When Chandala Brook was naturally vegetated, it probably flowed more slowly (and was therefore wider) and may have supported this species.

Birds

Separate bird lists were kept for each of the environments in the study area and these are presented on Table 1. With the ephemeral wetlands and the watercourses, the lists contain only those species which were actually seen to use the aquatic environment. Thus, arboreal birds that occurred in the same tree species on both farmland and the aquatic environments were not included in the latter.

There were few birds dependent upon the watercourses because these were fast-flowing and had barren shorelines due to grazing. The ephemeral wetlands supported slightly more species, but both the aquatic environments in the study area were poor in comparison to Lake Chandala, which offers a wider range of less disturbed aquatic ecosystems.

The farmland supported the most species of birds, and this list was typical for farmland in the general region. The shrub-thicket supported fewer species, both because it was a small area and because its structural diversity was limited; the shrub-thicket was uniformly dense and most birds were observed on its margin with the farmland. Some of the species, however, such as the Splendid Fairy-wren and Red-capped Robin, were observed only in the shrub-thicket.

The list of bird species recorded in the banksia woodland (14 species) was small in comparison to that expected even on a

brief visit. In the banksia woodland near Gingin previously studied by the consultant, a total of 80 species were recorded and a list of 30 would be considered normal for a day-trip. Furthermore, the numbers of individual birds seen was low, although standardized censussing would be needed to quantify this. A few migrant species may be present later in the year, but the poor result with birds in the banksia woodland was probably due to the impact of livestock.

Mammals

Only one species of native mammal was recorded; the Western Grey Kangaroo Macropus fuliginosus. Two introduced species were also seen, the European Rabbit Oryctolagus cuniculus and the European Fox Vulpes vulpes, while the Cat Felis domesticus and the house mouse Mus musculus were almost certainly present. Several species of native mammal regularly occur in banksia woodland, including the Honey Possum Tarsipes rostratus, the Pygmy Possum Cercartetus concinnus, the Dunnart Sminthopsis griseoventer, the Ashy-grey Mouse Pseudomys albocinereus and the Lesser Long-eared Bat Nyctophilus geoffroyi. None of these can be found without a programme of trapping, although the level of disturbance in the banksia woodland suggests that most of these species will have disappeared from the study area. Several species of bats may be present, since these can shelter under the bark of dead trees, while the shrub-thicket which has to some extent resisted the movement of livestock may support remnant populations of some of the small mammals.

The Water Rat Hydromys chrysogaster is known from Lake Chandala and from several streams in the Bullsbrook to Gingin area, so may be present along Chandala Brook in the study area.

Again, however, the level of disturbance by stock in this environment may be excessive.

DISCUSSION

The fauna of the study area can only be described as depauperate, and the main reason for this is the indiscriminant grazing of livestock. The only environment which has the diversity and abundance of species that could be expected of it is the farmland, where the grazing of livestock is normal.

Despite this grim conclusion on the present status of fauna in the study area, it should be noted that this condition could be quickly reversed by excluding livestock from the watercourses, some of the ephemeral wetlands, the shrub-thicket and the banksia woodland. Some rehabilitation, especially along Chandala Brook where the banks require stabilization and where the construction of an artificial lake would be invaluable to waterfowl, would also be desirable.

The most important areas for fauna (at present or potentially) are: Chandala Brook, the entire area of shrub-thicket, the central and western areas of the banksia woodland, the ephemeral lake in the north-east of the study area and the ephemeral wetlands between the shrub-thicket and Chandala Brook. Apart from their conservation value, some of these areas are important in providing a visual screen for the processing plant. The vegetation on the hill may also be important in controlling the salinity of the water in the seepage on the western side of this hill.

There are several other aspects regarding the fauna in the study area which need to be considered. There are many waterfowl in the general region, and these are certain to be attracted to

the settling and precipitation ponds that will be constructed as part of the processing plant. If they may be a problem for the management of the ponds, or if the water in the ponds could harm them, then these factors need to be considered. The possible impact of any accidental discharges into Chandala Brook need also to be taken into account, since the Brook flows through important agricultural and conservation areas after passing through the study area.

Table 1. The species of birds recorded in each of the environments within the study area. The environments are: 1 - watercourses; 2 - ephemeral wetlands; 3 - farmland; 4 - shrub-thicket, and 5 - banksia woodland.

Species	1	2	3	4	5
Little-pied Cormorant	+				
Australian Shelduck		+	+		
Pacific Black Duck	+	+			
Maned Duck		+			
Crested Pigeon			+		
Red-capped Parrot			+		+
Port-lincoln Ringneck			+		+
Pallid Cuckoo					+
Welcome Swallow			+		
Red-capped Robin				+	
Rufous Whistler				+	+
Grey Fantail			+	+	+
Willie Wagtail			+		
Splendid Fairy-wren				+	
White-winged Fairy-wren			+		
Western Gerygone			+	+	+
Western Thornbill					+
Yellow-rumped Thornbill			+		
Varied Sittella			+		+
Red Wattlebird			+	+	+
Singing Honeyeater				+	+
Brown Honeyeater			+	+	+
Western Spinebill					+
Striated Pardalote			+	+	+
Silvereye			+		+
Australian Magpie Lark		+	+		
Black-faced Woodswallow			+		
Grey Butcherbird			+		
Australian Magpie			+		
Australian Raven			+		
Number of species	2	4	20	9	14

Figure 1. The northern end of the study area, showing the distributions of the main environmental categories.