Tailings Pond Rehabilitation Project And Effluent Management System Upgrade

CONSULTATIVE ENVIRONMENTAL REVIEW
TAILINGS POND REHABILITATION PROJECT AND EFFLUENT MANAGEMENT SYSTEM UPGRADE
WESTERN MINING CORPORATION BALDIVIS
CONSULTATIVE ENVIRONMENTAL REVIEW
# CONTENTS

## SUMMARY

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>vi</td>
</tr>
</tbody>
</table>

## INTRODUCTION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>1</td>
</tr>
<tr>
<td>1.2.1</td>
<td>1</td>
</tr>
<tr>
<td>1.2.2</td>
<td>2</td>
</tr>
<tr>
<td>1.2.3</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>8</td>
</tr>
<tr>
<td>1.4</td>
<td>8</td>
</tr>
<tr>
<td>1.5</td>
<td>9</td>
</tr>
<tr>
<td>1.6</td>
<td>10</td>
</tr>
<tr>
<td>1.6.1</td>
<td>10</td>
</tr>
<tr>
<td>1.6.2</td>
<td>11</td>
</tr>
<tr>
<td>1.6.3</td>
<td>11</td>
</tr>
</tbody>
</table>

## NEED FOR THE PROPOSALS

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
</tr>
</tbody>
</table>

## EVALUATION OF ALTERNATIVES

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>13</td>
</tr>
<tr>
<td>3.2</td>
<td>13</td>
</tr>
<tr>
<td>3.3</td>
<td>14</td>
</tr>
<tr>
<td>3.4</td>
<td>15</td>
</tr>
</tbody>
</table>

## PROPOSED LOCATION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>16</td>
</tr>
<tr>
<td>4.2</td>
<td>17</td>
</tr>
<tr>
<td>4.3</td>
<td>17</td>
</tr>
<tr>
<td>4.4</td>
<td>20</td>
</tr>
<tr>
<td>4.5</td>
<td>21</td>
</tr>
</tbody>
</table>
CONTENTS (CONT'D)

5 PROCESS DESCRIPTION OF CONTAMINATED GROUNDWATER RECOVERY AND EFFLUENT TREATMENT AND DISPOSAL PROCESS 22

5.1 Pond Liquor Recovery 22
5.2 Increased Groundwater Recovery 23

5.2.1 Recovery Rate 23
5.2.2 Recovery Duration and Endpoint 23
5.2.3 Pumping Beyond Proposed Endpoint 25
5.2.4 Effects on Groundwater Levels 25

5.3 Plant Effluent and Solid Residue 26

5.3.1 Historical and Current Discharges 26
5.3.2 Proposed Discharges 28
5.3.3 Summary of Effluent Discharge Proposals 31

5.4 Wastewater Treatment System 33

5.4.1 New Effluent Holding Tank 34
5.4.2 Solids Filtration Plant 34
5.4.3 Reverse Osmosis Plant 34
5.4.4 Pipeline to New Effluent Pond 35
5.4.5 Construction of New Effluent Pond 36

5.5 Proposals for Freshwater Injection 37
5.6 Backup Systems 38

6 DESCRIPTION OF TAILINGS POND REHABILITATION 40

7 SITE AND POTENTIAL POLLUTION MANAGEMENT 41

7.1 Effect of Weather Conditions on Treatment and Disposal Method 41
7.2 Plant or System Breakdown 41
7.3 Land Impacts 41
7.4 Amelioration of Existing Groundwater Contamination 42
7.5 Prevention of Further Groundwater Pollution 43

8 MONITORING 45

8.1 Proposed Monitoring to be Conducted by WMC 45
8.2 Operational Specifications 46
CONTENTS (CONT'D)

9 COMMITMENTS

9.1 General Commitments 47
9.2 Groundwater Plume Recovery 48
9.3 Commitments On Effluent Treatment 49
9.4 Environmental Monitoring Commitments 49
9.5 New Effluent Pond Structure: Effluent and Slurry 50
9.6 New Effluent Pond Structure: Leakage 50
9.7 New Effluent Pond Structure: Solids Buildup 50
9.8 New Effluent Pond Structure: Decommissioning and Rehabilitation 51
9.9 Solid Waste Disposal From Gold Recovery Unit 51
9.10 Spillage at Plant 52
9.11 Breakage of Effluent Pipeline 52
9.12 Storage Facilities for Contaminated Liquids and Solids in the Plant 52
9.13 Monitoring 52
9.14 Security 53
9.15 Other Commitments 53
9.16 General Reporting 54

10 REFERENCES 55

APPENDIX

1 GUIDELINES FOR THE CONSULTATIVE ENVIRONMENTAL REVIEW

TABLES

1 Summary of Geology 18
2 Current Refinery Effluent 27
3.1 Chloride Bleed Stream 29
3.2 Calcium Bleed Stream 30
3.3 Solids Backwash Stream 30
4 Slurry Composition 32
# CONTENTS (CONT'D)

<table>
<thead>
<tr>
<th>FIGURES</th>
<th>DWG NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Nickel Refinery Process</td>
<td>2329-1</td>
</tr>
<tr>
<td>2 Locality Map of the Baldivis Tailings Pond</td>
<td>2329-2</td>
</tr>
<tr>
<td>3 Baldivis Tailings Pond and Surrounding Area</td>
<td>2329-3</td>
</tr>
<tr>
<td>4 Ammonium Sulphate Plume</td>
<td>2329-5</td>
</tr>
<tr>
<td>4a Vertical North-South Section Through Plume</td>
<td>2329-15</td>
</tr>
<tr>
<td>4b Vertical East-West Section Through Plume</td>
<td>2329-16</td>
</tr>
<tr>
<td>5 Current Groundwater Recovery and Treatment System</td>
<td>2329-4</td>
</tr>
<tr>
<td>6 Proposed Rehabilitation Schedule</td>
<td>2329-6</td>
</tr>
<tr>
<td>7 Location of Groundwater Extraction and Monitoring Bores</td>
<td>2329-13</td>
</tr>
<tr>
<td>8 Lake Cooloongup Hydrogeology</td>
<td>2329-7</td>
</tr>
<tr>
<td>9 Proposed Effluent Management System Schematics</td>
<td>2329-17</td>
</tr>
<tr>
<td>10 Proposed Effluent Disposal Pond Construction</td>
<td>2329-9</td>
</tr>
<tr>
<td>11 Proposed Location of the Freshwater Injection System</td>
<td>2329-14</td>
</tr>
<tr>
<td>12 Mound Concept for Tailings Pond Rehabilitation</td>
<td>2329-11</td>
</tr>
<tr>
<td>13 Wetland Concept for Leaching Pond Rehabilitation</td>
<td>2329-12</td>
</tr>
</tbody>
</table>
1 Background

The operation of Western Mining Corporation Limited's (WMC's) Nickel Refinery at Kwinana results in the production of solid residue and liquid effluent. In 1969, WMC constructed a tailings pond to store such solid and liquid wastes at Baldivis, some 7 km from the Refinery.

The tailings pond was constructed to the standards prevailing at the time and was approved by all relevant authorities.

Since 1985, solid residue has not been discharged to the tailings pond at Baldivis but has been returned to the mine site for disposal with other wastes. Discharge of liquid effluent to the Baldivis tailings pond continues.

In March 1979, it was discovered that the tailings pond was leaking liquid comprised mainly of ammonium sulphate solution into groundwater below. Ammonium sulphate contains nutrients and is a major component in most garden and agricultural fertilizers.

The contamination plume resulting from the leakage is more dense than the natural groundwater and is located within the bottom third of the aquifer, thinning out at the edge. Adverse environmental effects have been minimal to date due to the location of the contamination at the bottom of the aquifer and a significant thickness of good quality groundwater above the contamination.

Actions by WMC to rectify the problem by recovering and treating contaminated groundwater have resulted in partial containment only of the contamination plume. Removal of liquor currently impounded in the existing tailings pond, continued recovery of contaminated groundwater, and rehabilitation of the pond is required to prevent potential deleterious effects on the surrounding environment. This action necessitates the upgrading by WMC of the refinery's existing wastewater treatment plant to enable treatment of effluent currently being discharged to the tailings pond, and continued treatment of contaminated groundwater.
WMC's proposals in this regard are to be formally assessed by the Environmental Protection Authority (EPA) at Consultative Environmental Review (CER) level.

2 The Existing Environment

The area surrounding the Baldivis tailings pond includes two areas subject to System 6 'Red Book' recommendations (Lake Cooloongup and Leda), recreation reserves, privately owned farming lands and an area allocated for possible future housing development (Leda).

The primary concern arising from the groundwater contamination plume is its potential effects on vegetation on the eastern fringe of Lake Cooloongup. Lake Cooloongup is a natural salt lake which is dry during summer. The contamination plume appears to have risen adjacent to a natural saline plume beneath the lake. The contamination plume may have an adverse effect on the natural vegetation following an initial stage of increased growth due to nutrients in ammonium sulphate contained in the plume.

3 WMC's Proposal and Commitments

To enable resolution of the contamination problem, the source of contamination (liquid effluent in the tailings pond) must be eliminated, and recovery of contaminated groundwater is required to continue, preferably with increased flowrates.

WMC proposes to undertake the following:

\( \checkmark \) recovery and treatment of liquid effluent from the tailings pond;

\( \checkmark \) cessation of diposal of refinery liquid effluent to the existing tailings pond;

\( \checkmark \) increased recovery of contaminated groundwater;
significant upgrading of the wastewater treatment plant to handle liquid effluent from the refinery and liquid effluent recovered from the tailings pond, in addition to contaminated groundwater;

construction of a new double-lined effluent disposal pond structure comprising two compartments for evaporation of effluent resulting from the upgraded wastewater treatment plant, and one compartment for intermittent disposal of solid residue if required;

rehabilitation of the existing tailings pond to ensure structural and environmental integrity;

continued monitoring of the extent and movement of the groundwater plume and the condition of vegetation fringing Lake Cooloongup and the undertaking of necessary preventative and remedial action if required;

maintain the above activities until the groundwater contamination plume has been satisfactorily recovered and the existing tailings pond has been rehabilitated. WMC's commitments will apply in the event of continued operation of the nickel refinery at current production levels or an increase or decrease in production levels or closure of the refinery.

4 Alternatives

Prevention of Further Groundwater Contamination

Decommissioning and dewatering of the existing tailings pond (ie removal of liquid effluent from the pond) is the only means by which continuing leakage into groundwater can be minimized.
Tailings Pond Rehabilitation

Two methods of tailings pond rehabilitation after dewatering have been evaluated:

(i) Mounding and covering with a clay layer and a sand surface, with possible eventual use for active recreation;

(ii) A wetland concept involving covering of the tailings with clay and sand and permanent inundation.

Both concepts would be effective in minimizing long-term leachate loss from the rehabilitated pond.

Detailed design of the rehabilitation strategy to be adopted is not covered in this review. A detailed rehabilitation strategy will be finalized following field trials on the tailings. Trials by WMC will commence following pond liquor removal.

Upgraded Effluent Disposal

Alternatives to the implementation of an upgraded effluent disposal system are limited to discharge of effluent to sewer or deep groundwater injection. The Water Authority of Western Australia has indicated that discharge into the sewer system is not acceptable. Deep groundwater injection is not considered to be an environmentally appropriate solution.

5 Conclusions

The activities proposed by WMC, in this document, will significantly improve the current standard of effluent disposal from the Kwinana Nickel Refinery and greatly reduce environmental risks. The proposal also addresses the best available means of minimizing the potential impact of the existing groundwater contamination plume.

Dewatering and stabilization of the existing tailings pond will reduce further contamination of the groundwater and provide environmentally safe long-term storage of tailings.
1 INTRODUCTION

1.1 Proponents and Responsible Authorities

The proponent for this Consultative Environmental Review (CER) is Western Mining Corporation Limited (WMC). WMC has engaged A G Consulting Group Pty Ltd (AGC) to assist in the preparation of this CER. The review covers WMC’s proposed effluent management system at the nickel refinery site at Patterson Road, Kwinana and the new effluent disposal pond and existing tailings pond at Millar Road, Baldivis, south of Perth. The Environmental Protection Authority (EPA) is the responsible and coordinating authority for the review and approval of the proposals outlined herein.

1.2 Background

1.2.1 Refinery

WMC’s Kwinana Nickel Refinery (‘the refinery’) was established and is operated by WMC pursuant to an agreement with the State and set out in the Nickel Refinery (Western Mining Corporation Limited) Agreement Act 1968. The refinery commenced production of nickel metal in 1970, initially utilizing 12% nickel concentrate from Kambalda, and after 1972 a 70% nickel matte produced from WMC’s nickel smelter in Kalgoorlie. Capacity of the Kwinana refinery was initially 15 000 tonnes per annum (tpa) nickel metal (1970), increasing to 35 000 tpa following complete change-over to nickel matte feedstock in 1985. Currently the plant is operating for about 60% of available processing time.

The refining process involves oxidation of nickel matte or concentrate feedstock (containing nickel, copper, cobalt and iron in both metallic and sulphide form) in an ammonia solution to produce:
a leach solution containing nickel, copper and cobalt as ammine ions, ammonia and ammonium sulphate;

a solid residue waste consisting mainly of iron oxide.

The leach solution is treated to remove ammonia (reused in the process) and copper sulphide product, and is then reduced using hydrogen to produce nickel metal, ammonium sulphate solution and a mixed nickel/cobalt sulphide product.

Recovered ammonium sulphate solution is crystallized to solid form for use in fertilizer manufacture.

The products produced are nickel metal, copper sulphide, mixed nickel/cobalt sulphide and ammonium sulphate with the main waste being iron oxide residue. Wastes also contain iron sulphides and ammonium sulphate.

A diagrammatic summary of the overall process is presented on Figure 1.

1.2.2 Waste Disposal

In 1970 the operation of the refinery resulted in the production of 400 tonnes per day (tpd) of solid residue, which was decreased to 20 tpd by 1985 with progressive change-over to nickel matte feedstock. Since 1988 solid wastes have been treated at the refinery site with a cyanide process to extract gold.

All solid and liquid waste from the process was initially disposed of as a slurry via an underground pipeline to a 30 ha tailings pond at Millar Road, Baldivis, 7 km south-east of the refinery (Figures 2 & 3). The land on which the tailings pond is sited is owned by the Industrial Lands Development Authority and leased to WMC under the terms of the Nickel Refinery (Western Mining Corporation Limited) Agreement Act 1968.
The tailings pond was constructed in a natural sand depression above a limestone base. The pond was lined with a polythene membrane (with the approval of state authorities), to prevent contamination of groundwater below by leachate from the pond. Observation bores were installed around the perimeter of the pond to detect any leakage through the liner. Since commencement of the gold extraction process in 1988, solid wastes (containing small amounts of residual complexed cyanide as a result of the process) have been railed to Kambalda for disposal with WMC's gold treatment plant residues. This has resulted in the almost complete cessation of solid waste disposal at the Baldivis site since that time.

1.2.3 Leakage from the Existing Tailings Pond

(i) Background

In March 1979, a leak of liquor (containing ammonium sulphate) from the pond was detected during a routine maintenance inspection. Investigations subsequent to the repair of this leak indicated that the pond had most likely been leaking for some time. Lack of prior detection of the leak was found to be due to migration of the leaked liquor to the bottom of the aquifer, to levels beneath the depth of the observation bores.

(ii) Contamination Plume

The plume of ammonium sulphate solution resulting from the leak has been subject to considerable investigation.

An abridged list of the reports that have been prepared describing the investigations into the extent and nature of the plume (and potential methods of contaminant recovery) is presented in Section 10 (References).

The plume varies in nature with its distance from the tailings pond, becoming thinner and less concentrated the further it is from the tailings pond.
The horizontal extent of the plume is shown on Figure 4. This figure shows the estimated maximum concentration of ammonium sulphate in the groundwater, as calculated from measurements of conductivity with depth and calibration with analysis results of water samples for each monitoring bore. Cross sections through the plume on Figures 4A and 4B show the vertical distribution of the ammonium sulphate contamination.

The plume has a generally higher total dissolved solids content than the surrounding groundwater (in excess of 5 g/L compared with less than 1.5 g/L). It is elongate in the north-south direction extending over approximately three kilometres. The plume has migrated only a short distance to the east from the pond, however, in the west it appears to underlie the easterly fringes of Lake Cooloongup.

The shape of the plume is considered the consequence of prevailing groundwater gradients and the nature of the aquifer within which the plume is migrating.

WMC's initial response to the contamination plume, commencing in 1979, involved the recovery of contaminated water through recovery bores and return of contaminated groundwater to the tailings pond. In 1981 WMC installed a reverse osmosis plant at the refinery to remove ammonium sulphate from extracted groundwater and to allow reuse of recovered water in the refinery. By the end of 1989 the reverse osmosis plant had treated 3 400 ML of groundwater and recovered 31 000 tonnes of ammonium sulphate but, over the same period, 16 500 tonnes of ammonium sulphate was estimated to have leaked from the pond.

A total of 45 000 tonnes of ammonium sulphate is currently estimated to be contained in the groundwater contamination plume. Current recovery procedures are stabilizing the plume but not significantly reducing its extent. The current reverse osmosis plant cannot directly treat plant effluent or tailings pond liquor as the concentration of salts is too high for effective operation.

Figure 5 summarizes the current treatment process for recovered groundwater.
(iv) Possible Environmental Effects

Lake Cooloongup

The plume appears to currently underlie the eastern fringe of Lake Cooloongup (a naturally occurring salt lake to the west of WMC's tailings pond) and vegetation to the east of the lake (between the lake and tailings pond - see Figure 2). However, a saline plume is thought to underlie Lake Cooloongup, possibly preventing contact between the lake water and the contamination plume. This saline plume may also be a reason for the contamination plume to adopt the shape evident on Figure 4.

Lake Cooloongup which dries out over summer, forms part of a north-south chain of lakes on the Swan Coastal Plain, and is of some importance for flora and fauna preservation. Vegetation surrounding the lake is predominantly open tuart (*Eucalyptus gomphocephala*) and paperbark (*Melaleuca sp.*) woodland. The area has been extensively surveyed (Tingay and Tingay 1977) and recently has been subject to further investigation at the instigation of WMC (Mattiske 1989, 1990).

Lake limnology studies have also been conducted (Tingay and Tingay, 1977 Dames and Moore 1983 a, 1983 b, and 1985). The work of Dames and Moore, commissioned by WMC, was carried out to assess the current biological and nutrient status of the lake and to assess the likely response of the lake biota to any increase in nitrogen levels. Because nitrogen is an essential plant nutrient and often limiting in aquatic (and terrestrial) ecosystems, nitrogen enrichment of waterbodies may cause an increase in plant growth. Increased plant growth can change the nature of ecosystems through an increase in the total biomass and/or a shift in the dominant species. These changes in turn can lead to marked and permanent changes in the ecosystem.

Dames and Moore (1983 a, 1983 b, and 1985) concluded:

... that Lake Cooloongup is greatly enriched in nitrogen compared with other aquatic ecosystems on the Swan Coastal Plain;
the aquatic vegetation of the eastern edge of the lake and the lake algal community are important in removing and recycling nutrients;

the aquatic ecosystem is phosphorus limited. An increase in plant-available phosphorus in the lake is likely to cause greatly increased algal growth;

the alkaline pH (>9.0) of the lake and the well oxygenated water minimizes the toxic build-up of ammonia and causes phosphorus to remain in the sediments in forms largely unavailable to aquatic plants;

lake conditions cause ammonium to be transformed via ammonia to nitrogen gas and lost to the atmosphere. Although the rate of loss of nitrogen to the atmosphere is less than the apparent input of nitrogen to the system, lack of available phosphorus has reduced the rate of ecological change to that comparable with the changes occurring in other lake ecosystems;

no evidence is available to show that the high nitrogen content of the lake is related to the ammonium sulphate plume resulting from leakage from the tailings pond to the east of the lake.

Terrestrial Vegetation

In addition to the possible effects to the Lake Cooloongup waterbody, concern has been expressed that the contamination plume may adversely affect vegetation fringing the eastern edge of Lake Cooloongup. The depth to groundwater near the lake is generally shallow (less than 10 m) and ammonium sulphate in groundwater at the base of this aquifer may be available to the fringing vegetation.
Although the plume may not mix with water in Lake Cooloongup (see Section 4.3), fringing vegetation could possibly draw on ammonium sulphate contaminated groundwater. The likelihood of adverse effects are extremely difficult to assess. Relevant factors are:

- the depth of the plume;
- the ammonium sulphate concentration in the plume and the variation in concentration with depth;
- the root depth of the vegetation;
- the depth from which the vegetation will draw (contaminated) groundwater;
- the period over which (contaminated) groundwater is drawn.

Even if exposed to the plume, the concentration of ammonium sulphate in groundwater likely to cause toxicity in the fringing vegetation is unclear. Although data are limited, concentrations above 5-7 grams per litre are known to be toxic to most plants. At lower concentrations growth is likely to be stimulated.

With increasing exposure to ammonium sulphate contaminated groundwater, plant growth rates would be expected to initially increase, but in the longer term deterioration or death could occur as the concentration rose to toxic levels.

Comparative work on vegetation fringing Lake Cooloongup and that associated with Lake Clifton and Lake Haywood in the Yalgorup National Park (approximately 80 km south) have been conducted for WMC by Mattiske (1989, 1990). These studies show some deterioration in the quality of the vegetation near Lake Cooloongup, but the effects are thought to be mainly attributable to a number of factors including pests, weeds and frequency of fires, and not to the contamination plume.
Tailings Pond Leakage - Conclusions

As the liquor leaking from the existing tailings pond is the source of the ammonium sulphate contamination in groundwater and a means of remedying the leakage is not available, dewatering of the pond is an essential component of the long-term strategy to minimize potentially deleterious environmental effects.

WMC plans to dewater and rehabilitate the tailings pond and to recover contaminated groundwater in order to reduce the possibility of detrimental effects to Lake Cooloongup and fringing vegetation to the east of the lake, and to install a new effluent treatment and disposal process for the refinery.

1.3 Objectives

The overall objectives of the activities described in this proposal are:

(i) to reduce existing ammonium sulphate contamination in the groundwater resulting from past pond leakage;

(ii) to ensure further contamination is eliminated.

Specific objectives are to recover contaminated groundwater, to permanently rehabilitate the existing tailings pond, to construct a new effluent pond, and to install an upgraded wastewater treatment plant to treat effluent currently produced from the refinery, liquor from the existing tailings pond and recovered contaminated groundwater.

1.4 Timing of the Proposal

Timing of the various elements of the strategy is indicated in Figure 6. Full operation of the upgraded effluent disposal system will take approximately two years from EPA approval. Dewatering of the existing tailings pond will take an additional four years and rehabilitation is expected to take a further 18 months. Groundwater recovery will continue until satisfactory retraction
of the contamination plume has been achieved as defined in Section 5.2 of this review.

1.5 Statutory Requirements and Approvals

The proposals described in this CER are being formally assessed by the EPA pursuant to the provisions of Part IV of the Environmental Protection Act, 1986. Following its assessment of WMC's proposals, the EPA will submit its Report and Recommendations to the Hon Minister for Environment. The approval of the Minister and the statutory authorities described below will be required before the proposals (either in their present form, or modified in response to the EPA’s assessment) can be implemented.

Individual aspects of the proposal will require specific approvals as follows -

- Groundwater extraction, freshwater injection and access on reserve areas requires approval from the Department of Land Administration and the Department of Planning & Urban Development and, in the case of vested reserve areas, the body in which the reserve is vested and also the occupier (if applicable).

- Groundwater extraction bores require licensing by the Water Authority of Western Australia.

- Rehabilitation of the existing tailings pond is subject to the directions of the Minister for Resources under the Nickel Refinery (Western Mining Corporation Limited) Agreement Act 1968.

- The project site is subject to the provisions of Clause 32 of the Metropolitan Region Scheme which requires that non-rural development on land zoned Rural under the Scheme be referred to the Department of Planning and Urban Development for determination.
Construction of the new effluent disposal pond structure requires the approval of the Environmental Protection Authority, the Minister for Resources under the Agreement Act, and the Department of Planning and Urban Development.

WMC will ensure regular consultation with the relevant local authorities; the City of Rockingham and Town of Kwinana, during the planning and implementation of the proposals described herein.

1.6 Scope, Purpose and Structure of this Consultative Environmental Review

1.6.1 Scope

This CER addresses the following aspects of WMC's tailings pond rehabilitation and effluent treatment proposals:

- dewatering (removal of liquid effluent) of the existing tailings pond;
- rehabilitation of the existing tailings pond;
- continued extraction of the existing ammonium sulphate groundwater contamination plume;
- upgrading the existing wastewater treatment plant to increase total treatment capacity and ammonium sulphate recovery;
- construction of new effluent disposal pond structure;
- construction of a new tank for temporary storage of refinery effluent and liquor recovered from the tailings pond;
- discharge of treated effluent to the new effluent disposal pond;
shallow injection of fresh water adjacent to the eastern edge of Lake Cooloongup (or other measures), if deemed necessary as a result of monitoring.

This CER does not present a detailed strategy for the rehabilitation of the existing tailings pond which will be subject to a separate submission of detailed proposals to the EPA and other responsible authorities for approval.

1.6.2 Purpose

The purpose of this document is to allow the EPA and other relevant authorities to assess WMC's proposals. Readers are referred to the reports listed in the references (Section 10 of this CER) for detailed technical information.

1.6.3 Structure

The structure of this review is as follows:

- summary;
- introduction, covering background information on the existing problem, past and current strategies for addressing the problem, and the background and need for the current proposals;
- documentation of the proposed strategies, the alternatives considered, and the expected outcome of the proposals;
- evaluation of the environmental impacts of the proposals and environmental monitoring to be undertaken by WMC;
- commitments made by WMC with respect to the proposals;
- supporting references for this CER;
- EPA guidelines for this CER.
2 NEED FOR THE PROPOSALS

As outlined in the Introduction, leakage at WMC's tailings pond at Baldivis has caused a groundwater contamination plume of ammonium sulphate which has the potential to cause environmental damage to Lake Cooloongup and surrounding vegetation. Recovery of contaminated groundwater reduces this risk and allows use of the water in the refinery process and the recovered ammonium sulphate as a fertilizer. However, groundwater recovery at existing rates can only contain the plume and not eliminate the problem.

The proposal includes increased recovery of the contaminated groundwater, recovery of the remaining liquor in the tailings pond, rehabilitation of the pond to stabilize the existing tailings and construction of a new pond to provide storage and evaporation of the reduced effluent volumes produced by an upgraded wastewater treatment plant at the refinery.

Benefits of the proposal are:

- reduction of existing groundwater contamination and reuse of recovered water and ammonium sulphate;
- reduction of the possibility of environmental damage to Lake Cooloongup and surrounding vegetation;
- provision of permanent contained storage of existing tailings and future solid and liquid effluent;
- local and national employment and business opportunities arising from significant expenditure in the design and construction phase of the project.

Costs of the proposals, estimated at $20 M, are to be borne by WMC. The work proposed is expected to have no significant adverse effect on surrounding landholders.
EVALUATION OF ALTERNATIVES

3.1 Decommissioning and Dewatering of Existing Tailings Pond

No alternative to the cessation of discharge to, and subsequent dewatering and decommissioning of, the existing tailings pond exists if the groundwater contamination problem is to be resolved.

Leakage from the existing pond cannot be contained as the polythene lining membrane is buried below a large depth of solid residue. A grout curtain to contain the groundwater plume is considered unlikely to be effective, particularly in the long-term.

Decommissioning and dewatering of the existing tailings pond is necessary because leakage from the pond cannot be prevented and continuation of the current losses is not environmentally acceptable.

3.2 Tailings Pond Rehabilitation

Two methods of tailings pond rehabilitation after dewatering have been evaluated:

(i) Mounding and covering with a clay layer and a sand surface, with possible eventual use for active recreation;

(ii) A wetland concept involving covering of the tailings with clay and sand, and permanent inundation.

Work carried out to date demonstrates that both concepts would be effective in minimizing long-term leachate from the rehabilitated pond.

WMC have not nominated the preferred option at this stage as the information from studies and testwork carried out so far is not sufficient to conclusively select the optimum solution.
Field trials will be required to evaluate alternatives for materials handling of the solid residue and to develop and evaluate various construction techniques. WMC believe that field trials should not be carried out until dewatering of the pond liquor is well advanced. Disturbance of the solid residue, which is a semi-permeable layer assisting in seepage reduction, may exacerbate loss of ammonium sulphate to groundwater.

WMC will submit a detailed proposal for rehabilitation of the existing tailings pond to the EPA for approval following completion of field trials and will carry out the rehabilitation in accordance with the approved proposal to the satisfaction of the EPA.

3.3 Upgraded Effluent Disposal

Alternatives to the implementation of an upgraded effluent disposal system are limited to discharge of effluent to sewer or deep groundwater injection. The ammonium sulphate content of the effluent, and of the (untreated) contaminated groundwater, is unacceptably high for the Water Authority of Western Australia to allow discharge via the Cape Peron outfall. Deep groundwater injection has been rejected due to the high flow rates required and potential for adverse environmental effects.

Sufficient area is available on the WMC leased site at Baldivis for construction of the new effluent pond structure. The site is currently leased to WMC for the purpose of effluent disposal. Upgraded treatment of refinery effluent and the proposed construction method of the new pond structure will greatly reduce any potential environmental problems from future treated effluent discharge.

The WMC plant site in Patterson Road is not considered suitable as an alternative location for the new effluent disposal structure because there is insufficient space available on the Refinery site, and the State Agreement provides for effluent disposal at a separate site.
3.4 Protection of Lake Cooloongup and Surrounding Vegetation

Work conducted by Groundwater Resource Consultants for WMC identified freshwater injection as the most effective method for protecting the vegetation in the vicinity of Lake Cooloongup against any adverse effects of the contamination plume. Accelerated groundwater extraction close to Lake Cooloongup was found to be likely to lead to either upconing of contaminated water (shallow extraction) or increased inflow of contaminated water into the area (deep extraction). Both could aggravate any adverse effects on the vegetation surrounding the lake.

As an alternative to shallow injection of freshwater (above the watertable), sprinklers could be used to supply freshwater. This method is considered less practical than injection through bores. Similar comments are applicable to irrigation via trenches or similar structures, and the environmental impact of sprinklers or trenches is likely to be greater than that of a line of bores.

Interception or blocking of the plume in the vicinity of the lake is also considered impractical and undesirable for environmental impact reasons. Additionally, as some upward movement of groundwater near the edge of the lake could occur, such techniques would be unlikely to be effective.

In the long term, recovery of the contamination plume will reduce the potential for adverse effects on Lake Cooloongup and surrounding vegetation.
4 PROPOSED LOCATION

The proposed location of each element of the proposals is -

- rehabilitated tailings pond - existing site (Cockburn Sound Location 2209);
- new effluent pond to the east and adjacent to the existing tailings pond, on Location 2209;
- upgraded reverse osmosis plant - existing refinery site;
- holding tank - existing refinery site;
- monitor bores - see Figure 7;
- groundwater extraction bores - see Figure 7.

4.1 Cadastral and Zoning Details

A locality plan is presented on Figure 2 and cadastral information is presented on Figure 3. The tailings pond site (Location 2209) is immediately to the south of Millar Road and flanked by a recreation reserve and privately owned land to the west and south and Industrial Lands Development Authority land to the east. An Important Regional Road is proposed in an area immediately west and south of the site.

Land use zonings in the vicinity of the site are currently in a state of flux. With the exception of a wedge of Public Open Space immediately south-west of the site, land in the general vicinity is zoned rural under both the City of Rockingham and Town of Kwinana Town Planning Schemes. However, as both these schemes are being reviewed land use zonings could change in the future.
At the regional level, lands to the south of Millar Road (including the site) were generally designated for future urban development under the 1987 planning strategy for the South-West Corridor. The regional planning strategy for the South-West Corridor is also under current review.

At the more localised scale, various development strategies have been put forward for the Leda locality to the north of Millar Road and the adjacent railway line. Finalisation of a development strategy for Leda will involve decisions about System 6 Recommendation M104 for the area immediately north of the railway line and the desirable juxtaposition of residential areas and the south-eastern extremity of the East Rockingham industrial area. Although this strategy has not yet been finalized, it is likely that there will be a significant open space buffer immediately north of the railway line, in the vicinity of the site.

4.2 Topography and Other Features of the Site

The tailings pond is constructed in a natural depression in yellow sand overlying limestone, on an elevated ridge which slopes down to Lake Cooloongup to the west and lower lying rural land to east (Baldivis locality). The area is naturally vegetated with tuart woodland, with paperbark wetland associations near Lake Cooloongup.

4.3 Hydrogeology of the Site

The near-surface geological sequence of the tailings pond and Lake Cooloongup area comprises sediments of Cretaceous and Quaternary age and is summarised in Table 1 (reproduced from Dames and Moore, 1983 c).

The Tamala (Coastal) Limestone is by far the most significant aquifer in the region with measured transmissivity values up to 8 000 m²/d. The tailings pond lies in a depression developed in a hill formed of this limestone (possibly the result of sinkhole formation in the underlying limestone). The Osborne Formation brown clay directly underlies these limestone beds and forms a very low permeability base to the shallow groundwater system.
TABLE 1

SUMMARY OF GEOLOGY

<table>
<thead>
<tr>
<th>Age</th>
<th>Unit</th>
<th>Main Lithology</th>
<th>Typical Thickness (m)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarternary</td>
<td>Lake marls</td>
<td>Clay and silt</td>
<td>0 - 7</td>
<td>Limited lateral extent</td>
</tr>
<tr>
<td>Quarternary</td>
<td>Safety Bay Sand</td>
<td>Fine to coarse limey sand with basal siltstone or claystone</td>
<td>0 - 10</td>
<td>Occurs west of Mandurah Road only</td>
</tr>
<tr>
<td>Quarternary</td>
<td>Cooloongup Sand</td>
<td>Fine to coarse sand</td>
<td>0 - 4</td>
<td>Thin wedge under and east of lake only</td>
</tr>
<tr>
<td>Quarternary</td>
<td>Coastal Limestone</td>
<td>Coarse to medium calcarenite</td>
<td>15 - 20</td>
<td>Is believed to thin westwards under lake as Safety Bay Sand thickens</td>
</tr>
<tr>
<td>Quarternary</td>
<td>Rockingham Sand</td>
<td>Medium to coarse sand</td>
<td>0 - 80</td>
<td>Distribution not well known near lake</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Osborne Formation</td>
<td>Brown clay</td>
<td>5 - 10</td>
<td>Impermeable base to Quarternary sequence</td>
</tr>
</tbody>
</table>
The limestone ridge on which the tailings pond is constructed outcrops as a north-south trending ridge approximately 3 to 5 km wide lying to the east of Lake Cooloongup. Lithological logs of the numerous monitor bores constructed by WMC, and shown in Figure 7, indicate that the base of the limestone aquifer, at least in the vicinity of the contamination plume is probably cavernous in nature. Solution channels at the aquifer base appear to affect groundwater flow within the aquifer, and exert a considerable effect on the preferred direction of groundwater flow, which appears to be in a north-south direction.

Additionally, the limestone aquifer is expected to be heterogeneous in nature such that over short distances significant changes in the hydraulic properties are likely.

Towards the margin of Lake Cooloongup the Safety Bay Sand overlaps the limestone. These sands extend under the lake and thicken considerably further west. On the eastern margin of Lake Cooloongup, the Cooloongup sand occurs as a thin wedge between the limestone and Safety Bay Sand.

Groundwater levels within the limestone (and other surficial aquifers) fluctuate seasonally, resulting in a relatively high groundwater gradient dipping towards the west at the end of winter and a near flat water table at the end of summer. Using an assumed aquifer transmissivity of 7 700 m²/d, an effective porosity of 25% and average water table gradients, an aquifer throughflow of about 1 kL/d per metre width of aquifer has been estimated.

The only other geological unit of importance in the area are the marls developed over the base of Lake Cooloongup. Although their distribution is not well known, they are believed to vary from 1 m to 7 m in thickness and are considered to be of low permeability. With the natural saline plume believed to exist under the lake, this marl will further restrict groundwater - lakewater interaction.

During periods of high lake levels, however, interaction of waters at the margins of the lake could occur where the shoreline is not covered by lake marls.
Groundwater modelling studies carried out to date have all assumed that no interaction of lake water and groundwater occurs, however, limited data are available to support this assumption. The installation of piezometers through the base of the lake combined with accurate measurement of lake water levels would be required to provide definitive evidence.

A generalised cross-section of the hydrogeology through the limestone aquifer and Lake Cooloongup is shown on Figure 8.

4.4 Separation from Dwellings and Properties

The site (Cockburn Sound Location 2209) is bounded to the immediate west partly by existing recreation reserve A 22429 and partly by WMC owned Lot 283, and further to the west by Mandurah Road and Lake Cooloongup and the surrounding reserve area (A 24411 and A 18452). The Leda locality, in which housing development is proposed, lies to the north of Millar Road (which provides road access to the site) and the adjoining railway line.

Immediately to the east is a limestone quarry on the site of the proposed City of Rockingham waste disposal site. Lots immediately south of Location 2209 are owned by WMC and currently leased for farming purposes. Partly because of the swampy nature of this land, these may in future be used for recreation purposes.

The closest existing dwellings to the south are approximately 500 m from the boundaries of the pond site and to the west are approximately 300 m from the boundaries of the pond site. Future housing development of the Leda site to the north (still subject to planning and zoning proposals) could overlie the outer edge of the existing groundwater plume.
4.5 Proximity to Conservation Reserves

Lake Cooloongup, 600 m to the west of the tailings pond, is a reserve (A 24411) for 'National Park', and the adjacent area is a Reserve (A 18452) for Recreation and Picnic Ground. Both are vested in the City of Rockingham and comprise part of System 6 area M 103. Reserve A 22429, for Recreation and Parklands, between Lake Cooloongup and the tailings pond forms part of the M 103 area, but is not vested. All these Reserves are also reserved under the Metropolitan Region Scheme for Parks and Recreation. Lake Cooloongup in particular, is considered important for flora and fauna conservation. The entire System 6 M 103 area is proposed as a regional park, with conservation being the management priority identified for Lake Cooloongup.

The Leda area to the north of the tailings pond comprises System 6 area M104 and contains several reserves and areas of freehold land. The area is regarded as having a high conservation value as it encompasses an interface between three soil, landform and vegetation associations. The wetlands within the western sector of the System 6 area (in particular the most southerly) contribute significantly to the conservation value of this area. The System 6 area also forms an important link between the Rockingham Lakes open space and the proposed Beeliar - Serpentine wetlands park system.

As indicated previously, this area is subject to various development proposals and possible rezoning by the Town of Kwinana. The boundaries of the System 6 area may be altered as a result of development activities.
The proposed upgrade of the effluent treatment and disposal process involves the following elements:

- recovery of liquor from the existing tailings pond;
- increased recovery of contaminated groundwater;
- upgrading the existing reverse osmosis plant to allow treatment of contaminated groundwater, tailings pond liquor and refinery effluent;
- construction of new effluent disposal ponds and new treated effluent disposal pipeline between the refinery and the new effluent pond;
- freshwater injection if required.

5.1 Pond Liquor Recovery

Liquor will be recovered from the existing tailings pond by means of a submersible pump on a floating pontoon, and transferred to the refinery using the existing effluent pipeline. The recovered liquor will be combined with refinery effluent, filtered to remove suspended solids, combined with contaminated groundwater and treated in the upgraded reverse osmosis plant. Temporary storage of the liquor and refinery effluent will be in a new storage tank constructed on the refinery site.

The pond liquor recovery system will operate at 600 kilolitres per day (kL/d) generally, but will have a capacity of 850 kL/d.
5.2 Increased Groundwater Recovery

5.2.1 Recovery Rate

Recovery of contaminated groundwater will continue using existing bores, and new bores will be installed to increase the extent of recovery. The location of existing and proposed bores is indicated on Figure 7.

Mathematical modelling of the groundwater system and contamination plume has indicated that, under the proposed recovery strategy, the ammonium sulphate contamination plume will be gradually retracted and the higher concentration contours will disappear. As the contaminant is recovered from the groundwater, the concentration of ammonium sulphate in the extracted water will gradually fall.

Groundwater will be extracted from production bores at a rate of 2 000 kL/d, whilst liquor is being recovered from the tailings pond and, thereafter, increasing to approximately 2 600 kL/d until the contamination plume has been satisfactorily retracted.

Recovery rates are determined by the capacity of the refinery wastewater treatment system, the current pipeline capacity and the ability to reuse the freshwater generated from the reverse osmosis plant.

5.2.2 Recovery Duration and Endpoint

Mathematical modelling of the effect of groundwater pumping from the production bores located within the plume (Australian Groundwater Consultants, 1990) has been used to define a practical end point to extraction of the plume. This work shows that, at the production rates indicated above, the ammonium sulphate concentration in water extracted from the most concentrated area of the plume (initially using bores RB1-RB5, P1 and P2; and bores P1 and P2 only after the year 2000) would be reduced to 2 g/L by the year 2005, and that the maximum concentration of ammonium sulphate in groundwater at that time would be below 5 g/L. The maximum concentration is predicted to persist at this point only in the immediate vicinity of the tailings pond.
The end point for extraction and treatment of contaminated groundwater is nominated as being when there is no longer a practical threat to the use of groundwater for human or stock consumption and no significant threat exists to the broader environment. The greatest concentration of ammonium sulphate occurs in the lower portion of the aquifer. Accordingly, by pumping from the base of the aquifer, groundwater containing the highest concentrations of ammonium sulphate will be removed.

It is therefore reasonable to conclude that, when the ammonium sulphate concentrations at the base of the aquifer would no longer pose an environmental threat (ie < 5 g/L - refer to Section 1.2.3), recovery of the contamination plume has been successfully completed.

Western Mining Corporation will extract groundwater until the maximum concentration of ammonium sulphate in the contamination plume is reduced to 5 g/L when averaged over 12 months, or the concentration of ammonium sulphate in recovered groundwater cannot be maintained above 2 g/L over a three month period using an efficient practical extraction technique. At this time, the following conditions are anticipated:

(1) The maximum concentration of ammonium sulphate will occur in a restricted area adjacent to or underlying the tailings pond, and underlying land leased by WMC and not used for residential purposes.

(2) As groundwater extraction for contaminant recovery will be predominantly from the lower levels of the aquifer (to extract maximum concentrations of ammonium sulphate), groundwater pumped from shallow irrigation bores would have lower concentrations than those being pumped for contaminant recovery. Mathematical modelling of contaminant upconing in irrigation bores (Dames and Moore, 1984), carried out for the contamination plume, support the above assumption.
(3) The concentrations of ammonium sulphate in the residual plume would be less than the level which would be toxic to vegetation. In addition, vegetation would have access to water containing even lower concentrations of ammonium sulphate at shallower depths in the aquifer which would mean that the threat posed to vegetation would have been removed.

5.2.3 Pumping Beyond Proposed Endpoint

The reasons for selection of the proposed endpoint have been described previously in Section 5.2.2. In summary, this endpoint is based on a level of ammonium sulphate contamination in the residual plume which is both achievable and which poses minimal threat to vegetation or future groundwater users.

Recovery and treatment of contaminated groundwater with concentrations of ammonium sulphate of less than 2 g/L would be extremely unproductive and would result in minimal further improvement of the residual contamination plume.

By means of example, pumping at 2600 kL/d and 2 g/L of ammonium sulphate would result in ammonium sulphate recovery of approximately 1900 tonnes for a full year and represents only 4.2% of the original 45 000 tonnes estimated to be stored underground. Continued pumping would therefore not have a significant effect on recovery of the residual plume.

5.2.4 Effects on Groundwater Levels

The strategy outlined in Section 5.2.2 for pumping of the most concentrated area of the contamination plume means that recovery bores will be located well away from existing or likely future irrigation bores.

This separation indicates that recovery operations based on the anticipated flowrates (refer to Section 5.2.1) would not adversely affect groundwater levels at irrigation bores utilized by occupiers of adjacent land.
The high transmissivity of the aquifer, regional flow of groundwater through the area of influence of contaminated water recovery bores, and natural recharge of the aquifer from local precipitation indicate the unlikelihood of any significant change in groundwater levels in the aquifer, or water levels in adjacent wetlands.

5.3 Plant Effluent and Solid Residue

5.3.1 Historical and Current Discharges

Historically, refinery tailings slurry and liquid effluent were pumped directly to the tailings pond for settling and evaporation. Liquid effluent is still currently being disposed of to the existing tailings pond. Since 1988, refinery tailings solids (20 tpd) have been cyanide leached to recover gold. The leached ('barren') solids residue so obtained (which contains cyanide compounds) is then solar dried and railed to Kambalda for co-disposal with tailings from WMC's Kambalda gold plant.

The current refinery liquid effluent is generated from:

- stormwater runoff from paved and bunded process areas;
- demineralized water plant wash and rinse liquor;
- cooling tower blowdown;
- cleaning water from tanks and pipes;
- process bleed streams.

Ammonium sulphate is the major component in refinery liquid effluent, together with smaller amounts of magnesium, calcium, nickel and copper. Minor amounts of other elements are also present. Table 2 shows a typical analysis for historical and current refinery effluent.
TABLE 2

CURRENT REFINERY EFFLUENT

Estimate for the Average Annual Values for major constituents and flowrate of Current Plant Effluent (disposed of to existing tailings pond; to be discontinued once proposed new system is installed);

<table>
<thead>
<tr>
<th>Flowrate</th>
<th>300 - 450 kL/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Constituents</td>
<td>Concentration (ppm)</td>
</tr>
<tr>
<td>Ammonium</td>
<td>2 500 - 6 000</td>
</tr>
<tr>
<td>Sulphate</td>
<td>7 000 - 16 000</td>
</tr>
<tr>
<td>Nickel</td>
<td>100 - 300</td>
</tr>
<tr>
<td>Copper</td>
<td>30 - 150</td>
</tr>
<tr>
<td>Cobalt</td>
<td>25 - 100</td>
</tr>
<tr>
<td>Sodium</td>
<td>400 - 900</td>
</tr>
<tr>
<td>Chloride</td>
<td>150 - 400</td>
</tr>
<tr>
<td>Calcium</td>
<td>70 - 160</td>
</tr>
<tr>
<td>Magnesium</td>
<td>25 - 60</td>
</tr>
</tbody>
</table>
5.3.2 Proposed Discharges

(i) Effluent Discharge

Following the installation of the proposed wastewater treatment system (described later), a number of treated effluent streams will result from the process.

The new streams include:

- a "chloride bleed" stream (Table 3.1) which allows chlorides to be removed from the system so that they do not build up and cause problems in downstream equipment;

- a "calcium bleed" stream (Table 3.2) which allows calcium to be removed from the system so that it does not build up and cause problems in downstream equipment;

- a "solids backwash" (Table 3.3) containing solids removed from pond liquor and plant effluent prior to the reverse osmosis plant.

Chlorides and calcium appear in plant effluent mainly as a result of concentration of those ions present in water supplied by the Water Authority. Chlorides and calcium in contaminated groundwater recovered result from refinery effluent which has leaked from the pond and also occurs naturally in the groundwater.

Typical analysis for treated effluent predicted for the proposed wastewater treatment system are shown in Tables 3.1, 3.2, 3.3.
TABLE 3.1

CHLORIDE BLEED STREAM

Average annual rates and concentrations predicted for proposed chloride bleed stream (to be disposed of to new effluent pond once installed).

<table>
<thead>
<tr>
<th>Flowrate</th>
<th>30 - 75 kL/day</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major Constituents</strong></td>
<td><strong>Concentration (ppm)</strong></td>
</tr>
<tr>
<td>Ammonium</td>
<td>4 000 - 12 000</td>
</tr>
<tr>
<td>Sulphate</td>
<td>1 500 - 20 000</td>
</tr>
<tr>
<td>Chloride</td>
<td>5 000 - 30 000</td>
</tr>
<tr>
<td>Calcium</td>
<td>0 - 300</td>
</tr>
<tr>
<td>Nickel</td>
<td>0 - 300</td>
</tr>
<tr>
<td>Sodium</td>
<td>250 - 3 000</td>
</tr>
</tbody>
</table>
TABLE 3.2

CALCIUM BLEED STREAM

Average annual rates and concentrations predicted for proposed calcium bleed stream (to be disposed of to new effluent pond once installed).

<table>
<thead>
<tr>
<th>Calcium Bleed Effluent</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowrate</td>
<td>7 - 14 kL/day</td>
</tr>
<tr>
<td>Major constituents</td>
<td></td>
</tr>
<tr>
<td>(a) Solids</td>
<td>calcium sulphate precipitate</td>
</tr>
<tr>
<td>Concentration</td>
<td>10 - 100 grams per litre</td>
</tr>
<tr>
<td>(b) Liquor</td>
<td>Concentration</td>
</tr>
<tr>
<td>Ammonium</td>
<td>4 000 - 27 000 ppm</td>
</tr>
<tr>
<td>Sulphate</td>
<td>11 000 - 73 000 ppm</td>
</tr>
<tr>
<td>Nickel</td>
<td>0 - 720 ppm</td>
</tr>
<tr>
<td>Sodium</td>
<td>500 - 3 500 ppm</td>
</tr>
<tr>
<td>Chloride</td>
<td>200 - 950 ppm</td>
</tr>
<tr>
<td>Calcium</td>
<td>80 - 900 ppm</td>
</tr>
</tbody>
</table>

TABLE 3.3

SOLIDS BACKWASH STREAM

Average annual rates and concentrations predicted for proposed solids backwash stream (to be disposed of to new effluent pond once installed).

<table>
<thead>
<tr>
<th>Pond Liquor and Effluent Filtration Solids Bleed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowrate</td>
<td>4.5 - 9.0 kL/day</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>100 - 500 ppm</td>
</tr>
<tr>
<td>Composition of solids</td>
<td>As for residue in Table 4 below</td>
</tr>
<tr>
<td>Composition of liquor</td>
<td>As for current effluent Table 2</td>
</tr>
</tbody>
</table>
(ii)  

*Solid Waste Discharge During Plant Maintenance*

Because of plant maintenance requirements at WMC's Kalgoorlie Nickel Smelter, it is possible that the Kwinana refinery may treat nickel concentrate (12% Ni) rather than nickel matte (70% Ni) for approximately three months every 5 - 10 years. Disposal of the resulting waste would be to a separate compartment of the proposed new effluent pond once the new facilities have been completed, or to the existing tailings pond prior to that time. The slurry to be disposed of would generally have the specifications shown in Table 4. During operation of the refinery on nickel concentrate feedstock, cyanide leaching for gold extraction would not be carried out and therefore residue would not contain cyanide or complexed cyanide compounds.

WMC are currently reviewing a number of options for the production, concentrating, smelting and refining of nickel for the medium and long terms. At this stage it is not possible to determine the requirement or timing for possible intermittent operation of the refinery on concentrate feed and therefore the requirement for further solids disposal at the Baldivis site.

5.3.3  

**Summary of Effluent Discharge Proposals**

Upgrading of the effluent treatment facilities at the refinery will result in an estimated major reduction (75 - 85%) in the liquid volume currently discharged and, apart from the possible intermittent requirement for discharge due to maintenance at the Kalgoorlie nickel smelter, will result in almost no solids discharge at Baldivis. Although the concentration of ammonium sulphate in the liquid effluent may increase, the greatly reduced volume of discharge means the estimated total discharge of ammonium sulphate is less than 20% of current rates. The estimated quantity of ammonium sulphate discharge to the new effluent pond resulting from treatment of plant effluent is estimated to be only 4% of the current discharge. The balance results from treatment of pond liquor and groundwater.
TABLE 4

SLURRY COMPOSITION

Typical composition of slurry for discharge to the proposed effluent pond during plant maintenance.

<table>
<thead>
<tr>
<th>Solids Flowrate</th>
<th>: 350 tonnes per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquor Flowrate</td>
<td>: 125 - 165 kilolitres per day</td>
</tr>
<tr>
<td>Duration</td>
<td>: 3 months every 5 - 10 years</td>
</tr>
<tr>
<td>Slurry density</td>
<td>: 1 400-1 600 grams of solids per litre</td>
</tr>
<tr>
<td>Special Gravity of Slurry</td>
<td>: 2.0 - 2.2</td>
</tr>
<tr>
<td>Specific gravity solids</td>
<td>: 3.6 - 4.0</td>
</tr>
<tr>
<td>% Solids</td>
<td>: 68 - 74</td>
</tr>
</tbody>
</table>

**Typical Solids Composition**

(a) Minerals

- Pentlandite 1.5%
- Chalcopyrite 0.5%
- Pyrrhotite 7%
- Pyrite 12%
- Magnetite 3%
- Talc 28%
- Other Silicates 10%
- *Goethite 38%

*Goethite (Fe₂O₃H₂O) is produced from leaching of iron sulphides.

(b) Trace Elements

<table>
<thead>
<tr>
<th>ppm</th>
<th>Bi</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Sb</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Te</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>5 000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ppm</th>
<th>Sn</th>
<th>Pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>&lt;50</td>
<td></td>
</tr>
<tr>
<td>Sb</td>
<td>&lt;50</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>&lt;50</td>
<td></td>
</tr>
<tr>
<td>Te</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Liquor Analysis - As for current effluent (Table 2)
Current proposals are not to dispose of the solid tailings after extraction for gold (barren residue) to the existing tailings pond or new effluent pond at Baldivis. If any proposal is developed for disposal of these residues at Baldivis in the future, EPA approval will be sought at that time.

5.4 Wastewater Treatment System

The proposed upgrade of the wastewater treatment system will be designed to handle refinery effluent and tailings pond liquor in addition to contaminated groundwater. The following components are involved:

- installation of a new effluent holding tank for temporary storage of refinery effluent and pond liquor;
- installation of a filtration plant for removal of solids from the refinery effluent and pond liquor prior to the reverse osmosis plant;
- substantial upgrading of the reverse osmosis plant to allow removal of chlorides and calcium and the production of "purified" water and ammonium sulphate;
- installation of a pipeline between the refinery and the new effluent pond for disposal of waste streams described in Section 5.3.2 (i);
- installation of a new effluent pond for storage and evaporation of waste streams described in Section 5.3.2. (i) and (ii).

A simplified schematic diagram of the proposed system is shown in Figure 9.
5.4.1 New Effluent Holding Tank

A new effluent holding tank with 1.8 megalitres capacity will be constructed on the refinery site for temporary storage of pond liquor and refinery effluent prior to reverse osmosis treatment. This holding facility will allow control of the rate and quality of input flow to the reverse osmosis plant.

5.4.2 Solids Filtration Plant

The solids filtration plant will remove solids from refinery effluent or pond liquor in order to prevent fouling of reverse osmosis membranes by solids. The filtration plant will be designed to handle a flowrate of 850 kL/d.

A solids backwash stream as described in Table 3.3 will be generated from the plant.

5.4.3 Reverse Osmosis Plant

The reverse osmosis process is based on a semi-permeable membrane which allows the passage of water, but not ions, causing concentration of ions in one recovered fraction (the 'concentrate') and depletion of ions in the other (the 'permeate'). In addition to conventional membranes, ion-selective membranes can be used which allows passage of some ions (usually smaller ions of low charge), but not others.

WMC currently treats contaminated groundwater by conventional reverse osmosis at a throughput of approximately 2 000 kL/d whilst the refinery is in operation. The ammonium sulphate recovered by crystallisation of dissolved solids in the concentrate is used in the manufacture of high-nitrogen agricultural and garden fertilisers. The 'purified' permeate water is returned to the refinery for processing stream make-up. Use of the permeate in this way decreases the total demand on water supplied by the Water Authority.

The existing reverse osmosis plant cannot currently be used to treat refinery liquid effluent or tailings pond liquor since:

- the total salt concentration is too high;
the high pond liquor chloride concentration would cause severe corrosion problems within the ammonium sulphate crystallisation plant;

pond liquor or plant effluent suspended solids would impair membrane performance through fouling of the membrane;

the quality of refinery liquid effluent is too variable.

The plant will be extensively upgraded by installation of a higher treatment capacity unit and selective membranes to allow chloride to be initially taken into the permeate and subsequently removed.

Permeate (with chloride removed) will then be received within the refinery. Upgrading of the plant reverse osmosis will achieve a total capacity of 2,850 kL/day which will consist of 850 kL/day pond liquor or refinery effluent and 2,000 kL/d of recovered groundwater during dewatering of the tailings pond, subsequently changing to 300 kL/day of plant effluent and 2,550 kL/day of contaminated groundwater once tailings pond dewatering is complete.

5.4.4 Pipeline to New Effluent Pond Structure

A new polythene pipeline will be constructed between the refinery and the new effluent pond structure and will be designed with sufficient capacity to transport the waste streams described in Section 5.3.2 (i).

Disposal of solid residue on an intermittent basis as described in Section 5.3.2 (ii) will be through the existing (and currently unused) solid residue line, or a new (but similar) line as determined following inspection and testing of the existing line.
5.4.5 Construction of New Effluent Pond Structure

New disposal and storage facilities for refinery effluent and residue are required:

(i) As an evaporation pond for the streams described in Section 5.3.2 (i);

(ii) As an emergency storage facility for refinery effluent in the event of lengthy shut-down of the wastewater treatment plant;

(iii) For possible storage of solid residue resulting from intermittent operation of the refinery on concentrate feed as described in Section 5.3.2 (ii).

A new pond structure will be constructed, comprising two compartments to accept treated liquid effluent, and a possible third compartment to accept the solid residue resulting from intermittent operation of the refinery on concentrate feed. The new pond structure will be double lined. Proposed location and construction details for the new pond structure are shown on Figures 3 and 10 respectively.

The new pond structure will be partitioned and lined with a primary and secondary liner of one millimetre thick HDPE membrane. The two liners will be separated by a layer of HDPE drainage netting or similar which will drain to sumps located outside the pond for detection and collection of any leakage from the primary liner.

A detailed geotechnical investigation has not been carried out for the new pond structure. However, it is envisaged that local materials will be used for construction of embankments, and covering where required.

The area beneath the liners of the ponds will be cleared, grubbed and ripped where necessary to remove limestone pinnacles prior to proof rolling and compacting.
The new treated effluent evaporation pond compartments will have a total area of 6 hectares. The solids disposal compartment, if required, will have an area of 1.5 hectares in addition to the effluent evaporation pond compartments. Design will be such that overtopping will not occur (see Section 7.1).

At the end of the operational life of the proposed pond structure, it will be rehabilitated. This will involve dewatering by evaporation, and filling and capping using techniques similar to those proposed for rehabilitation of the existing tailings pond (see Chapter 6). The liquid effluent disposal compartments will contain residual salts after evaporation and, although it may be feasible to remove these salts by mechanical means, their disposal at another site could create additional environmental risk. Residual salts will build up at a rate of approximately 10-20 mm per year over the life of the pond. Capping with a low permeability membrane will provide safe long term disposal at the Baldivis site, and the ultimately rehabilitated site would be suitable for recreational purposes.

5.5 Proposals for Freshwater Injection

It is predicted that under the current proposal for groundwater recovery and treatment, extraction of contaminated groundwater will be required for a significant length of time in order to reduce groundwater concentrations of ammonium sulphate to the desired levels. In the interim period, vegetation along the eastern shore of Lake Cooloongup may be affected, from time to time, by the ammonium sulphate plume. The likelihood of this occurring is, however, unclear.

Shallow groundwater quality near Lake Cooloongup and vegetation fringing the lake will continue to be regularly monitored. If groundwater quality or vegetation deterioration is identified to be caused by the ammonium sulphate plume, it is proposed that freshwater injection into shallow bores fringing Lake Cooloongup (or other measures) would be implemented following discussion and agreement with the relevant government authorities.
Freshwater for injection would be pumped from production bores located upstream from the ammonium sulphate contamination plume. The system would operate only in periods considered to be of high stress or threat to vegetation from the contamination plume (determined from monitoring data), with production bores being monitored to avoid extraction of naturally saline water.

Hydrogeological investigations to date have indicated the possibility of maintaining a layer of fresh water over the top of the plume by injection of fresh water into shallow bores placed along the shore line. Current indications are that up to 10 shallow wells spaced at 100 m, in a line approximately 50 m distant from the lake edge would be sufficient to supply fresh water to the vegetation during periods of stress.

The conceptual locations of the injection wells are shown on Figure 11.

At this stage it is estimated that up to 900 kL/d of fresh groundwater would be required to operate the system.

Detailed design and installation of the fresh water injection system would be undertaken if monitoring confirms the requirement to do so. Construction of the system would proceed with a pilot trial initially, followed by staged construction following assessment of performance.

It is not known with certainty that the proposed fresh water injection system would fully protect the shoreline vegetation from the possible effects of the plume. However, the proposal is considered to offer the best possibility for protection of the trees if necessary.

5.6 Backup Systems

The backup system for the upgraded effluent management system will be in two parts:
(i) **Storage Tank**

A storage tank facility will be constructed to temporarily hold refinery effluent and, during dewatering, liquor from the existing tailings pond. The tank will allow short-term variation in the effluent composition and volume to be evened for better operation of the filtration and reverse osmosis plants. The total capacity of the tank will be 1.8 megalitres to allow two days storage during pond dewatering and six days storage thereafter.

The tank will be built within the existing nickel refinery site;

(ii) **New Effluent Pond Structure**

The new double lined effluent pond structure will provide evaporation facilities for liquid effluent (liquid effluent compartment), and an additional compartment to hold solids resulting from operation of the refinery on concentrate feed (solids compartment) if required. Spare pond capacity is included in the design to hold untreated refinery effluent in the event of an extended shutdown of the reverse osmosis plant or to hold the contents of a compartment in the unlikely event of leakage. The primary function of the pond is for storage and evaporation of treated effluent and WMC do not intend to regularly or permanently divert untreated effluent to the pond.

By installation of the two backup facilities indicated, effluent from the wastewater treatment plant after commissioning of the upgraded treatment system will have very little potential for adverse effects on groundwater or the local environment.
After removal of the pond liquor, the existing tailings pond will be rehabilitated to provide permanent storage of the solid wastes. This can be achieved by either consolidation and dry mounding of the residue or by use of a wetland concept (Figures 12 and 13).

The characteristics of the solid residue and the feasibility of both dry and wetland rehabilitation have been investigated (Kinhill Engineers, 1990). Potential difficulties in removing all the pond liquor, moving the residue for reshaping of the pond surface, and the necessity for ensuring a minimum residual water content in the residue to prevent acid formation through oxidation of sulphide minerals, were highlighted.

Both the mound concept and the wetland concept can be designed to maintain sufficient water content of the tailings to minimize both diffusion of oxygen into the tailings (to prevent acid generation) and leaching through the tailings. This will be achieved by capping the tailings mass with a layer of 'impermeable' clay, with a surface layer of coarse sand to support vegetation cover and to prevent desiccation of the clay layer.

The exact method chosen for rehabilitation and therefore the final use of the area, will be subject to further detailed assessment and design after dewatering has progressed sufficiently as discussed in Section 3.2 of this review. Final design of the rehabilitation proposals will be submitted to the Environmental Protection Authority and other responsible authorities for assessment and approval.
7 SITE AND POTENTIAL POLLUTION MANAGEMENT

7.1 Effect of Weather Conditions on Treatment and Disposal Method

As most of the treatment facilities are not subject to the effect of weather conditions, treatment will be minimally affected by adverse conditions. The new effluent pond will be designed to provide sufficient net evaporative capacity (evaporation minus rainfall) to remove water at the projected rate of disposal of treated liquid effluent to each, and to hold the maximum once in 100 year frequency precipitation to be expected over a 24 hour period, whilst maintaining a minimum freeboard of 500 mm for the duration of operation of each pond.

7.2 Plant or System Breakdown

In the event of breakdown of the reverse osmosis plant, refinery effluent will be stored in the holding tank. For extended shutdowns, disposal of untreated effluent will be to the proposed new effluent pond.

7.3 Land Impacts

The area of land (Location 2209) used for tailings and effluent disposal (old and new ponds) will be fully fenced to exclude human and animal intrusion. This will involve realignment and extension of the existing fence. Buffer zones of various widths depending on road proximity etc., will be included within the fenced area. Environmental effects on the surrounding land from the new sealed effluent disposal pond will be minimal. Groundwater contamination from the existing tailings pond currently underlies surrounding areas including Lots 284, 285 and 286 zoned parks and recreation reserve, the eastern fringe of Lake Cooloongup, and lots to the north and east of the tailings pond. The impact of the existing ammonium sulphate plume have been discussed in other sections of this review.
Modifications to the reverse osmosis plant and the installation of the new effluent holding tank will have no adverse environmental impact.

Because of the long term acid generation potential of the rehabilitated tailings pond, and the uncertainty of the competence of the re-formed tailings to support specific development, long-term use of the rehabilitated area is likely to be for recreational purposes (see Figure 3).

7.4 Amelioration of Existing Groundwater Contamination

As outlined previously in this review, amelioration of the existing groundwater contamination problem will continue using existing bores to recover groundwater, with pumping from additional bores.

A total throughput maximum of 2 850 kL/day comprised of current refinery effluent, recovered tailings pond liquor and recovered groundwater will be possible with the upgraded reverse osmosis plant whilst the nickel refinery is in operation. During the period of tailings pond liquor recovery and treatment, 2 000 kL/day of recovered groundwater will be treated, rising to 2 550 kL/day after dewatering is complete.

More rapid groundwater recovery is precluded by limitations on:

- refinery reuse of recovered water;
- the rate of concentrate treatment by the ammonium sulphate crystallization plant;
- the need to treat both recovered tailings pond liquor and refinery effluent;
the undesirability of returning untreated recovered groundwater to the leaking tailings pond, or to the new effluent pond. To allow sufficient area to evaporate recovered groundwater, the surface area of the new pond would need to greatly increase. Any benefits from return of recovered groundwater to the existing tailings pond would be very short term, due to continued leakage;

- the environmental unacceptability of disposal of recovered groundwater either to sewerage or to deep groundwater;
- pumping capacity through existing pipelines.

In addition to contaminated groundwater extraction, monitoring of shallow groundwater adjacent to Lake Cooloongup and of the eastern fringing vegetation to detect possible adverse effects of the ammonium sulphate contamination plume will continue. If adverse effects are detected, a groundwater injection programme, using specially installed bores and water pumped from uncontaminated areas, may be initiated (see Section 5.5 and Figure 11).

7.5 Prevention of Further Groundwater Pollution

Steps undertaken to recover contaminated groundwater and tailings pond liquor will reduce existing groundwater contamination. However, as discussed in other sections of this review, loss of ammonium and sulphate to groundwater will continue for some time after decommissioning of the existing tailings pond as ammonium sulphate that is already present in the tailings pond solids will continue to leach. Groundwater interception to recover this leachate will continue.

The new effluent pond will be constructed as indicated in Section 5.4.5.
Construction of the new effluent pond will be carried out using proven materials and rigorous testing techniques far superior to the technology available at the time the existing tailings pond was constructed. In addition, the provision of a secondary liner and leak detection system provides additional security against leakage.

In the event of leakage being detected from the primary liner on either pond, leachate will be recovered and the leaking segment contained, closed, dewatered and repaired.

As a result of the increased capacity of the upgraded reverse osmosis plant to remove much of the ammonium sulphate from the refinery effluent, any threat to the groundwater posed by effluent disposal will be reduced compared to the existing situation.
8 MONITORING

8.1 Proposed Monitoring to be Conducted by WMC

Proposed monitoring will include:

(i) *Effluent Disposal*

- volume of effluent - continuous metering;
- composition of effluent - daily composite samples;
- volume of ammonium sulphate concentrate from the reverse osmosis plant - continuous metering;
- concentration of ammonium sulphate concentrate from the reverse osmosis plant - three times per week;
- volume of reverse osmosis permeate for refinery reuse - continuous metering;
- composition of reverse osmosis permeate - three times per week.

(ii) *Groundwater Plume*

- conductivity profiles of ammonium sulphate contamination - three times per annum in all accessible bores;
- sampling and analysis of all bores - once per annum, and three times per annum for bores close to Lake Cooloongup;
- volume and concentration of recovered groundwater - continuous metering and monthly analysis from weekly samples.
(iii) *Lake Cooloongup Vegetation*

vegetation condition assessment - twice per year (September, April) on the fringe of Lake Cooloongup. In addition to visual estimation, leaf analyses will be conducted on representative tuart and paperbark trees to determine total nitrogen concentration and comparison made with the same species from sites within the Yalgorup National Park. Significant elevation in nitrogen content will indicate contact with the contamination plume and the possible need for commencement of the freshwater injection (or other) proposals.

8.2 Operational Specifications

(i) *Effluent Disposal*

Quantities will be minimized as far as is practical. Composition and flow rates will generally be within the ranges indicated in Section 5 of this review;

(ii) *Groundwater Plume*

Monitoring will be as detailed in Section 8.1 (ii). The extraction rate of contaminated groundwater will generally be between 2,000 kL/day and 2,550 kL/day whilst the nickel refinery is in operation, with a maximum rate of 3,600 kL/day;

(iii) *Wetlands*

Monitoring will be as detailed in Section 8.1 (ii);

(iv) *Vegetation Condition Assessment*

As for (iii) above;
The proponent, Western Mining Corporation Limited (WMC) has provided the following commitments to the Environmental Protection Authority in the CER on its Tailings Bond Rehabilitation Project at Baldivis and Effluent Management System Upgrade at Baldivis and Kwinana.

9.1 General Commitments

(1) The proponent will adhere to the proposals as described in the CER and as assessed by the Environmental Protection Authority and will fulfil the commitments made therein and summarized below.

(2) The groundwater pollution resulting from the leaking tailings pond will be rectified as specified in the CER, to the satisfaction of all relevant Government agencies' including the following -

- EPA;
- Water Authority of WA;
- Department of Conservation and Land Management; and
- Mines Department.

(3) The proposed new effluent pond structure will be constructed, operated and managed to the satisfaction of -

- EPA;
- Water Authority of WA;
- Mines Department; and
- The Health Department.

(4) The proposed liquid, slurry and solid waste management practices will be carried out, where relevant, to the satisfaction of -
Environmental Protection Authority;
Water Authority of WA;
Mines Department;
The Health Department.

(5) If the EPA identifies an environmental impact on Lake Cooloongup or surrounding area resulting from polluted groundwater generated by the proponent, the proponent will take all reasonable remedial action to the satisfaction of the EPA and all other relevant Government agencies.

9.2 Existing Tailings Pond

(6) The environmental management programme will be modified where practicable to reduce the impact of pollution on the environment to the satisfaction of the EPA.

(7) The proponent will cease discharging effluent to the existing tailings pond as soon as the proposed new effluent pond structure and upgraded effluent treatment plant are commissioned. Construction and commissioning of the new effluent pond structure and upgraded effluent treatment plant will be carried out as soon as possible after all statutory approvals have been granted, and will be to the satisfaction of the EPA.

(8) The proponent will, at least six months prior to decommissioning the existing tailings pond, prepare a decommissioning and rehabilitation plan to the satisfaction of the EPA.

(9) The proponent will commence to dewater the existing leaking tailings pond immediately after cessation of effluent disposal and at the time of commissioning the new effluent pond structure. Dewatering will be carried out as quickly as is practical and to the satisfaction of the EPA. The recovered water will be treated or disposed of to the satisfaction of the EPA.
(10) Rehabilitation of the existing tailings pond site will be carried out to the satisfaction of the EPA, Health Department, Water Authority, the Department of Resource Development and any other relevant agency.

(11) During rehabilitation, the leaking tailings pond will be stabilized to minimize leakage as far as possible, even during periods of high rainfall, and this will be done to the satisfaction of the EPA and the Water Authority of Western Australia.

9.3 Upgrading of Wastewater Treatment Plant

(12) The proponent will upgrade its reverse osmosis wastewater treatment plant to a level which will enable processing of contaminated groundwater at the treatment rates indicated in the CER. The proponent will undertake further upgrading of the wastewater treatment plant if treatment of the contaminated groundwater is not progressing at a reasonable rate to the satisfaction of the EPA.

(13) The proponent will operate and manage its wastewater treatment plant to the satisfaction of the EPA.

(14) The proponent will monitor the performance of its wastewater treatment plant so that waste recovery can be continually optimized, and this will be done to the satisfaction of the EPA.

(15) The proponent will continue to investigate new technology and improvements to improve its wastewater treatment plant to optimize recovery of pollutants and this will be done to the reasonable satisfaction of EPA.

9.4 New Effluent Pond Structure: Construction and Management

(16) The proposed new effluent pond structure will be constructed to the satisfaction of the EPA, Water Authority and the Health Department and any other relevant statutory agency.
(17) The proposed new effluent pond structure will be operated and managed to the satisfaction of the EPA, Water Authority, the Health Department and any other relevant statutory agency.

9.5 **New Effluent Pond Structure: Effluent and Slurry**

(18) To ensure that the final residue in the new effluent pond structure conforms to predicted specifications for future management, the plant effluent, slurry and solid residue quality and discharge rates, will be monitored to the satisfaction of the EPA. If the quality or quantity of effluent does not conform to predicted specifications and is unacceptable to the EPA, the effluent will be retreated or otherwise disposed of to EPA's satisfaction.

9.6 **New Effluent Pond Structure: Leakage**

(19) If leakage were detected from the proposed new effluent pond structure, EPA will be notified immediately. The proponent will take immediate action to recover leakage and mend the leak and this will be done to the satisfaction of the EPA.

9.7 **New Effluent Pond Structure: Solids Buildup**

(20) Solid residues building up in the new effluent pond structure over the lifetime of the ponds would be managed to the satisfaction of the EPA and Health Department.
9.8 New Effluent Pond Structure: Decommissioning and Rehabilitation

(21) The proponent will be responsible for decommissioning the new effluent pond structure and rehabilitating the site to the satisfaction of the EPA.

(22) The proponent will, at least six months prior to decommissioning the new effluent pond structure, prepare a decommissioning and rehabilitation plan to the satisfaction of the EPA.

(23) Upon decommissioning, the proponent will cease discharge to and dewater the new pond structure. This will be carried out to the satisfaction of the EPA. The recovered water, if any, will be evaporated or treated and disposed of, to the satisfaction of the EPA.

(24) Rehabilitation of the new effluent pond structure site will be carried out to the satisfaction of the EPA, Health Department, Water Authority, and any other relevant agency.

(25) During rehabilitation, the new effluent pond structure will be stabilized to prevent leakage subsequently occurring even during periods of high rainfall. This stabilization will be carried out to the satisfaction of the EPA and the Water Authority.

9.9 Solid Waste Disposal From Gold Recovery Unit

(26) The proponent will continue to transport contaminated solid waste residues, resulting from its gold recovery unit, back to its Kambalda minesite and this will be done to the satisfaction of the EPA and the Health Department. If the proponent were to change this practice and dispose of this solid waste elsewhere, it would only do so after first obtaining approval from the EPA.
9.10 Spillage at Plant

(27) Any new operations at the existing plant will be designed and operated to contain any liquid spillages and contaminated runoff within the site boundaries to the satisfaction of the EPA.

9.11 Breakage of Effluent Pipeline

(28) In the case of spillage to the environment resulting from effluent pipeline failure, the proponent will immediately inform the EPA of such spillage, immediately clean up the leakage and as soon as possible remediate any environmental impact to the satisfaction of the EPA.

9.12 Storage Facilities for Contaminated Liquids and Solids in the Plant

(29) All new facilities which are used on site to hold contaminated materials associated with polluted groundwater recovery or polluted effluent/slurry or solid waste disposal will be so designed so as to contain spillage from entering the environment. The design of containment and recovery methods to be used will be to the satisfaction of the EPA.

9.13 Monitoring

(30) Prior to construction of the new effluent pond structure, the proponent will submit and subsequently implement a monitoring programme to the satisfaction of the EPA and the Water Authority.
The monitoring programme will include -

- data outlining existing status of groundwater contamination so that a benchmark can be set to measure performance of recovery of polluted groundwater;
- proposed sampling period to determine performance in recovery of polluted groundwater;
- monitoring Cooloongup Lake environment for impacts;
- parameters to be measured;
- sampling sites and times and
- reporting times to the EPA.

(31) All samples taken in the monitoring programme will be analysed in a laboratory acceptable to the EPA.

9.14 Security

(32) The proponent will ensure that the old and new tailings ponds are fenced so as to avoid public access at all times and that this will be done to the satisfaction of the EPA.

9.15 Other Commitments

(33) The proponent will control insects and weeds around the tailings ponds (evaporation ponds) to the satisfaction of the EPA, the Health Department and the City of Rockingham.
(34) The proponent will modify its polluted groundwater recovery programme and its tailings pond management procedures, if it cannot meet licence conditions placed on it by EPA. Such modifications will be to the satisfaction of the EPA.

(35) The proponent will not transfer ownership, control or management responsibility of groundwater cleanup, tailings ponds management, solid waste disposal or tailings dams rehabilitation without prior consultation and arrangements being made which are to the satisfaction of the EPA and The Hon. Minister for Environment.

9.16 General Reporting

(36) Reports will be provided to the EPA as directed by the EPA. Reporting will include advice to the EPA on the fulfilment of any Ministerial Conditions and Commitments given by the proponent at relevant project stages and of works approval and licencing conditions.
REFERENCES


Dames and Moore Pty Ltd (1983 a) "Lake Cooloongup Limnology Study" April 1983.

Dames and Moore Pty Ltd (1983 b) "Lake Cooloongup Limnology Study - Addendum" August 1983.


Stuart Miller and Associates Pty Ltd; "Geochemistry of Process Tailings and Implications for Tailings Pond Rehabilitation and Leachate Control - Stage 1 Report"; August 1989.


Western Mining Corporation Limited, Kwinana Nickel Refinery; "Baldivis Tailings Pond Progress Report No. 11"; December 1988.

APPENDIX I

GUIDELINES FOR THE CONSULTATIVE ENVIRONMENTAL REVIEW
Guidelines for this CER were developed by the EPA and are detailed below.

Summary

The Consultative Environmental Review should contain a brief summary of:

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

Introduction

The Consultative Environmental Review should include an explanation of the following:

- identification of proponents and responsible authorities;
- background and objectives of the proposal;
- brief details of, and timing of the proposal;
relevant statutory requirements and approvals;

the scope, purpose and structure of the Consultative Environmental Review.

Need for the Proposal

The Consultative Environmental Review should briefly examine the justification for the proposal. Broad costs and benefits of the proposals at local and regional levels should be briefly discussed. Consequences of not implementing the proposal should be outlined.

Evaluation of Alternatives

A discussion of the alternative sites at Kwinana and scale (size) of the proposed operation should be provided. This discussion should clearly explain the rationale for choosing the preferred option.

Proposed Location

The preferred location is to be described, including:

- cadastral and zoning information;
- topography of the site;
- separation from dwellings and properties;
- proximity to Conservation Reserves.
procedures used to ensure that the treatment system operates efficiently, both for the present and future;

use of land that is subject to potential impacts including details of buffer zones;

steps to be taken to ameliorate existing groundwater contamination;

procedures to be adopted in the event of further pollution being detected in groundwater or drains.

Monitoring

The waste treatment system will require monitoring to ensure that it operates efficiently. Specifications for the operation of that system should be assigned.

Commitments

A numbered list of all environmental management commitments should be given.

A commitment should include:

who makes the commitment:

what is the nature of the commitment;

when will the commitment be carried out and to whose satisfaction.
Process Description

This section should provide a clear description of each stage of the process. A description of the reverse osmosis process and an indication of the capacity of the plant should be provided.

Effluent Treatment and Disposal

This section should provide;

- a description of the nature of waste discharged, including volume and composition;
- a description of the treatment of the wastes, including the design basis used to determine the size of the treatment process and the rationale for selecting the particular treatment process;
- a description of the composition of discharges at the final treatment stage;
- an outline of backup systems.

Site and Potential Pollution Management

Having described the waste treatment process, it is important to indicate approaches that will be adopted to reduce or prevent problems from arising. For example:

- effect of climatic factors on treatment and disposal method;
- procedures to be adopted in the event of plant or treatment system breakdown;
Guidelines

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

References

All references should be listed.

Appendices

Where detailed technical or supporting documentation is required, this should be placed in appendices.
W.M.C. NICKEL DIVISION

NICKEL REFINERY PROCESS

MINES

Kambalda, Windarra and Leinster

3% Nickel Ore includes Iron, Sulphur

12% Nickel Concentrate

CONCENTRATOR

KALGOORLIE SMELTER

Iron Slag

EXPORT

 Nickel Matte

70%

Ammonia

Water

Air

Cyanide

Nickel Metal

Ammonium Sulphate

Gold loaded Carbon to Kambalda

Barren residue to Kambalda

KWINANA REFINERY

FIGURE 1

DWG No. 2329-1
AMMONIUM SULPHATE CONCENTRATION FOR 1989

CONTOURS ARE FOR THE MAXIMUM AMMONIUM SULPHATE CONCENTRATION IN THE GROUNDWATER MEASURED IN GRAMMES PER LITRE.

SCALE 1 cm. = 200 metres
NORTH - SOUTH SECTION THROUGH PLUME
AT 7250E SHOWING CONCENTRATION OF AMMONIUM SULPHATE IN GRAMS PER LITRE

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:300

AUSTRALIAN GROUNDWATER CONSULTANTS
PTY LIMITED

VERTICAL NORTH-SOUTH SECTION THROUGH PLUME

Date July '90 Dwg. 2329-15 Fig. 4A
EAST-WEST SECTION THROUGH PLUME
AT 6750N SHOWING CONCENTRATION OF AMMONIUM SULPHATE IN GRAMS PER LITRE

SCALE HORIZONTAL 1:20000
VERTICAL 1:300
CONTAMINATED WATER RECOVERY

Weak Ammonium Sulphate

Let-down Valve

Feed in

High Pressure Pump

Semipermeable membrane

Permeate to Recycle

Concentrate to Ammonium Sulphate Plant

REVERSE OSMOSIS PLANT

Membranes

Recycle Water

Pond

Clean Water

Amm. Sulphate

Clay

Reverse Osmosis Plant

Recycle Steam

Ammonium Sulphate Crystal

RECOVERY SYSTEM

CURRENT GROUNDWATER RECOVERY AND TREATMENT SYSTEM

FIGURE 5
DWG No. 2329 - 4

AUSTRALIAN GROUNDWATER CONSULTANTS PTY LIMITED
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<td>GROUNDWATER RECOVERY</td>
<td>1400 KL / day</td>
<td>2000 KL / day</td>
<td>2550 KL / day</td>
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Proposed Recovery Bore
● Existing Monitoring Bore
○ Existing Recovery Bore
KWINANA NICKEL REFINERY
EFFLUENT MANAGEMENT SYSTEM

PLANT EFFLUENT → TAILINGS POND

SOLIDS BLEED TO EVAPORATION POND

FILTRATION FOR SOLIDS REMOVAL

LIQUOR

FILTERED LIQUOR → ION SELECTIVE REVERSE OSMOSIS PLANT

CONCENTRATE TO AMSUL PLANT

CALCIUM BLEED TO EVAPORATION POND

CONTAMINATED GROUNDWATER → HIGH CHLORIDES

CONCENTRATE TO EVAPORATION POND

PERMEATE TO REVERSE OSMOSIS POLISHING PLANT FOR REMOVAL OF CHLORIDES

CLEAN WATER FOR RE-USE IN REFINERY
TYPICAL SECTION THROUGH EXTERNAL BUND IN FILL

1mm THICK HDPE
HOPE DRAINAGE LAYER
SAND
LOCAL BORROW

TYPICAL SECTION THROUGH INTERNAL BUND

EXISTING SURFACE

TYPICAL SECTION THROUGH EXTERNAL BUND IN CUT
RAILWAY LINE

MILLAR ROAD

PIPELINE

TAILINGS POND

FRESHWATER PRODUCTION BORES

SHALLOW FRESHWATER INJECTION BORES

MANDURAH ROAD

LAKE COOLOONGUP (WHITE LAKE)

KEROSENE LANE

BALDIVIS TAILINGS POND FRESHWATER INJECTION FOR PROTECTION OF VEGETATION

PROPOSED LOCATION OF FRESHWATER INJECTION SYSTEM
DETAIL A

N.T.S. LAYERED COVER

RESHAPED TAILINGS

SAND

GEOTEXTILE FABRIC

PLASTIC LINING

TAILINGS RESIDUE

SAND

CLAY

REFERENCE DECEMBER 1975

FIGURE 12

DWG No. 2329-11

MOUND CONCEPT FOR TAILINGS POND REHABILITATION
TAILINGS GEOTEXTILE INJECTION (OVER CENTRAL WET AREA ONLY)

LAYERED COVER DETAIL (NTS)

HIGH WATER LEVEL
LOW WATER LEVEL

CROSS SECTION AT 426 7BOE

WETLAND CONCEPT FOR TAILINGS POND REHABILITATION