WORSLEY ALUMINA JOINT VENTURERS BODDINGTON GOLD MINE PROPOSAL

Report and Recommendations by the Environmental Protection Authority

Department of Conservation and Environment
Western Australia

Bulletin 219 October 1985

WORSLEY ALUMINA JOINT VENTURERS

BODDINGTON GOLD MINE PROPOSAL

ENVIRONMENTAL PROTECTION AUTHORITY REPORT AND RECOMMENDATIONS

DEPARTMENT OF CONSERVATION AND ENVIRONMENT

PERTH, WESTERN AUSTRALIA

BULLETIN NO. 219,

OCTOBER 1985

ISBN 0 7309 0610 8

CONTENTS

SUMMARY AND RECOMMENDATIONS

The Worsley Alumina Joint Venturers (JV) have proposed a gold/bauxite mining operation of up to 3 million tpa over at least 15 years. This would be within their Principal Mineralised Area in the north eastern Darling Range. The main features of the project are the mine, processing and, water supply reservoir, tailings dams and power supply. All are within the catchment of 34 Mile Brook, a tributary of the Hotham River. The 1 200 ha project would be predominantly on private land. However, some 90 ha of State Forest would be affected. 34 Mile Brook has been proposed by the Western Australian Water Authority as a public water supply source because of its low salinity.

The assessment report considers the information provided in the Environmental Review and Management Programme together with submissions from the public and Government Departments and further details provided by the JV. Issues discussed include flora and fauna, forest disease, residue disposal, salinity downstream water supply, rehabilitation, social effects and reporting. The main requirement of project environmental management will be the long term maintenance of the 34 Mile Brook Water quality.

The Authority concludes that sufficient information has been provided to decide that the proposal would be environmentally acceptable subject to the JV following the management commitments in their ERMP and subsequent submissions, and making a firm agreement with the State that they:

1 Report to the State the results of biological studies for the project area, making commitments to adjust project management to take these into account.

2 Establish a biological monitoring programme that is acceptable to the State prior to project commissioning. The results, in terms of changes from the baseline, and any consequent changes to management should be provided to the State for consideration and approval as necessary.

3 Include regular assessments of forest stress, including jarrah growth monitoring adjacent to the mine site, in the ongoing biological monitoring of the project area, with a commitment to change practices if disease spread unacceptable to the State is noted.

4 Use caustic soda in which mercury does not exceed 1000 ug/l and has a mean of 100 ug/l or less.

5 Provide the State with the results of studies of chemical decay, removal, or amelioration from the residues, specifically for cyanide, TSPP, caustic soda and sodium carbonate.

6 Provide the State with the results of the detailed design, geotechnical and hydrological investigations of the residue and water storage sites and monitoring/recovery borefields.

7 Take responsibility for clean up and rehabilitation of the stream system to the satisfaction of the State in the unlikely event of a dam failure.

8 Apply for and comply with the conditions of Waste/Effluent Disposal and Referable Dam Licences.

9 Provide the State with quantified estimates of the effects of clearing for the project and various rehabilitation alternatives on stream flow volumes and salinities at the inflow to the Water Supply Reservoir. This should include a review of the progressive interaction of mine pits with stream and groundwater flow and salt movement from commencement through to the cessation of mining.

10 Develop and carry out a surface and groundwater monitoring programme acceptable to the State, particularly in relation to residue disposal, water supply reservoir, mine and downstream areas.

This should include a discussion of the effectiveness of the various project and mining systems and any management changes for State approval.

11 Conduct progressive rehabilitation to a land use suitable for ensuring that the water quality of the Water Supply Reservoir is such that it would be a viable source for a public water supply at the completion of the project.

12 Undertake vegetation and topsoil salvage in all disturbed areas for subsequent rehabilitation.

13 Endeavour to design final rehabilitation mine face and waste dump slope angles of 10 to 15 degress.

14 Provide the State, for its agreement, with 10 year mining and rehabilitation plans, to be updated annually.

15 Carry out rehabilitation at the site of possible deep mining if no decision for such mining has been made at the cessation of lateritic ore extraction.

16 Provide details of the proposals to facilitate the level of environment assessment required for State approval prior to deep mining or extension of lateritic ore mining.

17 Take into account the aesthetic factors of noise and visibility in the Hotham River pump station design.

18 Provide the information required prior to commencement of the project in the form on an environmental management programme.

19 Prepare for State consideration brief annual and comprehensive triennial reports discussing the results of environment management and future plans.

1. BACKGROUND

1.1 BAUXITE MINING

The Worsley Alumina Joint Venturers (JV) commenced bauxite mining operations on leases within a defined Principal Mineralised Area near Boddington in the south-west of Western Australia in 1982, following Government approval of the project. Initial mining activities are confined to the Saddleback Timber Reserve and adjacent private land although there are plans to progressively mine the areas north east of Boddington. This mining has been approved subject to the JV following the Worsley Alumina project Environmental Review and Management Programme and subsequent Government requirements. The location is shown in Figure 1.

The potential for bauxite mining to increase stream salinity in the intermediate and low rainfall zones (less than 1 100 mm) and spread disease had been highlighted by 1978. During that year plans to further expand bauxite mining and alumina refining were submitted to Government by Alcoa and the JV. This lead to considerable public debate on the issue and an extensive environmental review of the proposal. As a result of this review process the need for joint State-Company planning of mining operations was highlighted and the need for broader based co-ordination of research programmes was recognised. In addition, Alcoa of Australia as part of its revised ERMP undertook to only mine in the higher rainfall zone until research showed that mining in the eastern portion of its lease would be without significant increases to stream salinity. A trial mining and rehabilitation research programme in Alcoa's intermediate rainfall zone is now being planned to evaluate its mining effects on stream salinity.

1.2 GOLD MINERALISATION

In the late 1970s significant gold values were discovered in the bauxite associated with the Saddleback Greenstone Belt. The JV were granted Mineral Claims over the area of interest within their Bauxite Lease 258SA in the northern section of the Principal Mineralised Area. Mining Leases are currently under review.

A pre-feasibility study which was completed in 1983 proved approximately 40 million tonnes of economic grade open-cut gold ore co-existing with the bauxite in a series of ore bodies south of Mount Wells. Additional reserves of ore exist on the adjacent

Alcoa lease area. The JV have indicated that these could be mined in conjunction with their ore extraction.

In early 1984 Reynolds Australia Mines Pty Ltd., on behalf of the JV, submitted a Notice of Intent to develop a gold recovery project within the Worsley Agreement Lease area north-west of Boddington. As the gold was associated with the bauxite reserves the JV proposed to develop the project under the Alumina Refinery (Worsley) Agreement. Upon consideration of the proposal, the Environmental Protection Authority advised that an Environmental Review and Management Programme (ERMP) should be prepared. In January 1985 the ERMP was submitted to the EPA and subsequently released for a public review period of 12 weeks. The review period closed on the 26 April 1985 and responses to the submissions were prepared by the JV. As a result of deficiencies in the ERMP and in the responses to submissions, the EPA requested a series of additional responses from the JV. The responses are provided in Appendix 1.

2. PROJECT DESCRIPTION

The JV have proposed a gold/bauxite operation of up to 3 million tpa within the Principal Mineralised Area of their Mining Lease 258SA, in an area approximately 12 km north-west of Boddington (see figure 2). It is proposed that associated gold and bauxite ores be mined and the gold ore processed on-site in operations lasting at least 15 years. The bauxitic and non bauxitic residues (tailings) will be stored until the JV's bauxite mining operation, currently centred in the Saddleback Timber Reserve, progresses to this area. They have envisaged that these bauxite mining operations would be in the vicinity of the Boddington Gold Mine in 20-25 years.

Of the total area of 1 200 ha to be directly affected by the project, the gold mining operations, progressing at an average rate of about 20 ha p.a. would affect a total area of approximately 600 ha. The operation would involve approximately 90 ha of State Forest. The rest is predominantly private land owned by Bunning Bros. The majority of the proven gold reserves lie within the weathered profile, within 10 metres of the natural surface, with limited areas extending down to 70-80 metres. The potential for mining mineralised basement rock is currently subject to investigation and four areas have been broadly defined. No detailed mining plans were made available for consideration by the Authority.

It is proposed that the gold processing plant using the Carbon-in-Pulp (CIP) technique, would be constructed on private land adjacent to the ore body. The proposed process water supply is via a reservoir (WSR) to be constructed on 34 Mile Brook, a tributary of Hotham River. The WSR would utilise 52 hectares of State Forest. In years of low rainfall the process water supply might need to be supplemented by pumping winter flow water from the Hotham River to the storage reservoir. Potable water would be obtained from bores on private property.

The power supply would be from the SEC Muja-Northern Terminal 132 kV transmission line. It would involve a 3 km route through State Forest.

Tailings from the gold-extraction process would be stored in two valleys on private property north of the plant site, within the catchment of the Water Supply Reservoir. Bauxitic tailings would ultimately provide feed for the Worsley Alumina Refinery.

Full development of the Boddington Gold Mine is estimated to cost $110 million (June 19, 1984), with an annual expenditure of $25-30 million on goods and services. The construction phase would provide 250-300 jobs, and about 220 jobs would be created during the operations phase.

3. EXISTING ENVIRONMENT & LAND USE

The proposed Boddington Gold Mine is located in the eastern forest of the Darling Range. The area is dissected by 34 Mile Brook, which flows intermittently into the Hotham River. The valleys associated with 34 Mile Brook and its tributaries are generally broad and relatively shallow.

The soils of the area vary from the coarse textured lateritic gravels of the upper slopes and ridges, gradually becoming finer downslope to the fine textured sandy yellow and grey earths of the broad valley floors. No information on erosion potential was provided for the project area.

The climate is typically Mediterranean with cool wet winters and hot dry summers. Approximately 80% of the 810 mm average rainfall is received between April and November. Pan evaporation is approximately 1710 mm per year. The JV provided no information on wind conditions or the occurrence of inversions.

The Boddington Gold Mine area has been characterised as Jarrah-Marri Forest with varying admixtures of Allocassuarina, Banksia and Persoonia on the slopes and ridges. A mosaic of wandoo woodlands, heaths and swamp complexes occur in valley systems associated with 34 Mile Brook.

Timber production is presently the primary land use on the private portion of land comprising 94% of the area of interest. The remaining 6% is currently State Forest.

Stream salinity is an issue of particular concern in the Darling Range. In the higher rainfall region (over 1 100 mm pa) little salt has accumulated in the landscape and consequently no serious salinity problem occurs when vegetation is disturbed. In the region below 900 mm pa there is less water available to flush salt from the soil profile, and large quantities of salt have accumulated.

Areas cleared for agriculture in the region below 900 mm pa have caused a major deterioration to the quality of water resources throughout the south west of Western Austrlaia. The mining proposal, for example, occurs within the water catchment of 34 Mile Brook, which maintains a high water quality in its forested section (eg mean TDS 569 ppm Nov 82 to Dec 84). This catchment forms part of the Murray River Basin.

The catchments of the Hotham and the Williams Rivers, whose confluence forms the Murray River, have been extensively cleared for agriculture resulting in relatively high stream salinity levels.

Downstream of the proposed mine, 34 Mile Brook flows through predominantly cleared private property, where it is utilised for stock watering during periods of flow, before joining the Hotham River. The mean TDS for the brook here is 4060 ppm over May 78 to August 85.

Streams throughout the region are used for a range of recreational activities, particularly fishing. Apiculture is also carried out in the area. Further to the south and east, agriculture is the predominant land use, grazing and cropping being the principal activities. The nearest residences to the proposed mine are 5 km to the north-east (Bunning Bros' House for timber workers) and south-east (farm houses).

A number of Conservation Reserves near the project have been recommended by the Authority in the System 6 Red Book, the closest to the proposed being the Duncan MPA north of Mt Wells. An amalgamation of Conservation and Land Management Department MPAs has been proposed as a Wandoo Reserve north of Albany Highway. These reserves would be outside the JV Principal Mineralised Area and the area of potential gold mineralisation.

Areas of forest stress due to disease occur scattered within the proposed project area. Concentrations occur in the 34 Mile Brook Valley both in the WSR area and north of the pit limits and processing plant. Within the State Forest, classified as a Disease Risk Area, forest stress occurs in isolated patches to the east of the SEC 132 kV power line. The State Forest is likely to be increasingly important for recreation and is being managed for protection of forest values.

More specific details of the existing environment and potential impacts of the proposed mining operations are described in Section 5.

4. PUBLIC AND GOVERNMENT SUBMISSIONS

Five public submissions and 13 responses from State and Commonwealth Government agencies were received during the public review period. A summary of respondents and issues raised is provided in Tables 1 and 2.

The predominant concerns were related to the effects of the operation on 34 Mile Brook particularly with regard to tailings (residue) disposal. Submissions stressed the need for detailed site investigations prior to approvals or consideration of alternative locations for the residue.

Submissions also commented on:

i) the lack of detailed biological and hydrological baseline information;

ii) effects of forest clearing including disease spread, stream salinity increases and agriculture disruption; and

iii) the social implications of the project.

The Joint Venturers have addressed the issues raised by the public and Government agencies in their submissions and by the Authority. Appendix 1 provides the JV replies.

Table 1. SUBMISSIONS SUMMARY

No. Of Submissions Commenting on Issue	Issue
3	State forest destruction, compensation.
7	34 Mile Brook. Salinity, chemical pollution, flow reduction.
2	Old Soldiers Road. Alternative access to forest, truncation of private land.
4	Rehabilitation. Face design, stability of open cut, area to be left open, vegetation and topsoil salvage from disturbed areas, consider details of vegetation for forest and pasture revegetation, rehabilitation of deep pits.
3	Forest disease. Treat adjacent forest to increase disease resistance, enrich dieback degraded areas, concern about spread of disease.
4	Fauna. Lack of baseline data, residue and pit effects.
2	Mine waste rock disposal. Location.
4	Air pollution including dust suppression. Water sources.
3	Cost benefit analysis.
5	Residue disposal. Alternative sites, dust generation, need detailed site investigations, consequences of leakage, wildlife effects, visual pollution.
2	Eastern jarrah forest conservation reserve.
3	Social Aspects. Development of community facilities, standard thresholds, recreational use of reservoir.
1	Hazardous chemicals risks.
1	Inspection. Regular inspections by the Department of Mines.
1	Blast noise. Consider use of Health Department exceedance guidelines. Monitoring.
1	Apiary sites.
1	Power line. Compensation.

Table 2 RESPONDENTS

GOVERNMENT DEPARTMENTS

Department of Agriculture

Department of Arts, Heritage and Environment (Commonwealth)

Department of Community Services

Department of Conservation and Land Management

Education Department

Health Department of Western Australia

Western Australian Herbarium

Department of Lands and Surveys

Department of Mines

Western Australian Museum

Public Works Department and Metropolitan Water Authority

State Energy Commission Western Australia

Department of Youth, Sport and Recreation

PUBLIC

Australian Conservation Foundation

Australian Conservation Foundation Western Chapter

S Edwards

J L Gibbs

Worsley Timber Pty Ltd

5. ENVIRONMENTAL IMPACT ASSESSMENT

A large project of this type raises numerous environmental concerns because of the diverse nature of the development and competing land uses. The EPA has examined the major environmental issues. The environmental provisions of the Agreement Act or conditions on the Mining Leases will have to ensure that there is adequate consideration of the wide range of environmental matters which a project of this type will require. The JV commitments to environmental management have been summarised in Appendix 2.

5.1 FLORA AND FAUNA

The project will result in direct impact by the mine, processing plant and services of 1160 ha with up to 92 ha in State Forest. The area of disturbance is predominantly owned by Bunning Bros.

The JV have undertaken to complete and publish a biological study programme to provide a quantitative baseline to assist in the assessment of project impacts and rehabilitation. Early results of the studies show that no unique or rare ecosystems or flora would be destroyed. However, some of the flora located in high impact areas has been poorly recorded in the region, particularly Boronia ovata and Hibbertia rhaphinodpoda. The conservation status of poorly recorded flora should be defined during the biological study and project management adjusted accordingly.

The Carpet Snake and Western Quoll, gazetted as rare or otherwise in need of special protection occur in the project area and are locally common in the north eastern parts of the Darling Range. Care should be taken to avoid disturbing their habitats.

Of the more limited environments that may be adversely affected, the swamp communities (eg Pillow Swamp) are particularly important. The JV should endeavour to preserve these habitats.

RECOMMENDATION

The Joint Venturers should report to the State the results of biological baseline studies for the project area, making commitments to adjust project management to take these into account.

Forest clearing will directly affect apiary sites in both the State Forest and Bunnings areas. The land managers will need to discuss project implications with apiarists.

The JV have undertaken to monitor bird use of the residue storage areas, reporting the results to the Department of Conservation and Land Management and where appropriate, taking action to deter or prevent wildlife access to these tailings dams. This is acceptable to the Authority. In addition the JV have proposed the establishment of a biological monitoring programme for the project site and downstream areas. This should be agreed to by the State prior to project commissioning. The JV showed report to the State the results of the biological study and their implications for management of the project.

RECOMMENDATION

The Joint Venturers should establish a biological monitoring programme that is acceptable to the State prior to project commissioning. The results, in terms of changes from the baseline, and any consequent changes to management should be provided to the State for consideration and approval as necessary.

The proposals for the WSR and power line have been accepted by the Department of Conservation and Land Management on the condition that the JV both slightly alter the location of the powerline easement and pay compensation to the State for the loss of forest values. These conditions have been accepted by the JV. As a result the Authority agrees with power line proposal.

The nature and scale of the proposed mining provide considerable potential for forest disease spread. Even the most conscientious application of hygiene may not fully eliminate this. However the JV have proposed following the Forest Improvement Rehabilitation Scheme (FIRS) treatments, as developed by the Department of Conservation and Land Management, that are a synthesis of current knowledge from all sources of dieback and rehabilitation research. The scheme aims at increasing the disease resistance of areas and enrichment of areas degraded by dieback.

The biological monitoring of the project area should include annual assessments of forest stress with a commitment to change practices if unacceptable disease spread is noted. As the FIRS approach is still under investigation, its effectiveness in relation to this mining operation should be ascertained by a programme of jarrah growth monitoring.

RECOMMENDATION

The Joint Venturers' ongoing biological monitoring of the project area should include regular assessment of forest stress, including jarrah growth monitoring adjacent to the minesite, with a commitment to change practices if disease spread unacceptable to the State is noted.

5.2 RESIDUE DISPOSAL

The Authority notes that the residue storage areas were located following an investigation of sites outside the WSR catchment. It is understood that other sites were discounted because of a lack of suitable terrains. The WSR is proposed to be downstream of these tailings dams.

The Western Australian Water Authority has stressed the future water supply potential of 34 Mile Brook and has indicated its desire in the long term to incorporate the Water Supply Reservoir (WSR) into its domestic water supply scheme. 34 Mile Brook is also in the catchment of the recreationally important Murray River. As a result of the water resource and environmental importance of the 34 Mile Brook it is considered important that its longterm water quality is not significantly impaired by the presence of the residue disposal areas.

At the point of discharge the residue slurries would contain 100 ppm cyanide, 1 500 ppm caustic soda and 300 ppm of the viscosity modifier tetra sodium pyrophosphate (TSPP).

Cyanide concentrations greater than 0.1 ppm HCN would kill sensitive fish species and there is extensive evidence that people can suffer various health disorders with cyanide exposure. However free cyanide occurs only rarely in nature because of its high reactivity. The JV have been undertaking testwork to determine the rate of cyanide decay in decant waters exposed to the atmosphere and in bodies of stored residue. In these tests, free cyanide commencing at 120 ppm had for waters, declined to 1 ppm within 2 weeks and for residue, declined to 40 ppm within 12 weeks. Laboratory studies of cyanide slurries from the Boddington Gold Mine ore have indicated that decay of cyanide complexes could provide a small continuing source of free cyanide, the ores generally containing less than 10 ppm of the complexing metals. The JV have undertaken to further investigate cyanide decay under conditions likely to prevail in the residue storage areas. As part of these studies, the cost of treating residue slurries for removal of cyanide or converting to stable compounds should be evaluated, as should disposal methods to enhance cyanide decay.

It is expected that dilution and natural decay accompanying any downstream movement would reduce the significance of any cyanide excursion. Preliminary calculations by the JV of the effects of the overtopping of the residue storage dams, designed for a 1 in 100 year 72 hour rainfall event show cyanide concentrations downstream of the WSR would be of the order of drinking water standards. As a result, detailed water balance calculations should be undertaken to assess if the 1 in 100 year 72 hour storm is a suitable design guideline. This work should review the overall storage requirements in the various structures in the knowledge of longterm hydrological studies.

Caustic soda in discharge slurries through elevation of soil and water pH could cause biological damage. On exposure to the atmosphere, it is converted to the less alkaline sodium carbonate. The residues are expected to have an initial soil pH of 8.5 which is at the extreme end of the range suitable for vegetable growing and does not suit plants native to the north eastern jarrah forest. To minimise the accumulation of mercury in the residue the JV should use low mercury caustic according to principles adopted by the alumina industry. The Authority notes that currently only low mercury caustic soda is used by the JV.

RECOMMENDATION

The Joint Venturers should use caustic soda in which mercury does not exceed 1000 ug/l and has a mean of 100 ug/l or less.

TSPP by natural degradation can produce phosphate which could lead to eutrophication of water bodies during periods of low stream flow. The JV have made a commitment to examining the extent of breakdown TSPP.

RECOMMENDATION

The JV should provide the State with the results of studies of chemical decay, removal or amelioration from the residues

specifically for cyanide, TSPP, caustic soda and sodium carbonate.

A range of measures have been proposed by the JV to avoid pollution due to spillages or leakage from the tailings system. To minimise risks of pollution from pipelines carrying slurries and decant water to and from residue storage areas, a drained corridor has been proposed with detention ponds to allow for salvage of contaminated waters. Also a network of monitoring/ recovery bores has been proposed to permit detection and interception of any groundwater pollution from the residue storages. The effectiveness of these bores should be shown by detailed geotechnical studies. Monitoring of the chemical quality of water upstream and downstream of the WSR has also been proposed. Detailed geotechnical and hydrological investigations are also proposed for the residue and water storage sites. These should include details of the geology, hydraulic conductivities of soils and rocks, and any preferred pathways or clay instability. The studies should describe any aquifers that would be affected by any leakage, the likely contaminant levels in these and ultimate consequences in terms of aquifer use or emergence of down flow seeps. Detailed water balance studies would be necessary including a review of the overall storage requirements of the various structures. The State would also need to be provided with sufficient data to ensure that the dam walls be engineered to a satisfactory standard.

RECOMMENDATION

The JV should proceed with the detailed design, geotechnical and hydrological investigations of the residue and water storage sites and monitoring/recovery borefields.

In procedural terms water management and dam construction should be regulated by both applying for a Waste/Effluent Disposal License and by following the anticipated Licensing and Control of Referable Dams provisions of the Rights in Water and Irrigation Act.

RECOMMENDATION

The JV should apply for and comply with the conditions of Waste/Effluent Disposal and Referable Dam Licenses.

Residue areas would be monitored for fugitive dust, although progressive peripheral discharge of residue should result in the residue being maintained in a moist condition so that wind erosion would be minimised. If problems do occur, the JV should follow the advice of appropriate Authorities.

The proponent have undertaken to carry out rehabilitation of affected areas if tailings pipeline spills occur. Further, if a tailings dam failure occurred they would notify downstream users and would monitor cyanide levels until they declined and safe values. It is considered by the Authority that in the unlikely event of a dam failure, the JV should take a responsibility for clean up and rehabilitation of the system.

RECOMMENDATION

In the event of a dam failure, the JV should take a responsibility for clean up and rehabilitation of the stream to the satisfaction of the State.

The Authority accepts the JV commitment to both modify the residue management system if unexpected problems occur and to take action if actual or potential risks to the environment, not adequately addressed in the ERMP eventuate, to the reasonable satisfaction of the State.

Although in general terms the residue disposal approach appears reasonable, there is a need for a completion of chemical decay studies and detailed geotechnical and water balance investigations to show that risks of pollution by the project to 34 Mile Brook are acceptable. The design construction and operation of the project should be such that at completion, any pollutants introduced to the stream from the residue areas would not exceed acceptable limits for potable water for public and environmental use. Design should consider remedial action to be taken if failure occurs in the system.

5.3 SALINITY

The project is proposed for the eastern forest zone of the north eastern Darling Range where rainfall is less than 900 mm pa and there is a high risk of stream salinity if the natural vegetation is disturbed. Extensive clearing for agriculture has increased the salinity of the downstream section of 34 Mile Brook. The zone from 900 to 1 100 mm rainfall pa has a variable hydrology with moderate levels of salt storage and the potential for increased salinity with vegetation disturbance.

Because of the variability and uncertainty associated with vegetation disruption in the 900 to 1 100 mm pa region and its critical importance to the current and future water supplies for Perth, Alcoa of Australia has agreed not to extend its mining operations eastwards into this rainfall zone until research indicates that it is safe to do so.

The JV's Mt Saddleback bauxite mining operation is taking place in the rainfall zone of less than 900 mm pa but is not seen as a threat to water resources. The area is surrounded by agricultural land and the rivers draining the area are already highly saline.

The 34 Mile Brook could be developed as a small water resource as it has been unaffected by downstream agricultural development. The Water Authority has considered the resource for development some time after the year 2000.

As only 10% of the catchment forest cover would be disturbed by the mining operation, the JV have said that the project would not be expected to cause a long term increase in the 34 Mile Brook salt load. However because of the high salt storages and low water yields of the region there is some concern that significant long term salinities could result, even with this low proportion of clearing, unless an active forest revegetation programme is followed. To support their expectation the JV, from published

Worsley Alumina Pty Ltd

Incorporated in the State of Western Australia

ACTING AS MANAGER OF A JOINT VENTURE OF PETROMIN AUSTRALIA ALUMINA LTD, THE SHELL COMPANY OF AUSTRALIA LTD, BHP MINERALS LIMITED AND KOBE ALUMINA ASSOCIATES (AUSTRALIA) LTD, REPRESENTING SEVERALLY IN THE PROPORTIONS OF 40%, 30%, 20% AND 10% RESPECTIVELY

Worsley Refinery, Worsley, Western Australia P.O. Box 344, Collie, Western Australia 6225

CDJ/DL

9 September 1985

Co-ordinator
Department Resources Development
SGIO Atrium
St George's Terrace
PERTH W.A. 6000

ATTENTION: Mr. Dean Giles

Dear Sir

BODDINGTON GOLD MINE ERMP

In our response to EPA questions dated 6 September 1985, we discussed hydrogeology of the BGM area in relation to design of the water and residue management systems (Section 3.0 of the submission: "Hydrogeological Aspects of Residue Disposal"). Paragraph 5 outlined the limited hydrogeological work carried out to date, and noted permeabilities and groundwater gradients.

We believe that it may be worth noting that this geotechnical work has been carried out at the site of the Water Supply Reservoir (WSR) dam, and is taken to be indicative of conditions expected to be encountered at the sites of residue storage dams. In particular, the work has delineated, as expected, a number of dolerite dykes, whose existence could, in the absence of appropriate engineering, have implications for seepage from the Reservoir.

We expect to find similar hydrogeological conditions at the sites of the residue storage dams, when geotechnical work is carried out in those areas after the JVs have committed to the project (as outlined in our 6 September submission). It is planned that geotechnical work at these sites will include a trench across the valley at or near the dam sites, allowing precise identification and mapping of the geology, particularly with respect to dykes. The delineation of such structures is considered critical to the siting of monitoring/recovery bores to provide an effective groundwater detection/diversion network downstream of the residue storage areas.

We trust that this information will assist in demonstrating the rigorous approach the JVs have instituted to planning of the BGM project in relation to protection of quality of downstream waters.

Please contact the undersigned should you require further information.

Yours faithfully
WORSLEY ALUMINA PTY LTD

DR C.D. JOHN
Environmental Management Co-ordinator

c.c: Director, Dept Conservation and Environment; Att: Mr W. Carr

Vegetation and topsoil salvage for use in rehabilitation works should be undertaken in all disturbed areas. This should include the residue storage and processing plant areas.

RECOMMENDATION

The JV should undertake vegetation and topsoil salvage in all disturbed areas for subsequent rehabilitation.

The face design and stability of the open cut and waste dump out slopes need to be considered both from a safety and future land use point of view. Slope angles of approximately 10^{o} to 15^{o} would be desirable to ensure safe, stable slopes with low erosion potential that would be suitable for recreational walking track development. The proponents have indicated their acceptance of Mines Department requirements in this regard. The Department of Conservation and Land Management has requested maximum slopes of 10^{o} in State Forest.

RECOMMENDATION

The JV should endeavour to design final rehabilitation mine face and waste dump slope angles of 10^{o} to 15^{o}.

The Joint Venturers have proposed that some areas of the mine pits will be left open for possible future hard rock mining. However if a decision has not been made on deep mining at the cessation of mining lateritic ore in these areas, rehabilitation should be carried out to the satisfaction of the State.

RECOMMENDATION

The JV should carry out rehabilitation at the site of possible deep mining if no decision for such mining has been made at the cessation of laterite ore extraction.

In order to assess the effectiveness of the proposed rehabilitation, the state should be provided with 10 year mining, and rehabilitation plans to be updated annually as proposed by the JV. Information should be provided on the flow of water from natural catchments, and progress of the mine and waste dumps. The discussion should include information on remedial action to be taken if a failure occurs in these systems. This should include details of silt control measures to be used during the various phases of the project.

RECOMMENDATION

The JV should provide the State, for its agreement with 10 year mining and rehabilitation plans to be updated annually.

5.6 FUTURE MINING PROPOSALS

Apart from the laterite, low grade gold mineralisation also occurs in both the weathered profile and in the basement rock. Further, the mineralisation extends into the Alcoa bauxite mining lease area. Prior to any decision to either undertake deep mining or to expand laterite ore mining outside the area described in the ERMP, details of the proposals should be provided to the State to facilitate the level of environmental assessment required.

RECOMMENDATION

The JV should provide the State with details of the proposals to facilitate the level of environmental assessment required approval prior to deep mining or extension of lateritic ore mining.

5.7 SOCIAL EFFECTS

A number of submissions commented on the social aspects of the proposal. As a result of community concerns, the Department of Resources Development has commissioned a social impact study to investigate the community effects of the proposal. The findings of this study will become a further input to Government in its decision making on the project.

Matters dealing with water supply, blasting and road construction are of particular note. The proposed Hotham R. pump station is adjacent to an old railway bridge with high recreation potential. As a result the pump station, if it is required for the project, should be designed with the aesthetic factors of noise and visibility in mind.

RECOMMENDATION

The JV should take into account the aesthetic factors of noise and visibility in the Hotham River pump station design.

Noise and vibration will result from blasting activity. However, Boddington is about 12 km away and the closest settlement is some 5 km distant. It is expected that only minor and infrequent disturbances would occur. The JV have proposed monitoring of the situation. They have also indicated that blasting will be deferred when weather conditions could lead to noise problems.

The JV may need to make specific arrangements with local land holders following the relocation of Old Soldiers Road.

5.8 REPORTING

In order that the wide range of detailed information required prior to commencement of mining is produced in a logical, coherent manner, it should be provided in the form of an environmental management programme. This would include the information required for licencing under the Rights in Water and Irrigation Act.

RECOMMENDATION

The JV should provide the information required prior to commencement of the project in the form of an environmental management programme.

As discussed in 5.5 the State should be provided with annually updated 10 year mining/rehabilation plans. In order that the progress of the environmental management of the project can be efficiently monitored, it is recommended that brief annual and comprehensive triennial reports are prepared for consideration by the State. The annual reports should provide a summary of

activities undertaken and plans for the next year, together with a discussion of any notable events. The triennial reports should provide a comprehensive discussion of the results of the environmental management programme and plans for the next triennium.It would be desirable for the reports to be based on the environmental management undertakings and Authority recommendations.

RECOMMENDATION

The JV should prepare for State consideration, brief annual and comprehensive triennial reports discussing the results of environmental management and future plans.

6. CONCLUSIONS AND RECOMMENDATIONS

In considering this proposal, the Authority considers that sufficient information was provided on flora and fauna, forest disease, residue disposal, salinity of the 34 Mile Brook catchment and rehabilitation to decide that the Boddington Gold Mine proposal would be environmentally acceptable subject to the Joint Venturers both following the management commitments in their ERMP and subsequent submissions and making a firm agreement with the State that they:

1 Report to the State the results of biological studies for the project area, making commitments to adjust project management to take these into account.

2 Establish a biological monitoring programme that is acceptable to the State prior to project commissioning. The results, in terms of changes from the baseline, to any consequent changes to management should be provided and the State for consideration and approval as necessary.

3 Include regular assessments of forest stress, including jarrah growth monitoring adjacent to the mine site, in the ongoing biological monitoring of the project area, with a commitment to change practices if disease spread unacceptable to the State is noted.

4 Use caustic soda in which mercury does not exceed 1000 ug/l and has a mean of 100 ug/l or less.

5 Provide the State with the results of studies of chemical decay, removal, or amelioration from the residues, specifically for cyanide, TSPP, caustic soda and sodium carbonate.

6 Provide the State the results of the detailed design, geotechnical and hydrological investigations of the residue and water storage sites and monitoring/recovery borefields.

7 Take responsibility for clean up and rehabilitation of the stream system to the satisfaction of the State in the unlikely event of a dam failure.

8 Apply for and comply with the conditions of Waste/Effluent Disposal and Referable Dam Licences.

9 Provide the State with quantified estimates of the effects of clearing for the project and various rehabilitation alternatives on stream flow volumes and salinities at the inflow to the Water Supply Reservoir. This should include a review of the progressive interaction of mine pits with stream and groundwater flow and salt movement from commencement through to the cessation of mining.

10 Developed carry out a surface and groundwater monitoring programme acceptable to the State, particularly in relation to residue disposal, water supply reservoir, mine and downstream areas.

the various project and mining systems and any management charges for State approval.

11 Conduct progressive rehabilitation to a land use suitable for ensuring that the water quality of the Water Supply Reservoir is such that it would be a viable source for public water supply at the completion of the project.

12 Undertake vegetation and topsoil salvage in all disturbed areas for subsequent rehabilitation.

13 Endeavour to design final rehabilitation mine face and waste dump slope angles of 10 to 15 degrees.

14 Provide the State, for its agreement, with 10 year mining and rehabilitation plans, to be updated annually.

15 Carry out rehabilitation at the site of possible deep mining if no decision for such mining has been made at the cessation of lateritic ore extraction.

16 Provide details of the proposals to facilitate the level of environmental assessment required for State approval prior to deep mining or extension of lateritic ore mining.

17 Take into account the aesthetic factors of noise and visibility in the Hotham River pump station design.

18 Provide the information required prior to commencement of the project in the form on an environmental management programme.

19 Prepare for State consideration brief annual and comprehensive triennial reports discussing the results of environment management and future plans.

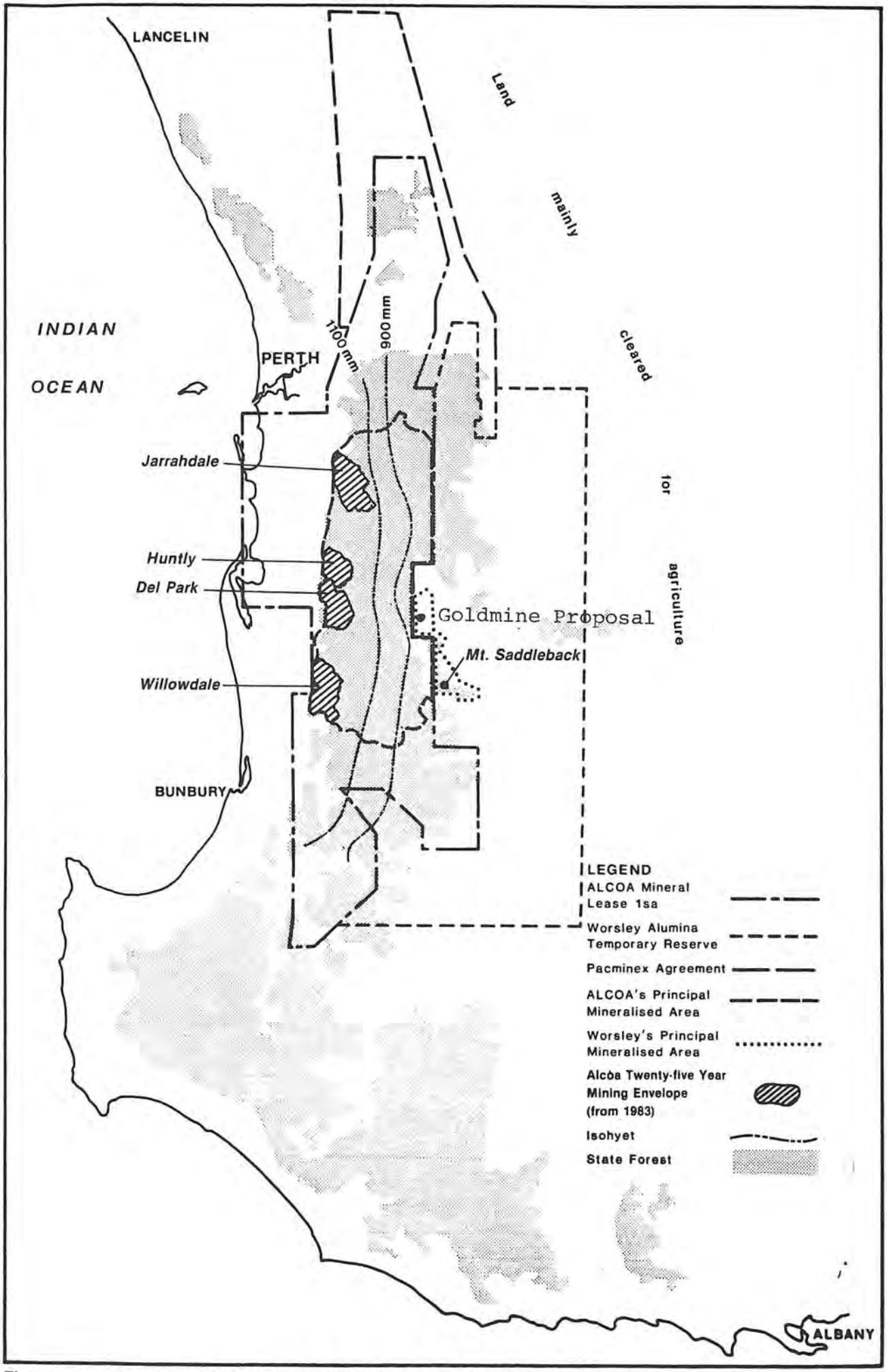
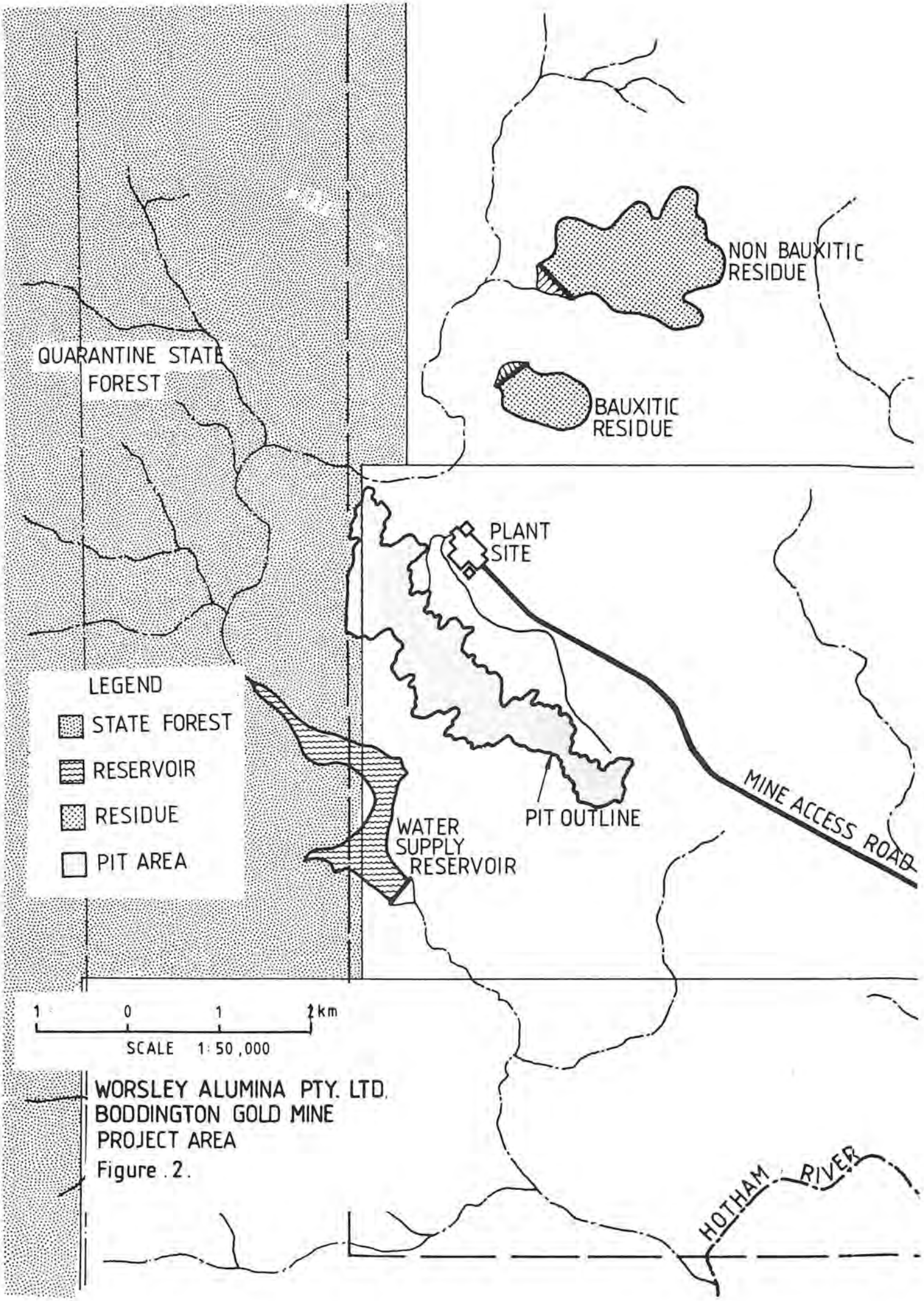


Figure 1. Mineral leases and minesites in south-west Western Australia



WORSLEY ALUMINA PTY. LTD.
BODDINGTON GOLD MINE
PROJECT AREA
Figure . 2.

APPENDIX 1

Worsley Alumina Joint Venturers' Replies

Worsley Alumina Pty Ltd.

Incorporated in the State of Western Australia

ACTING AS MANAGER OF A JOINT VENTURE OF BROKEN HILL AUSTRALIA ALUMINA PTY. LTD. THE SHELL COMPANY OF AUSTRALIA LTD. DAMPIER MINING CO. LTD. AND WORSLEY ALUMINA PTY. LTD. RESPECTIVELY

Worsley Refinery, Worsley, Western Australia P.O. Box 344, Collie, Western Australia 6225.

CDJ/AMF/1035

7 May 1985

The Chairman
Environmental Protection Authority
C/- Department of Conservation and Environment
BP House
1 Mount Street
PERTH W.A. 6000

Attention : Mr W. Carr

Dear Sir,

BODDINGTON GOLD MINE ERMP - RESPONSE TO PUBLIC SUBMISSIONS

As arranged with the Department of Conservation and Environment, the ERMP for the Boddington Gold Mine was advertised in early February, early March and early April in the following newspapers:

The West Australian
The South Western Times
The Collie Mail
The Narrogin Observor

Partly in response to these advertisments, 254 copies of the ERMP were distributed during the 12-week public comment period ending 26 April 1985.

Submissions made to the Director of the Department of Conservation and Environment have been made available to the Joint Venturers, and a response prepared.

In addition to the attached response, we would be pleased to discuss environmental aspects of the project with the Environmental Protection Authority, should such a meeting be considered desirable.

Please contact our Environmental Management Co-ordinator, Dr Chris John (097 348 311), for further information.

Yours faithfully,
WORSLEY ALUMINA PTY LTD

N.T. CHAPLIN
General Manager

c.c. Department of Resources Development (Mr D. Giles)

WORSLEY ALUMINA JOINT VENTURERS

BODDINGTON GOLD MINE ERMP

RESPONSE TO PUBLIC SUBMISSIONS

1. INTRODUCTION

This response has been prepared in consultation with the Department of Conservation and Environment, with whom submissions from the following parties have been reviewed:

Department of Conservation and Land Management

Department of Mines

Education Department

Public Works Department and Metropolitan Water Authority

Department of Agriculture

Department for Community Services

Department for Youth, Sport and Recreation

Health Department of Western Australia

Western Australian Herbarium

Western Australian Museum

Australian Conservation Foundation (Victoria)

Australian Conservation Foundation (Western Chapter)

Worsley Timber Pty Ltd

J.L. Gibbs, Boddington, W.A.

S. Edwards, Bedford, W.A.

Responses are made on subjects raised during the public review period, often by more than one party, rather than treating individual submissions.

During the public review period, discussions were also held with the Public Works Department and the Department of Conservation and Land Management, in relation to State Forest and water supply/quality impacts, respectively. Copies of correspondence resulting from those discussions are attached.

2. RESIDUE MANAGEMENT

2.1 Strategy

The over-riding principle in developing the residue management system for the Boddington Gold Mine has been the rational minimisation of risk of escape of potential pollutants to the broader environment.

It is considered that this risk minimisation is achievable because of:

(i) recycling of decant waters from residue storage areas back to the process;

(ii) the installation of a network of monitoring/recovery bores around residue areas to detect and divert improbable groundwater pollution.

(iii)) design of residue areas so that overtopping of dams would require rainfall events resulting in dilution of pollutants to concentrations of the order of those used as drinking water standards;

(iv) relatively high rates of natural decay of potential pollutants; and

(v) comparatively low concentrations of potential pollutants in process and residue streams.

2.2 Residue Area Location

It has been suggested that the quality of the water of the Water Supply Reservoir (WSR) could best be protected by location of residue storage areas outside of the catchment of the WSR on 34-Mile Brook. This option was investigated during the feasibility studies for the project, but was found not to be appropriate, largely because of a lack of suitable terrain in the immediate area of the BGM. The proposed residue management system involves the damming of existing relatively sharply-incised valleys: the construction and operation of dams in flatter terrain would require a much greater land area. Moreover, the monitoring and management of groundwaters around residue areas in flatter terrain would be difficult and expensive, compared with that required for residue storage involving single dam walls across valley mouths.

In view of the protection afforded to water quality by the proposed residue management system, it is considered that the advantages of locating the residue storage areas outside of the catchment of the WSR would not outweigh the attendant disadvantages.

2.3 Cyanide Decay

Industry experience has shown that free cyanide (HCN and CN^-) decays relatively quickly, the important factors influencing the rate of decay being temperature, turbidity of water (light) and pH. Laboratory tests on cyanidic slurries of the Boddington Gold Mine ores indicate decay rates of free cyanide measurable in days, or even hours under optimal conditions of light and aeration.

In terms of potential for pollution, complexes of cyanide with metals such as copper, nickel, cobalt, iron and zinc can present much greater problems. These complexes degrade at various rates to produce free cyanide, but the rates of degradation are very much slower than for free cyanide. Thus, the complexes can be regarded as a reservoir of free cyanide which can be progressively released.

Boddington Gold Mine ores generally contain less than 10 ppm of these metals. By industry standards, this represents a very low level of complexing metals, and thus a relatively unimportant source of cyanide persistence and potential pollution. Attachment 1 shows typical data for cyanide-complexing metals in 40% solids slurries from Boddington Gold Mine ores.

Testwork is currently in progress to investigate cyanide decay under conditions likely to prevail in the residue storage areas. The work involves regular sampling of decant (supernatant) water, and of entrained water at various depths, of residue contained in vertical columns. Total, free and complexed cyanide will be determined, and decay curves constructed. This data will facilitate detailed design of the residue management system.

2.4 Contingency Planning

To minimise risks of pollution from pipelines carrying slurries and decant waters to and from residue storage areas, it is proposed to locate the pipelines in a drained corridor. Spillages would be contained within the corridor, whose drainage will be constructed so that flows to appropriately-sized detention ponds will allow salvage of contaminated waters.

The network of monitoring/recovery bores around residue storage areas will permit detection and interception of improbable groundwater pollution. These bores will be concentrated downstream of dam walls, but will also be installed at other locations around the residue areas, as in the case of the established and operating system at the Worsley Alumina Refinery. Pumping capacities will be determined from "worst-case" scenarios developed from detailed geotechnical work to be carried out in the residue areas. In the highly unlikely event of contaminated groundwater by-passing the monitoring/recovery network, the comparatively non-persistent nature of the cyanide (free cyanide) should not constitute a long term pollution problem. Moreover, the dilution and natural decay which would accompany its downstream movement would further reduce the significance of such an event.

Overtopping of residue area dams, which are designed to contain a 1-in-100 year storm event, can be shown to result in cyanide concentrations of the order of those applied as drinking water standards (see Attachment 2). The residue areas will be surrounded by drains to divert overland flows from surrounding areas to the WSR, so that the catchments of residue areas will be restricted to their actual areas (approx. 270 ha).

3. WATER SUPPLY

In discussions with the Public Works Department (PWD) and the Department of Conservation and Land Management (CALM), the reasons for selection of the site of the WSR have been elucidated. Primarily, capital and operating costs at alternative sites have determined their unsuitability. It is noted that, subject to appropriate compensation, CALM accepts the proposed site on 34-Mile Brook.

With respect to the long term use of the WSR, the Joint Venturers recognise the State's desire to incorporate it into domestic water supply schemes. To the extent that the Joint Venturers would be able to facilitate such a use, they are disposed to. However, they point to the rights of Bunning Bros in this matter. Without prejudice to the rights of the Joint Venturers or other parties, no impediment is seen from the Joint Venturer's point of view to State use of the WSR when it is no longer of value to the Joint Venturers, and/or under terms which might be agreed between the State and the Joint Venturers.

The Boddington Gold Mine is located wholly within the Hotham River catchment, in the Murray River Water Reserve. It will not therefore involve disturbance of land within the catchments of existing water supply schemes.

With respect to water supply to the township of Boddington, the 1981 Agreement between the Joint Venturers and the State is considered to adequately address the expansion of the Boddington population that will follow development of the Boddington Gold Mine.

4. LAND USE IMPACTS

It is recognized that the area of State Forest impacted by the Boddington Gold Mine has the Management Priority of Recreation. It is also noted that the Boddington Gold Mine will have no foreseeable impact on Conservation or Scientific Management Priority Areas in the Northern Jarrah Forest.

With respect to State Forest impacts, it is noted that CALM accepts the proposed mining operation, modified power line route and Water Supply Reservoir location, conditional upon the State receiving compensation as provided by Clause 16(3) of the Alumina Refinery (Worsley) Agreement.

Impacts on downstream users of 34-Mile Brook are discussed in Section 7 in relation to stream salinity. It is noted here that no farm dams exist on the main water course, but are restricted to minor tributaries and cleared gullies: the seasonal stream (usually dry or not flowing from November through to April) is however used for random stock watering, particularly when farm dams either dry up or become too saline for consumption by stock.

5. FOREST DISEASE

In relation to the jarrah dieback disease, it is suggested that management of this disease on the Boddington Gold Mine project should be no less manageable than on other similar projects on forested areas. On the private property part of the project area, forest hygiene, based on "stress maps" produced by a forester and a botanist, has been practised for the past two years, and exploration of the "Quarantine Strip" between the Mining Lease and private property boundaries was carried out in the summer of 1983-84 under hygiene conditions developed with the Forests Department (now CALM).

The Joint Venturers undertake to carry out "enrichment" planting on areas of State Forest and, if appropriate, of private forest, where such planting adjacent to Boddington Gold Mine activities is likely to increase the disease resistance of the areas or enrich areas which have been degraded by dieback.

Drainage water from mine pits will generally be collected in sumps and pumped back to process. This action should minimise the risks of aggravating dieback spread downslope of pits by minimising the extent to which such downslope areas develop soil moisture regimes conducive to proliferation of the fungus.

6. FLORA & FAUNA IMPACTS

As stated in the ERMP, an extensive biological study programme has been established for the Boddington Gold Mine. The programme includes studies on vegetation and flora, vertebrate and invertebrate fauna, and aquatic biology. Publication of the report is currently scheduled for the end of the third quarter or early fourth quarter of 1985. In terms of methodology, the biological studies are modelled on, and are a geographical extension of, those recently reported on publicly as "Worsley Alumina Project - Flora and Fauna Studies, Phase Two". As with the Worsley Alumina Project studies, the Boddington Gold Mine studies are designed to provide a quantitative baseline against which project impacts and rehabilitation can be measured. Preliminary results of the Boddington Gold Mine work have recently been provided to the Department of Conservation and Environment, in the form of flora and fauna lists, a draft vegetation map and a "forest stress" map which is being used in forest hygiene measures.

With respect to the possibility of faunal, particularly waterfowl use of the residue storage areas, the Joint Venturers undertake to monitor and report to the appropriate authority (CALM), and to take appropriate practicable action to deter or prevent faunal access to the contaminated waters. In this context, it is noted that, at the Worsley Alumina Refinery, waterfowl tend to use the clean water of the Fresh Water Lake, rather than the Catchment Lake and Residue Disposal Area.

7. SALINITY

As evidenced by the results of existing clearing for agriculture downstream of the Boddington Gold Mine area, extensive clearing can significantly increase the salinity of 34-Mile Brook. However, the total area of disturbance over the life of the Boddington Gold Mine is projected at some 1200 hectares, which constitutes 13% of the catchment of the proposed Water Supply Reservoir, and about 10% of the total catchment of 34-Mile Brook. Based upon experiences elsewhere in the South-West, and considering the effects of existing clearing downstream of the Boddington Gold Mine, it is difficult to suggest that this clearing will cause deleterious or even perceptible long-term increases in the salt load of 34-Mile Brook.

As part of a regional water sampling programme, the Worsley Alumina Joint Venturers have regularly monitored stream quality at several points on 34-Mile Brook, some locations having been sampled since 1978. Attachment 3 (modified from Fig. 2 of the ERMP) shows the results of some of this monitoring : the effect on stream quality of the clearing for agriculture of private land to the south of the Boddington Gold Mine is pronounced. The waters of 34-Mile Brook in its lower reaches are still adequate for stock watering (7 000 - 10 000 ppm TDS is considered an upper limit, depending on species and condition), except in summer and early autumn, when the stream usually consists only of saline pools.

Thus, the continued value of 34-Mile Brook as a stock-water source is to some extent dependent on the maintenance of flows from the northern, forested part of the catchment, especially in summer and early autumn, when saline base-flows are probably the major contributor to stream flows on cleared land. In winter, these base-flows are likely to be less significant.

Even after construction of the Water Supply Reservoir, some forested catchment on Bunning Bros property would continue to supply comparatively high quality water to the lower reaches of 34-Mile Brook. The extent and impact of this supply is difficult to predict, particularly in terms of its effect on downstream water quality in summer and autumn. Nonetheless, the Joint Venturers are investigating the matter and will, if necessary, determine the efficacy and feasibility of releasing up to 50 megalitres of water from the Water Supply Reservoir in early summer and late autumn. That is, it may be appropriate to release compensation water at the start and end of what is the existing flow regime of the seasonal 34-Mile Brook, and thus maintain supplies of stock-water downstream of the Water Supply Reservoir.

8. MINING METHODS

Geotechnical work carried out to date will enable mine pits to be designed in accordance with industry and Mines Department safety standards. On-going liaison with the Mines Department will ensure appropriate mine pit safety and stability of faces.

Definite mine plans have yet to be finalised, making difficult any accurate projection of areas which might remain unvegetated until mining of deeper ores has been completed. Similarly, rehabilitation of deep pits is difficult to detail at this stage - the comments contained in the next section are probably appropriate.

9. REHABILITATION

As stated in the ERMP, mine pit rehabilitation strategies and prescriptions will be developed in consultation with CALM (State Forest) and Bunnings (private property). Clause 7 of the Alumina Refinery (Worsley) Agreement in relation to rehabilitation of private land (see page 22 of ERMP) provides for the State's involvement in planning rehabilitation on such land.

The Joint Venturers' experiences in rehabilitation will be of value in planning rehabilitation for the Boddington Gold Mine, together with the experiences from other mining operations in the South-west. The Joint Venturers have also noted the suggestion that rehabilitation should ideally attempt to re-establish vegetation in a structural sense as well as a floristic sense.

The ERMP originally proposed marginal auriferous ore stockpiles as well as non-auriferous bauxite ore stockpiles. Current planning removes the need for stockpiling most of the marginal ore, reducing the area to be disturbed and rehabilitated. In this context, it is planned, where practicable, to directly replace fresh overburden and topsoil from areas being developed for mining onto mined-out areas being prepared for re-vegetation. With [redacted] in general, areas cleared for all project activities will, where practicable and appropriate, have topsoil removed and either stockpiled or directly placed on current rehabilitation areas.

With respect to residue rehabilitation, it is proposed that appropriate contouring and drainage will prevent the rise of contaminated waters during the phase of re-establishment of vegetation. This contouring and drainage should prevent excessive recharge of the residue by rainfall. Moreover, it is considered that the method of residue deposition and the effluxion of time will render harmless most of the potential pollutants entrained in the residue after decant: the rate at which this decay will take place should be determined from the cyanide decay tests described in section 2.3 above.

10. ACCESS IN THE BODDINGTON GOLD MINE AREA

With respect to the effects of closure of the western part of Old Soldier's Road, the Joint Venturers intend to provide CALM and local Bush Fire Brigades with alternative access routes in the area. The details of these alternatives have yet to be confirmed, but are likely to involve vehicular movement through the plant site and mine area. The closure of Old Soldiers' Road will be discussed with the appropriate authorities, including the Boddington Shire Council.

The proposed re-alignment of eastern parts of Old Soldiers' Road will be discussed with affected land-owners. Reasonable steps will be taken on an individual basis to minimise, if not prevent, permanent disturbance to farming activities.

11. DUST SUPPRESSION

It is planned that mine-site dust suppression be effected by use of mine drainage water or water from the Water Supply Reservoir. Water containing levels of contaminants likely to cause environmental or health risks damage will not be used for this purpose.

Residue areas will be monitored for fugitive dust. Given the progressive peripheral discharge of residue proposed for the Boddington Gold Mine, it is considered unlikely that areas of residue will become dry, and thus wind-erodible, for long periods. However, should problems develop, the advice of appropriate authorities would be sought.

12. NOISE

As stated in the ERMP (page 74), the closest human habitation to the Boddington Gold Mine is some 5km from areas of primary activity. The township of Boddington is about 12km away. Thus, project activites, even mine-blasting, are unlikely to cause physical discomfort or damage, except perhaps under the most unfavourable atmospheric conditions. The effect of blasting should be little different from that currently experienced from the existing Saddleback bauxite mine, which is also about 12km from Boddington township - only minor and infrequent disturbances have been reported as a result of Saddleback operations.

13. SOCIAL IMPACTS

In comparison with other areas in which some of the mine workforce may have been located, the Boddington area will probably provide a most amenable environment. Its and the region's physical attractiveness and infrastructure, plus the relative proximity to the Perth Metropolitan Area and the coast, should represent a positive influence on recruitment and workforce stability. For that proportion of the workforce which elects to live in and commute from the Metropolitan Area, the attractiveness of that situation is self-evident.

With respect to housing, the Joint Ventures will probably make available a housing assistance scheme, as already operates for Worsley Alumina employees. This scheme facilitates home ownership, but places no restriction on place of residence; in the case of Boddington it provides for buy back.

ATTACHMENT 1

CYANIDE-COMPLEXING METALS IN 48-HR PREGNANT SOLUTIONS OF BODDINGTON GOLD MINE ORES (40% SOLIDS)

ORE TYPE	CONCENTRATION (ppm) (mean and standard deviation)			
	Zn	Co	Fe	Cu
Bauxitic	0.8± 0.3	0.09± 0.01	3.7± 1.8	2.1± 0.2
Non-bauxitic	3.8± 2.2	0.14± 0.02	1.4± 0.8	7.1± 0.3

ATTACHMENT 2

EFFECTS OF EXTREME RAINFALL EVENTS OVERTOPPING RESIDUE STORAGE DAMS

Assumptions

1. Flood retention capacity is 1-in-100, 72 rainfall hour event, = 150 mm rainfall.

2. Residue area contains 20 ML (megalitres) water at 50 ppm cyanide at time of flood.

3. Catchment of storage areas is only their actual areas (270 ha).

4. Catchment of Water Supply Reservoir (WSR) = 90 km^2.

5. Capacity of WSR = 4500 ML.

Calculations

1. 150 mm rainfall over 270 ha = 405 ML; therefore cyanide concentration in residue area =

$$\frac{20}{405} \times 50 = 2.47 \text{ ppm}$$

2. Assuming this 425 ML reached the WSR, cyanide concentration would be

$$\frac{425}{4500} \times 2.47 = 0.23 \text{ ppm}$$

3. 150mm rainfall over 90 km^2 (catchment of WSR) = 1.35×10^4 ML. Thus, cyanide would be further diluted, to

$$\frac{4500}{1.35 \times 10^4} \times 0.23 = 0.08 \text{ ppm (cf. drinking water standard 0.05 ppm)}$$

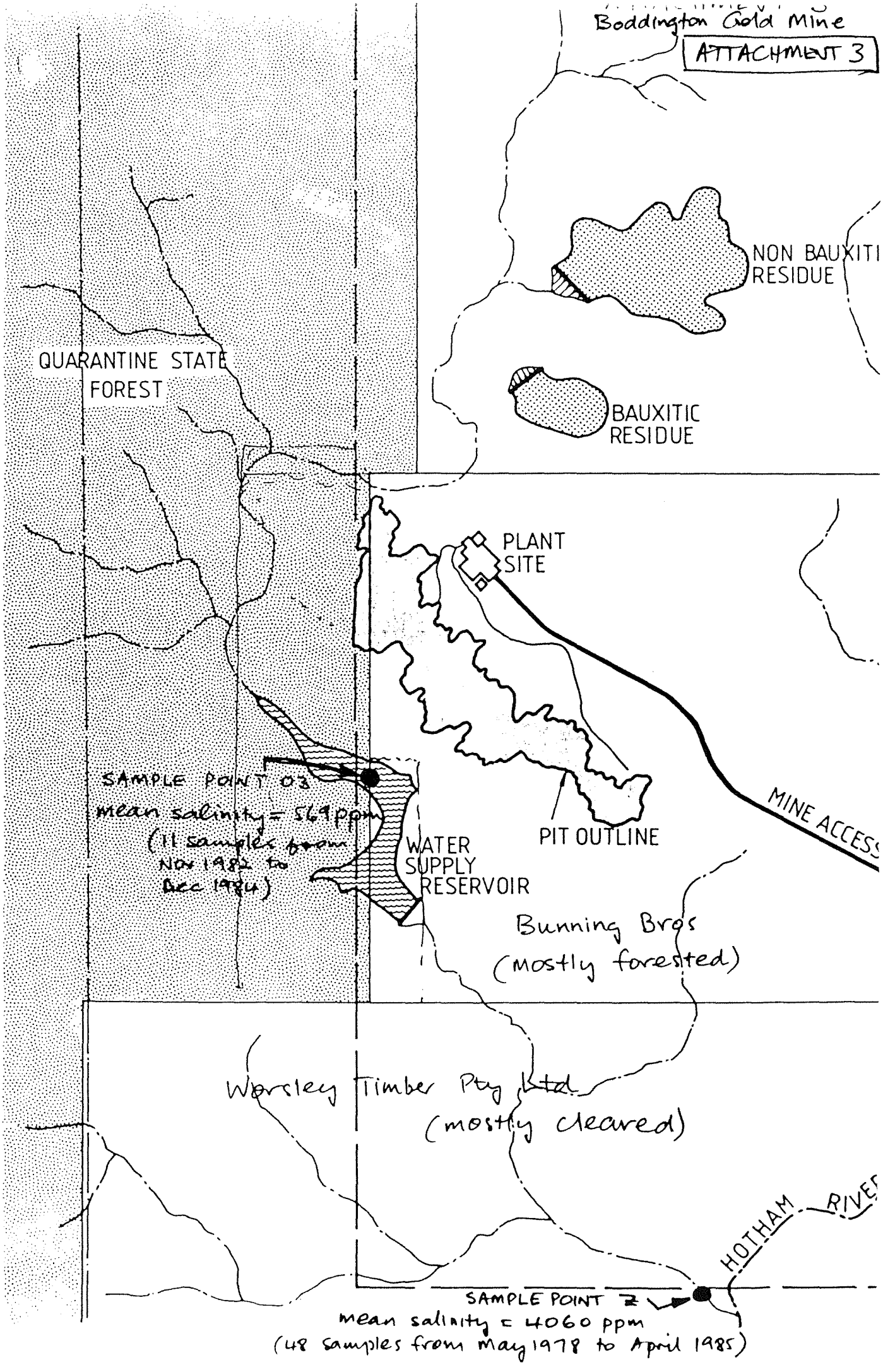
Comments

1. For simplicity, these calculations are based on a static event - in reality, the dynamic nature of such a flood event could produce different results at various points in time. Nonetheless, the calculations do indicate the order of magnitude of cyanide concentration likely to result from such a flood event.

2. The calculations assume that all cyanidic decant water would be removed from the residue areas by a 1-in-100 year flood. In fact, the data used actually relate to filling of the residue areas by rainfall: the greater rainfall required to actually overtop the dams and flush out all the cyanide would therefore reduce cyanide concentrations even further.

3. The effects of cyanide decay on ultimate cyanide concentrations have not been considered in these calculations.

1068a


Boddington Gold Mine
ATTACHMENT 3
NON BAUXITI
RESIDUE
BAUXITIC
RESIDUE
QUARANTINE STATE
FOREST
PLANT
SITE
SAMPLE POINT 03
mean salinity = 569ppm
(11 samples from
Nov 1982 to
Dec 1984)
WATER
SUPPLY
RESERVOIR
PIT OUTLINE
MINE ACCESS
Bunning Bros
(mostly forested)
Worsley Timber Pty Ltd
(mostly cleared)
HOTHAM RIVER
SAMPLE POINT 2
mean salinity = 4060 ppm
(48 samples from May 1978 to April 1985)

Worsley Alumina Pty. Ltd.

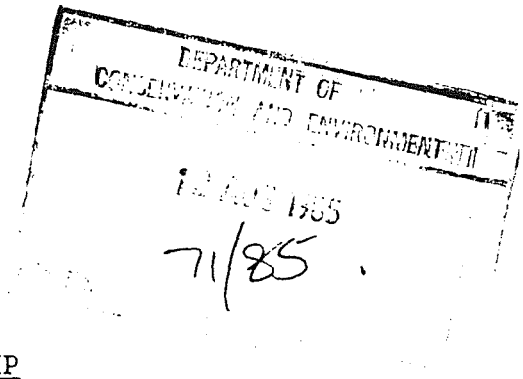
Incorporated in the State of Western Australia

Worsley Refinery, Worsley, Western Australia P.O. Box 344, Collie, Western Australia 6225

CDJ/AMF/1115a

12 July 1985

The Chairman
Environmental Protection Authority
Department of Conservation and Environment
BP House
1 Mount Street
PERTH W.A. 6000



Attention: Mr W. Carr

Dear Sir,

BODDINGTON GOLD MINE ERMP

On 28 May 1985, we received through the Department of Resources Development a copy of questions raised by the EPA in relation to the ERMP for the Boddington Gold Mine. On behalf of the Worsley Alumina Joint Venturers, we are pleased to now provide a response to those questions (see attached).

In responding to the questions raised, we have built on the discussion and commitments of the ERMP as submitted in January 1985 and our May 1985 response to public comments.

With particular regard to risks of cyanide excursion, we re-iterate our view that the residue management and monitoring strategies outlined already make decidedly small the risks of significant pollution. Nonetheless, with the emphasis of the Authority's questions being on containment of cyanide, we have initiated a study programme aimed specifically at minimising cyanide levels in residues and understanding the mechanisms of cyanide decay in those residues. This work will take several more months to complete, but preliminary results indicate that residues might contain cyanide levels significantly lower than the 100 ppm referred to in our January 1985 ERMP submission - this would even further lower the risk of significant excursion of cyanide from residue storage areas. While it is too early to commit unequivocally to a specific cyanide level in residue (other than the 100 ppm already mentioned), we have raised the possibility now because of the importance attached to this aspect of the environmental assessment of the project.

table at next meeting of EPA ←
CDJ
14/8/85

Please contact the undersigned or Dr Chris John (097 348 556) should you require further information.

Yours faithfully,
WORSLEY ALUMINA PTY LTD

N.T. CHAPLIN
General Manager

c.c. Co-ordinator, Department of Resources Development
(Attention: Mr Dean Giles)

WORSLEY ALUMINA JOINT VENTURERS

BODDINGTON GOLD MINE ERMP

RESPONSE TO COMMENTS BY THE ENVIRONMENTAL PROTECTION AUTHORITY

July 1985

INTRODUCTION

Following the EPA meeting of 16 May 1985, a number of comments on the Boddington Gold Mine were transmitted to Worsley Alumina Pty Ltd through the Department of Resources Development and the Department of Conservation and Environment. Responses to the matters raised are largely an elaboration of the description and commitments contained in the January 1985 ERMP and 7 May 1985 response to public comments. To facilitate their reading, the responses are presented in the same sequence contained in the EPA document received from the Department of Resources Development, and the EPA questions are reproduced at the start of each response.

RESPONSES TO EPA COMMENTS

1. *How long will it be before the area is mined for bauxite? Is it longer than 20 years, and what likelihood is there for a need to assume that waste will never be processed into alumina?*

   Based on current planning for development of the Worsley Joint Venturers' bauxite-mining operations within the Principal Mineralised Area (PMA) of Mining Lease 258 SA (for bauxite), the operations now centred on the Saddleback Timber Reserve, south of Boddington, will progress north through Crown land and onto private land. The bauxite-mining operation would then be in the area of the Boddington Gold Mine in 20-25 years.

   Within the Joint Venturers' ML 258 SA, bauxite reserves are considered to be only marginally adequate to support the authorised capacity of the Worsley Alumina Refinery - 63 years at 2 million tonnes per annum. For this reason alone, the Joint Venturers are keen to ensure that the operation of the BGM does not involve sterilization of significant bauxite reserves.

2. *What are the rehabilitation plans, both interim and long term, for the slime dumps?*

   Rehabilitation of residue areas was discussed in both the ERMP and the 7 May response to public comments. The following material represents a summary of and extension to those earlier comments and commitments.

   For both bauxitic and non-bauxitic residues, rehabilitation will commence when the areas are filled. It is likely that filling of both areas will not occur until the end of the ore-processing life of the project.

For both types of residue, the storage areas will not protrude above the sides of the valleys in which they are located. From a broad aesthetics point of view, therefore, the impact of the areas will be minimised.

Decant of process liquor from the residues will leave material containing comparatively small levels of caustic soda, cyanide and tetrasodium pyrophosphate (TSPP), at a pH projected to be 9-10. Natural decay of caustic soda to sodium carbonate will lower the pH even further. Similarly, decay of cyanide will reduce the potential for this compound to inhibit subsequent plant growth. TSPP is not regarded as a problem in this context, since it degrades to release phosphate, a plant nutrient.

Once residue has dried through evaporation to an extent sufficient to permit vehicular access, rehabilitation will commence. For bauxitic residue, the rehabilitation will be aimed primarily at providing erosion protection, rather than a long-term land use, since the material is suitable as feed for alumina production. The non-bauxitic residue will be rehabilitated to suit long-term land use.

As the residue areas are located on private property, the agreement between the Joint Venturers and Bunning Bros will, at least in part, provide the machinery for determination of rehabilitation strategies and prescriptions. Moreover, the Worsley Agreement provides a mechanism for State approval of rehabilitation plans for private property.

The details of rehabilitation prescriptions have not been determined, primarily because these activities are probably at least 10-15 years into the future, by which time technology and experience in the mining industry could make obsolete plans developed at this time. The Joint Venturers plan to carry out both small (pot) and large (field) trials to characterise soil properties of the residues and screen plant species suitable for rehabilitation programmes on residue areas. Nonetheless, existing knowledge would permit effective and appropriate rehabilitation for these areas, along the following lines.

- contouring and earthworks to provide drainage and erosion control
- topsoiling, to enhance seedling establishment and nutrition
- soil amelioration (e.g. with gypsum) as appropriate
- planting of tree seedlings as appropriate (dependent on discussions with Bunning Bros and the State)
- seed and fertilizer broadcasting as appropriate (see comment immediately above)

Ultimately, it is aimed to visually blend the residue storage areas into their immediate surrounds.

3. *A seven-way test is necessary for entry into quantitative* (sic. - read "quarantine") *forest. This has been done, and would be tactfully wise to specifically state that this has been done.*

   Prior to ERMP submission, discussions were held with CALM (then the Forests Department) in relation to Boddington Gold Mine impacts on Quarantine State Forest. Subsequently, a letter was received from the Forests Department (dated 25 February 1985 - a copy was attached to our 7 May 1985 response to the EPA on public submissions to the ERMP). In that letter, the Forests Department noted that 7-way tests have been applied to both the proposed mining in the narrow (160 m-wide) strip of quarantine forest between the private property and mining lease boundaries, and the powerline corridor connecting the BGM to the SECWA Muja-Northern Terminal 132 kV transmission line. The Forests Department also noted that they would prefer that the Water Supply reservoir (WSR) be located off State Forest; however, their formal submission on the ERMP accepted the location of the WSR partly on State Forest, subject to the State's receiving compensation for loss of forest values. In the ERMP, the Joint Venturers have already proposed that all clearing of State Forest be compensated for under the terms of the Worsley Agreement.

4. *A commitment not to blast on days of adverse weather conditions, and to remain within State laws for noise impact would make this a non issue.*

   Blasting at the BGM will be carried out in accordance with the Mines Regulations Act and the Noise Abatement Act. Moreover, and as stated in the January 1985 ERMP, the frequency and level of blasting, particularly in view of the distance of the BGM from sites of human habitation, make it unlikely that blasting noise will constitute a significant problem.

   Nonetheless, the Joint Venturers will defer blasting in those instances where weather conditions are determined to be such that noise nuisance would result.

5. *What is the reaction between caustic soda and slimes? What problems will there be with caustic material bound to reactive silica, and will this be a problem for long term management?*

6. *Same as above but for cyanide and TSPP*

7. *A quantitative assessment, rather than a statement that it would be okay, is necessary. It is also important that a commitment is given that the problems, if any, will be the responsibility of the proponent.*

   At the ambient temperatures and pressures at which the Boddington Gold Mine gold-extraction process will operate, reaction between caustic soda and silica in the ore is expected to be virtually nil, and thus insignificant in terms of formation of substances capable of binding hydroxyl ions

which might subsequently be released to the broader environment. Moreover, the concentrations of caustic soda employed are much lower than those used in the Bayer Process for alumina extraction, where such substances are produced. Similary, no reactions with cyanide or TSPP are considered likely.

Should unforeseen problems develop in this regard, the Joint Venturers would of course assume responsibility for their address and solution.

8. *A commitment to use low mercury caustic soda.*

It is intended that the level of mercury in caustic soda used in the BGM process will be no higher than that in caustic soda currently produced in Australia.

The matter of caustic soda import duties, in relation to Australian production and demand, is currently being addressed by the Australian Industries Assistance Commission. The source of caustic soda for the Boddington Gold Mine is therefore difficult to predict unequivocally. Nonetheless, the technology of caustic soda production is such that the above commitment can be made with a high degree of surety.

9. *A description of ground water hydrology, and how it relates to effectiveness of both monitoring bores and extraction bores for the purpose of pollution control.*

In general terms, the geotechnical and hydrogeological work carried out on the BGM area to date indicates that the groundwater hydrology of the area is typical of the Darling Range. More detailed work is scheduled prior to final design of the water and residue management system.

With regard to the monitoring and recovery bores proposed for the BGM around residue storage areas, their effectiveness in pollution control should be similar to that of the monitoring/recovery bore network around the Worsley Alumina Refinery. The detailed geotechnical and hydrogeological work to be undertaken in the future will determine the precise nature of ground water hydrology around BGM residue areas, and thus facilitate optimum design of the detection/recovery systems.

10. *What commitments if there is ground water contamination or stream contamination?*

In view of the comparatively low levels of potential pollutants in residues, the natural decay of those pollutants (particularly cyanide), the relatively low permeabilities of the clay profile beneath residue areas, and the provision of a monitoring/recovery bore network around residue areas, it is believed that significant groundwater pollution is highly improbable. However, should a significant malfunction or excursion occur, action can quickly be taken to extend the bore network and thus contain and remedy the problem.

In this context, it should be noted that contaminated groundwater which eluded the bore network would be diluted by uncontaminated flows from within the same catchment. Moreover, this dilution effect would increase as water moved downslope and into streams. Precise estimates of concentration at different points in this pathway are difficult to make, but it should also be noted that cyanide in BGM residues, since it is predominantly free cyanide, does not constitute a persistent potential pollutant. Decay test-work currently in progress should provide relatively precise prediction of cyanide decay rates in residues in situ, half-lives under laboratory conditions already having been measured in days, and even hours. Cyanide decay in the subsoil would be further enhanced by the low pH's of the clays of the area (pH 4-5): low pH facilitates cyanide loss through volatilisation.

11. *What commitments or contingencies in the unlikely event of extreme failure of (say) tailings dams?*

The residue area dams will be built to water-retaining standards, with appropriate allowance for seismicity. Their mechanical failure is therefore considered to be extremely improbable.

If their failure were considered likely to result from liquefaction after a storm event, it can be demonstrated that downstream concentrations of pollutant would be of the order of those employed as drinking water standards. For example, Attachment 2 to our 7 May 1985 response to public comment on the BGM ERMP addressed overtopping of residue storage dams following a 1-in-100 year, 72-hour rainfall event : it was shown that the final concentration of cyanide in the WSR would be slightly above the World Health Organisation potable water standard of 0.05ppm.

It can perhaps be argued that this calculation is overly-optimistic because it assumes dilution of cyanide by all of the rainfall falling on the catchment of the WSR in a 1-in-100 72-hour storm event. Since such an event, which would produce a stream-flow some three times the capacity of the WSR, would result in WSR overflow via the spillway to 34-Mile Brook, the extent to which the flows might dilute cyanide from residue areas would depend upon the timing of any loss of cyanide from the residue areas. If half of the catchment-wide flow were available to dilute cyanide from overtopped residue areas, the resultant concentration of cyanide in the 34-Mile Brook system would be 0.15 ppm (cf. 0.08 ppm as per Calculation 3 in submission 7 May 1985).

It should also be noted that any under-estimate of risks of cyanide pollution are couteracted by the factors commented on in Attachment 2 of our 7 May 1985 submission, viz:

(i) cyanide decay during and after a storm event has not been included in the calculations, but would further lower final levels of cyanide

which, because of the low levels of cyanide-complexing metals in BGM ore, cannot be regarded as a persistent pollutant (preliminary data from cyanide decay work shows half-lives of cyanide in agitated slurries and thin layers of residue measurable in hours); and

(ii) the calculations assumed that all cyanide decant water would be released from residue areas after a storm event, whereas a 1-in-100, 72-hour storm event would actually only fill the storage areas - further dilution of cyanide would result from the extra rainfall required to overtop the dams.

12. *What interactions with other projects or potential projects in the area. Has the only useable water supply been taken for exclusive use. It is appropriate to have written agreements on water rights with down stream users?*

With respect to project water supply, it is envisaged that, in the process of obtaining permission to divert waters and licences to construct and operate the WSR, downstream users' requirements would be assessed and catered for in discussion with both the users and the Water Authority. Indeed, Section 7 of our 7 May 1985 response to public comments noted that the Joint Venturers are investigating the feasibility and likely efficiency of compensatory release of waters from the WSR in early summer and late autumn, when such release can be expected to maximally assist in maintaining stock-watering supplies to downstream users. Should it be necessary to supplement the WSR with water from the Hotham River, the relatively small contribution of this source, together with the fact that low-salinity winter flows would be pumped to the WSR, should ensure that compensatory releases to downstream users would be of an acceptable standard.

In terms of alternative or competing uses of the WSR, the Joint Venturers have, in the 7 May response, noted in general terms their acceptance of possible ultimate use of the facility by the State.

13. *A commitment on the percolate from residue areas both during the operation phase and post operation.*

During the operational phase of the project, decant (percolate) from residue areas will be pumped back to process via the Process Water Pond, located within the plant complex.

In the decommissioning phase, decant will be pumped back over drying residue in a closed circuit, for evaporation and facilitation of pollutant decay. The Process Water Pond can similarly be employed to evaporate waters containing significant levels of potential pollutants.

14. *A description of the salt profile would remove perception of mining in salt risk areas.*

Twenty-nine holes have been drilled for salinity studies in the BGM area. The holes are located along five transects designed to sample the range of landforms over the mineralised area. All holes were drilled to bedrock, an average depth of 39.6 m.

Reverse circulation drill samples were taken over one-metre intervals, pulverised, and pH, electrical conductivity (EC) and chloride determinations made on 1:5 soil:water extracts. Total soluble salts (TSS) were calculated from EC data using the relationships published by the Public Works Department (Water Resources Branch Report No. W.R.B. 49, 1983). Soil salt storages were then calculated according to the methods currently employed by the PWD and CSIRO.

Soil salinities in the BGM area have thus been calculated at 1.62 ± 0.62 kg m^{-3}, about the level which would be predicted on the basis of rainfall (cf. PWD, Water Resources Technical Report No. 94, 1980). In terms of vertical distribution of salt, both of the typical "monotonically-increasing" and "bulge" profiles are present, the latter type being more common, although variable in the form and size of "bulge".

The impacts of the BGM on stream salinity were discussed in Section 7 of the 7 May 1985 response by the Joint Venturers to public comments on the ERMP. In summary, it was suggested that, because the total area of disturbance in the 34-Mile Brook catchment over the life of the BGM is estimated to be about 10% of that catchment area, deleterious or even perhaps perceptible long-term increases in the salt load of 34-Mile Brook are unlikely.

15. *A quantitative water balance of the area and process, and a description of how it changes with years of mining, would allow greater confidence in the perception that potential pollutants can be contained.*

A detailed description of the water balance of the BGM area and process is difficult to condense into a small number of pages, but has been summarised in the January 1985 ERMP and in the 7 May 1985 response to public comments. The work carried out to date during project feasibility studies occupies more than a single volume. Moreover, it is envisaged that water management, particularly as it relates to water quality protection, will be the subject of detailed scrutiny during the procedures to be followed for licencing of the water and residue management system by the appropriate water authority.

In the briefest terms, water quality protection is afforded by:

(i) the monitoring/recovery bore network;

(ii) the flood-retention capacities of the residue storage dams; and

(iii) the design of those dams to water retention standards.

16. *What contingency plans for pollutant management if mine is to shut down temporarily or permanently through unforeseen circumstances, such as dips in the price of gold?*

Most simply, water and residue management during temporary shutdown would proceed as described in response 13 above for the decommissioning phase of the BGM project: the Joint Venturers are committed to continue to monitor and manage the water/residue system until it is decided, in consultation with the State, that such activity is no longer required.

BODDINGTON GOLD MINE

RESPONSE TO EPA QUESTIONS OF AUGUST 1985

1.0 REHABILITATION OF RESIDUES

1.1 Chemical Content of Residues

Cyanide decay test-work has been in progress for several months, with the aim of characterising decay both in decant waters exposed to the atmosphere and in bodies of stored residues. In decant waters, half-lives of cyanide have been measured in hours, at most a few days; in bulk residue, cyanide decays exponentially for the first few weeks, followed by linear decay at the rate of approximately 20% per month (see Fig. 1). In both cases, in excess of 95% of the total cyanide present is in the form of free cyanide (HCN/CN^-), and thus easily degradable by natural mechanisms (microbiological activity, photo-oxidation); of the remaining 5%, less than half is in the form of the acid-labile iron-cyanide - the majority is in the form of other metal-cyanide complexes totalling less than 5ppm (cyanide).

Cyanide is therefore unlikely to pose a problem in re-vegetation of residue areas. Indeed, cyanide at up to 200ppm in soil can constitute a source of nitrogenous fertilizer (W.H. Fuller: Cyanide in the Environment, with Particular Attention to the Soil).

Sodium oxide (caustic soda and sodium carbonate) levels in residues are expected to give initial soil pHs of the order of 8.5. Such pHs, while not ideal for plant growth, are not high enough to prevent establishment of vegetation, which will itself, through the acidifying action of humic substances from decaying plant material, further lower the pH towards neutrality. During the establishment of vegetation, it may be necessary to treat the residue surface with gypsum to replace sodium on the clays with calcium - such treatment is common for alkaline soils with high exchangeable sodium values, and the Joint Venturers will undertake the appropriate testwork, at both a pot-trial and larger scale level, once typical residues from the process are being produced.

The extent of breakdown of TSPP to form phosphate will be examined as part of a test programme scheduled for 1986, after commitment to the project. At this stage, it is considered likely that phosphates so produced would be tightly adsorbed by the clay minerals contained in the residue. This adsorption is a characteristic of the soils of the Darling Range, unlike the sandy soils of the Swan Coastal Plain, where fertilizer-sourced phosphates have caused eutrophification of water bodies - no such result is expected in the Boddington Gold Mine area, even if liquor were to escape from the residue storage areas.

1.2 Timing of Rehabilitation of Residues

Once deposition in a residue area has permanently ceased, it is expected that vehicular access to that area will be possible after one dry season (November to April). Rehabilitation can then commence (see 1.4 below).

1.3 Residue Rehabilitation and Salinity (see also Section 6.2)

Since the residue management system is based on containment of water flows, both surface and underground, over the whole residue storage area, the operation of the residue areas as planned would remove the risk of saline flows from these areas to the 34-Mile Brook during the period of active deposition and the subsequent period of settling, decantation and evaporation.

Following re-vegetation of residue areas, some surface and near-surface flows from the areas could contain relatively high levels of sodium, particularly if gypsum treatment were employed to ameliorate the soil properties of the residues. These effects would be transient, resulting only in episodic saline flows to 34-Mile Brook. It would also be possible to divert these flows past the Water Supply Reservoir, should such action be desirable. Precise levels of salinity are difficult, if not impossible, to predict but, given that the residue areas represent less than 0.3% of the total catchment area of the Water Supply Reservoir (268 hectares out of 9000 hectares) and an even smaller proportion of the total catchment area of 34-Mile Brook, significant contributions to salinity of this stream appear highly improbable.

The type of vegetation established on the residues will to some extent influence the potential for saline flows from the residue areas. Any vegetation will reduce this potential, with tree establishment being more effective than pasture or other shallow-rooted crops. The Joint Venturers are committed to ensuring the long-term quality of water in the Water Supply Reservoir and should it be determined that residue area rehabilitation requires, for reasons of salinity control, the establishment of vegetation with high evapotranspirative demand (trees) rather than low water-use crops or pastures, the Joint Venturers will, within the framework of their agreement with Bunning Bros, the land-owner, facilitate the appropriate re-vegetation programme or modification of existing programmes.

1.4 Rehabilitation Prescriptions

While it is likely that advances in rehabilitation technology will take place before the residue areas become available for rehabilitation, existing knowledge would permit the effective vegetation of these areas. The key elements of a rehabilitation prescription could include:

(i) surface earthwork treatments to enhance visual aesthetic impacts and to control water flows and erosion - e.g. scarifying on contour, and forming bunds to direct overland flows;

(ii) soil amelioration with gypsum to enhance soil physical properties;

(iii) deep ripping to facilitate moisture penetration and root development;

(iv) topsoiling with previously salvaged materials;

(v) establishment of short-term cover crops to increase organic matter contents - leguminous crops would also enhance the nitrogen status of the soil so developed;

(vi) planting of tree seedlings and sowing of shrub species;

(vii) establishment of pastures, either as a cover crop or a semi-permanent land use.

(viii) vegetation management aimed at increasing soil organic matter levels (eg. green manuring), and water and salinity management (thinning, burning).

1.5 Dust Control in Residue Areas

Should fugitive dust prove to be a problem in residue storage areas, the Joint Venturers will, in consultation with the relevant authorities, apply the most cost-effective techniques to control dusting. Of the techniques likely to be available, a previous submission noted increased surface roughness (through ploughing and/or scarifying) as a possible approach. Additionally, topsoiling and/or treatment with dust-suppressants would be investigated.

1.6 Rehabilitation of Bauxitic Residue Area

As stated in a previous submission, bauxitic residues will be rehabilitated on a temporary basis, as these residues are suitable as feed for the Worsley Alumina Refinery. After removal of the residues for this purpose, the area would be rehabilitated along the lines discussed above (Section 1.4).

2.0 MERCURY CONTENT OF CAUSTIC SODA

Caustic soda is manufactured by two methods: the chlor-alkali process, which produces low-mercury caustic; and the mercury-cell process, which produces caustic of comparatively high mercury content.

For their current alumina-refining activities, the Joint Venturers use low-mercury caustic soda produced outside of Australia, whose relatively small caustic soda production involves the mercury-cell process. The Joint Venturers plan to use imported, low-mercury caustic soda for the Boddington Gold Mine process; only if they are forced by Australian law or regulation to use Australian-produced caustic soda would there be any possibility of use of "high mercury" material.

3.0 HYDROGEOLOGICAL ASPECTS OF RESIDUE DISPOSAL

The hydrogeology of the Boddington Gold Project site is broadly similar to that of the Worsley Alumina Refinery, where monitoring of groundwater levels, conductivity and chemistry has been in progress for over five years.

At the Worsley Alumina Refinery site, sixty bores are observed; these are located around the catchment perimeter and downstream of the storages of residue and contaminated liquor. Despite the presence of numerous faults and dolerite intrusions into the silty clay overburden (the result of weathering of the Archean granite), the groundwater flow appears to reflect the surface topography throughout the area. Apart from permeable layers in the pisolitic laterite cover, no zones of high permeability were found in the numerous permeability tests and grout injection observations for the foundation grouting of the Refinery Catchment Lake and Pipehead Dams; these holes were spaced four metres apart.

Groundwater recharge at the Worsley Alumina Refinery is predominantly into the elevated parts of the catchment, with discharges at the valley floors. There is some differentiation of water levels and chemistry for adjacent bores into bedrock and in overburden, suggesting the aquifer in rock is semi-confined by the low-permeability weathered clays above.

The permeability decreases with depth, typically being 10^{-6}m/s, and the gradient is typically 10-20m/km, so that the groundwater velocity is estimated to be in the range of 0.2 - 2.0m/day. Monitoring at monthly or quarterly intervals is therefore adequate for timely detection of any movement of contaminated water and establishment of remedial measures. These have not been necessary to date, as no movement of contaminated liquor from the various storages has been detected.

At the Boddington Gold Mine site, only limited hydrogeological work has been completed to date, but this has confirmed the general similiarity to the situation at the Worsley Alumina Refinery. Permeability generally decreases with depth, and is generally less than 10^{-5}m/s (0.86m/day). It is not confirmed that a continuous aquifer exists in the overburden, as water levels in several of the monitor bores show no seasonal variation. The valley gradient at the site of the proposed residue storage areas is about 10m/km, at the low end of the range found at the Worsley Alumina Refinery, so that the groundwater velocity should be even less.

Pump tests to date on various bores drilled for potable water have generally shown insignificant yields, the best yields being of the order of $100m^3$/day. Thus the rate at which contaminated liquor is likely to enter an aquifer is limited, and only modest power would be needed to remove such water (using a number of closely-spaced bores) if detected.

There is therefore every confidence that:

(1) a modest network of monitor bores will be adequate to allow timely detection of any movement of contaminated water;

(2) the permeability is so low that a major groundwater flow in unlikely;

(3) the sub-surface flow reflects the surface topography.

The detailed geotechnical work required to determine optimum bore locations and dam construction details will be commenced within six months of the Joint Venturers committing to development of the Boddington Gold Mine.

4.0 ACTION FOLLOWING GROUNDWATER OR STREAM CONTAMINATION

The systems proposed for residue management at the Boddington Gold Mine are conceptually designed to preclude excursion of contaminated groundwater from the region of the residue storage areas, the critical component being the network of monitoring/recovery bores around the areas, particularly downstream.

In the improbable event that this system fails to detect and/or contain a polluted groundwater flow, the bore network can relatively quickly be intensified so that the excursion is contained and diverted back to the process.

In the even more improbable event that the bore network were still by-passed, the amounts and concentrations of caustic soda and TSPP involved are unlikely to cause significant damage to stream ecosystems. Residues will be deposited at pHs less than 8.5, so that excursion of contaminated water from the residue areas to the nearby streams, while such excursion might, even allowing for dilution by uncontaminated waters, increase the pH of the streams, would not result in breach of the World Health Organisation drinking water pH standard of 6.5 - 8.5. At the low levels of TSPP which would be present in streams following such a pollution event, no toxicity would be apparent: TSPP is commonly used in the baking industry as a leavening acid, and in soap and cleaning agent manufacture - the potential for eutrophication of water bodies by phosphates from TSPP-breakdown are discussed above in Section 1.1.

5.0 RESIDUE EXCURSION MANAGEMENT

5.1 Residue Pipeline Failure Management

The residue pipeline will be located within a corridor drained so that, in the event of failure of the pipeline, residue slurries should not escape from the corridor: they will either drain to the Process Water Pond or the residue storage areas or, should topography require it, to intermediate sumps sized to contain the maximum flows likely to be experienced from a pipeline failure, allowing for time taken to detect such a failure.

While a pipeline failure would "contaminate" the pipeline corridor, no risk is seen to the broader environment. Natural decay of cyanide, and the lack of toxic effects from the low levels of caustic soda and TSPP involved (see Sections 1.1 and 3.0) make decidedly small the risk of a persistent "contamination".

In the improbable event that an excursion extended beyond the pipeline corridor, the volume of material involved would be small, as the Joint Venturers are committed to a twice per 8-hour shift patrol of the corridor: the volumetric capacity of the corridor drainage system will ensure that only the most improbable set of circumstances could result in excursion of residue slurry from the pipeline corridor. Nonetheless, should such an excursion occur, the Joint Venturers would remove contaminated material from affected areas and carry out appropriate rehabilitation work.

5.2 Risks and Effects of Residue Dam Failure

The standards to be applied to the engineering of the residue dams far exceed those normally applied to tailings dams. The earth-fill residue storage dams are planned to be constructed to water-retaining standards: the risks of failure are therefore similar to those pertaining to the Serpentine Dam in the Western Darling Range. Moreover, the Joint Venturers understand that dam engineering, and the residue-management system as a whole, will be subject to detailed review by the W.A. Water Authority as part of licensing procedures under the Rights in Water and Irrigation Act.

In the most improbable event that the larger non-bauxitic residue dam were to fail, some 32 million tonnes (approximately 20 million cubic metres) of residue would theoretically be exposed. It is unlikely that more than 20% (4 million cubic metres) of this would "slump" downstream, where the Water Supply Reservoir would serve as an effective trap. The volumetric capacity of the Water Supply Reservoir is 4.5 million cubic metres, not allowing for the 5 - 6 kilometres of the 34-Mile Brook valley between the Water Supply Reservoir and the residue storage area upstream. It is therefore likely that the solid material released by a catastrophic failure of the largest residue dam would be easily contained by the Water Supply Reservoir.

With regard to the chemicals entrained in the residue, such a catastrophic event could result in contaminated water overtopping the Water Supply Reservoir dam, depending on the pre-existing level of the Water Supply Reservoir, the time of the year, and the extent of the dam failure. However, as discussed above and in previous submissions, the low persistence and/or toxicity of these chemicals are such that a long-term and broad-range problem is unlikely to be generated, particularly in view of the dilution which such an event would involve.

In response to a catastrophe of this type, the Joint Venturers would of course immediately cease production. Indeed, such a catastrophe would likely terminate the project, emphasising the intentions of the Joint Venturers to prevent its occurrence. Of greatest concern under these catastrophic circumstances would be cyanide levels in the Water Supply Reservoir but, as previously discussed, cyanide from the Boddington Gold Mine decays at a predictable rate, and is thus not a persistent problem. Downstream users would be notified, and the Joint Venturers would accept responsibility for downstream monitoring until any elevated cyanide levels had declined to safe values.

6. SOIL SALINITY AND SALINITY MANAGEMENT

6.1 Soil Salinity

As noted in previous submissions, the Joint Venturers have carried out a preliminary soil salt storage study in the area of the Boddington Gold Mine, involving the drilling of 29 holes which were sampled at 1-metre intervals for salt determination. The average soil salinity has been calculated, according to the methodology used by Government instrumentalities, to be 1.62 + 0.62 kg/m^3 to basement; this level of soil salt storage is similar to that which would be predicted on the basis of rainfall (see Public Works Department of W.A., Water Resources Technical Report No. 49; April 1980). A consolidated report has not been produced, but typical examples of the "bulge" and "monotonically-increasing" profiles are presented in Tables 1 and 2, respectively.

6.2 Clearing and Stream Salinity

Concern has been expressed at the possibility of clearing for Boddington Gold Mine activities causing significant elevations of the salinity of 34-Mile Brook. The Joint Venturers have searched the literature to support the somewhat subjective view that clearing less than 10% of the catchment would not produce such an effect, but no directly-applicable information has been found. Nonetheless, it is considered that salinity of 34-Mile Brook will be substantially unaltered by Boddington Gold Mine activities - the basis for this view is described below.

The catchment area of the Water Supply Reservoir is some 9000 hectares, with the Boddington Gold Mine located in the eastern half of this area: approximately 50% of the catchment is in Quarantine State Forest to the west of the Boddington Gold Mine area. Over the past two winters, the Joint Venturers have monitored rainfall on an east-west axis across this catchment, and have preliminary evidence that rainfall is higher in the west than in the east. The variation on the 8km east-west axis does not appear to be large in absolute terms, but it should be noted that only small variations in rainfall on catchments in this part of the Darling Range can produce proportionate much larger changes in stream flows - i.e. the catchments can be considered as "sponges" which, once saturated, produce quite large ephemeral stream flows for only relatively small increases in rainfall.

Moreover, the Joint Venturers have monitored stream flows in the Boddington Gold Mine area at two locations (see Fig. 2): the upstream gauging point (1) has a catchment of 3000 hectares and the downstream point (2) 9000 hecatres. Gauging Point 2 was only established in 1985, but observations during the winter of 1985 have shown flows at Point 2 to be 4.2 - 12.8 times those at Point 1, despite the catchment area for Point 2 being only 3 times that for Point 1.

A likely explanation for these observations is that the western half of the total catchment yields more water than the eastern half. This view is supported by the above-mentioned higher rainfall in the western half, and by the observation that there are decidedly more and larger tributaries of 34-Mile Brook on the western half, compared with the eastern half of the catchment (i.e. the stream density is significantly greater in the west than in the east). It can therefore be argued that stream flows from the "BGM-half" of the catchment of 34-Mile Brook are significantly less than would be estimated on a relative area basis. Using the above data on stream flows, it can be conservatively estimated that the "BGM-half" of the catchment, while occupying 50% of the catchment area of 34-Mile Brook, produces only 25% of the flow at Gauging Point 2 (the site of the Water Supply Reservoir). It follows that 75% of flows to the Water Supply Reservoir are provided from the Quarantine State Forest area to the west of the Boddington Gold Mine - these areas will not be disturbed by Boddington Gold Mine activities, and will therefore continue to yield low-salinity water to 34-Mile Brook.

With respect to areas cleared for BGM activities in the eastern half of this catchment, the figure of 1200 hectares has in previous submissions been quoted as the total area to be impacted. It must be recognised that not all of this area, when cleared, will potentially contribute to saline water flows: the following comments are relevant.

(i) The 100 hectare (maximum) plant site area will consist largely of sealed or compacted and drained areas - infiltration of rainfall, and consequent elution of salt from the soils below, will therefore be very small, and perhaps negligible.

(ii) Stream salinity in relation to the residue storage areas (268 ha) has been discussed in section 1.3 above - again, this "clearing" cannot be likened to clearing for agriculture in terms of potential for increased stream salinity.

(iii) The power line corridor clearing (21 hectares, maximally 40 metres wide), by its very "ribbon-like" nature is unlikely to have a pronounced effect on infiltration and salinisation of stream flows.

(iv) The Hotham River Pump Station and pipeline (9 hectares) will be at least partly located on cleared land and outside the catchment of the Water Supply Reservoir. Where the pipeline traverses forested land, its potential impact on stream salinity will be the same as that for the power line corridor.

(v) Mine pits are therefore the area of greatest potential impact on stream salinity. However, it should be noted that:

(a) a considerable amount of soil salt will be removed with the ore and sequestered in the residue areas;

(b) to facilitate equipment access to pits, surface and sub-surface flows in pits will be diverted, collected and pumped back to the process - it is likely that pit-dewatering will actually lower surrounding water tables; and

(c) pits will be progressively rehabilitated - the whole area will not be open at a single point in time.

These considerations markedly reduce the superficially-perceived potential for mine-pit activities to cause elevated stream salinities. Moreover, the ERMP-quoted figure of 600 hectares for mining is a maximum figure derived from the Joint Venturers' Agreement with Bunning Bros; the actual area currently scheduled for progressive clearing for mine-pits and attendant facilities (haul roads etc.) is approximately 300 hectares.

In light of the above facts, the figure of 1200 hectares cannot be used to predict effects of clearing on stream salinity. Indeed, in the context of salinity, a figure of 300-400 hectares is considered more appropriate. This area is 3.3-4.4% of the total area of the catchment of the Water Supply Reservoir. When one considers to likelihood that 75% of the flows to the Water Supply Reservoir come from the western half of the catchment (as discussed above), and that this latter half of the catchment will be unaffected by Boddington Gold Mine activities, it is difficult to regard the Boddington Gold Mine as potentially causing significant increases in the salinity of the 34-Mile Brook and the Water Supply Reservoir.

7.0 PROJECT WATER BALANCE

Fig. 3 is a preliminary water balance for an average year, for a plant operating at a capacity of three million tonnes per annum. It shows that water needs to be imported to the plant from the 34-Mile Brook Water Supply Dam even in winter months, so that excessive rainfall on the residue storage areas can be accommodated by:

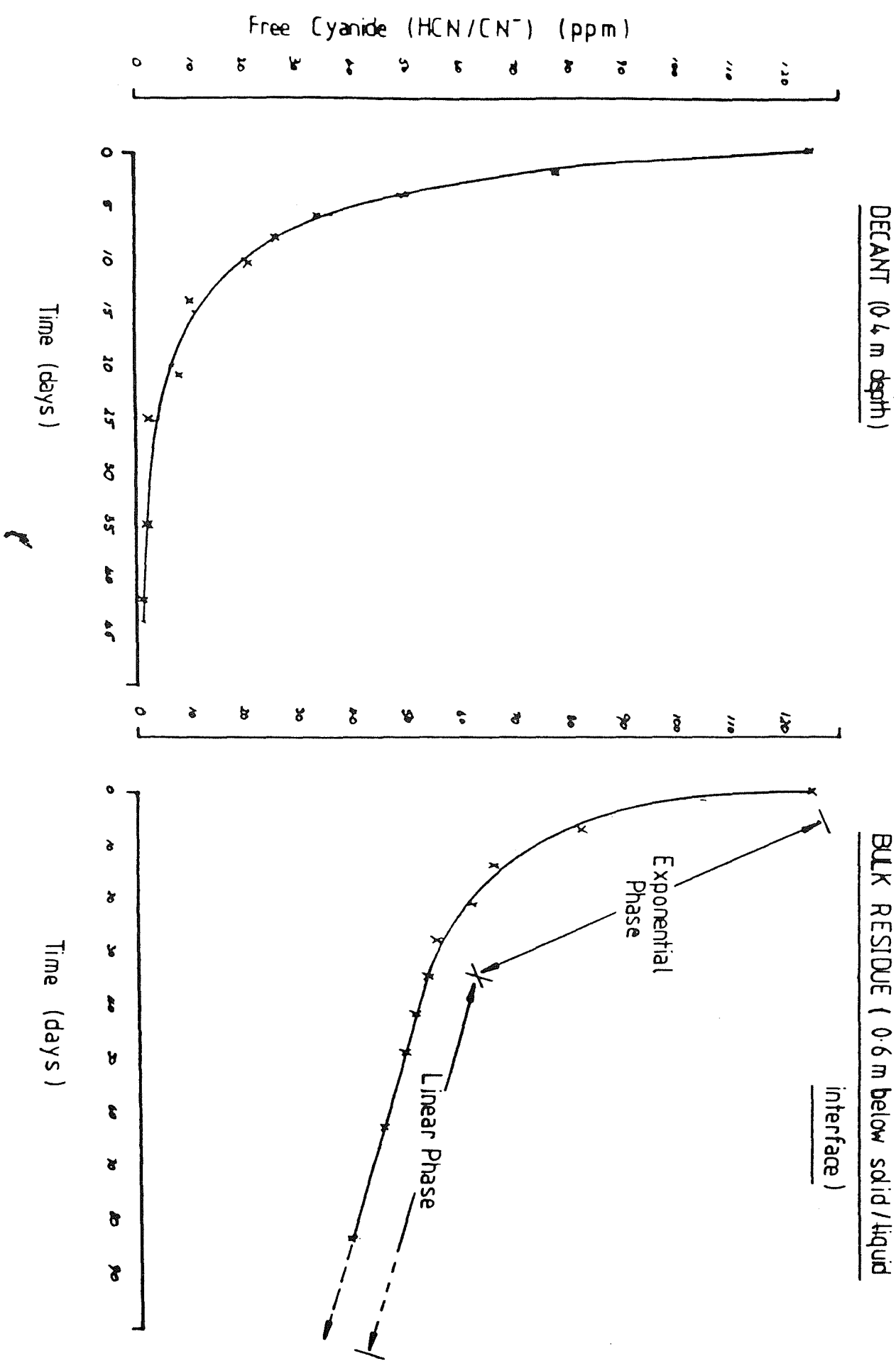
(i) increasing the pumping rate from the residue area back to the plant, substituting for water from the 34-Mile Brook Dam; and

(ii) temporary ponding in the residue area.

It is also likely that, in certain months of the year, rainfall pumped from the mine pits (together with the mine dewatering, obtained by lowering the water table in deep sections of the mine) could be diverted to the 34-Mile Brook Dam, allowing additional runoff from the residue area to be used in the plant immediately. Monitoring of this water would be used to confirm the feasibility of diversion, in relation to turbidity, salt content and pH.

The net runoff volume from the residue area (1500Ml/a) is based on various computer models by Kinhill Stearns and GHD-Dwyer (WA) Pty Ltd, Consulting Engineers, and allows for runoff from separate storage areas for bauxite and non-bauxitic residue.

Additional water will also need to be imported during the first few years, when the volume of runoff from residue areas is less than in later years (when saturated residue causes a higher proportion of rain to become runoff than from a vegetated catchment).



Worsley Alumina Pty. Ltd.	DATE 5·9·85	BY R.J.C.	APPR
FIG.1 Decay of Free Cyanide in Decant Water and Bulk Residue (Typical Data)	SCALE	CHKD	APPR
	DRG NO		REV

Fig. 2

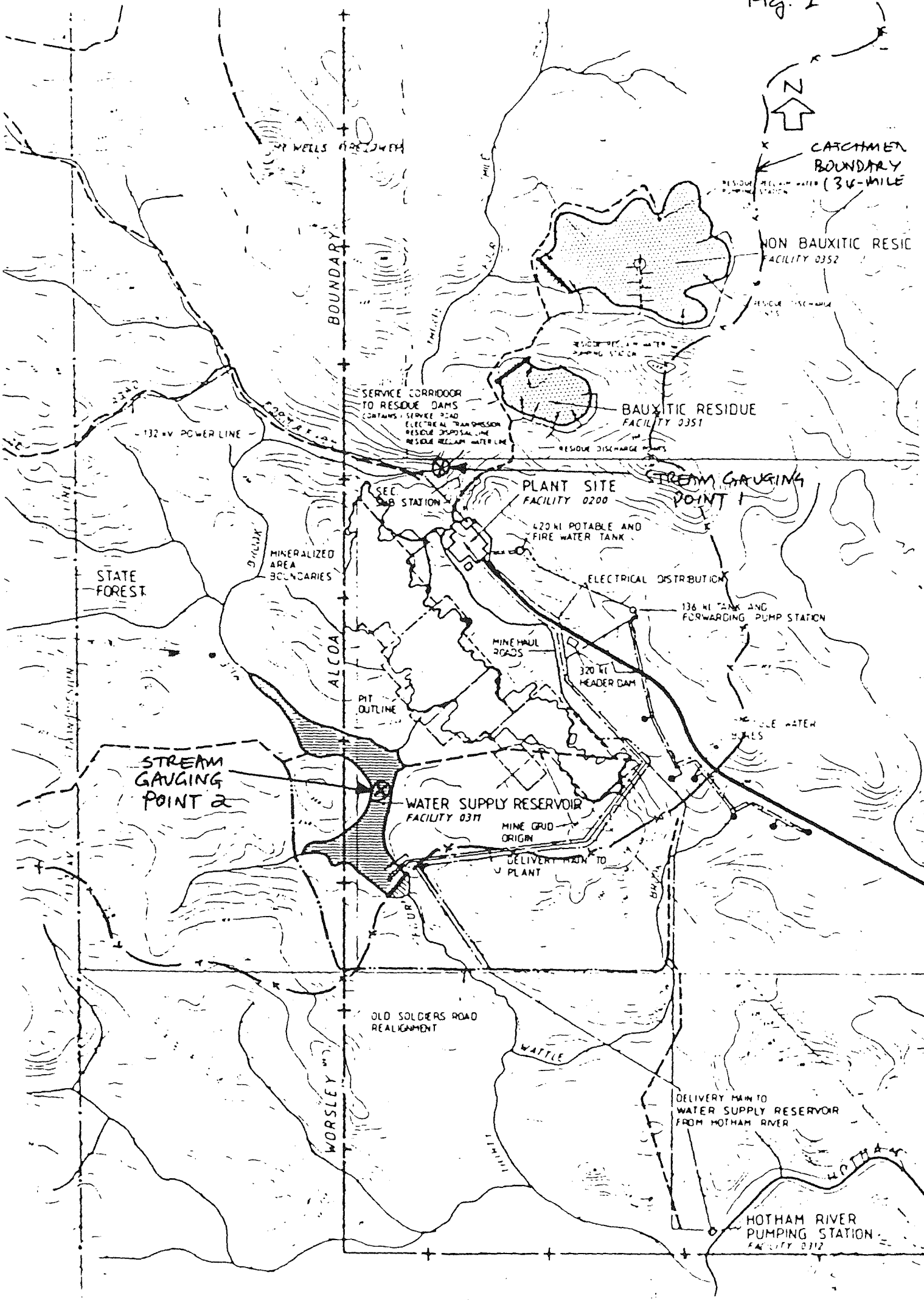
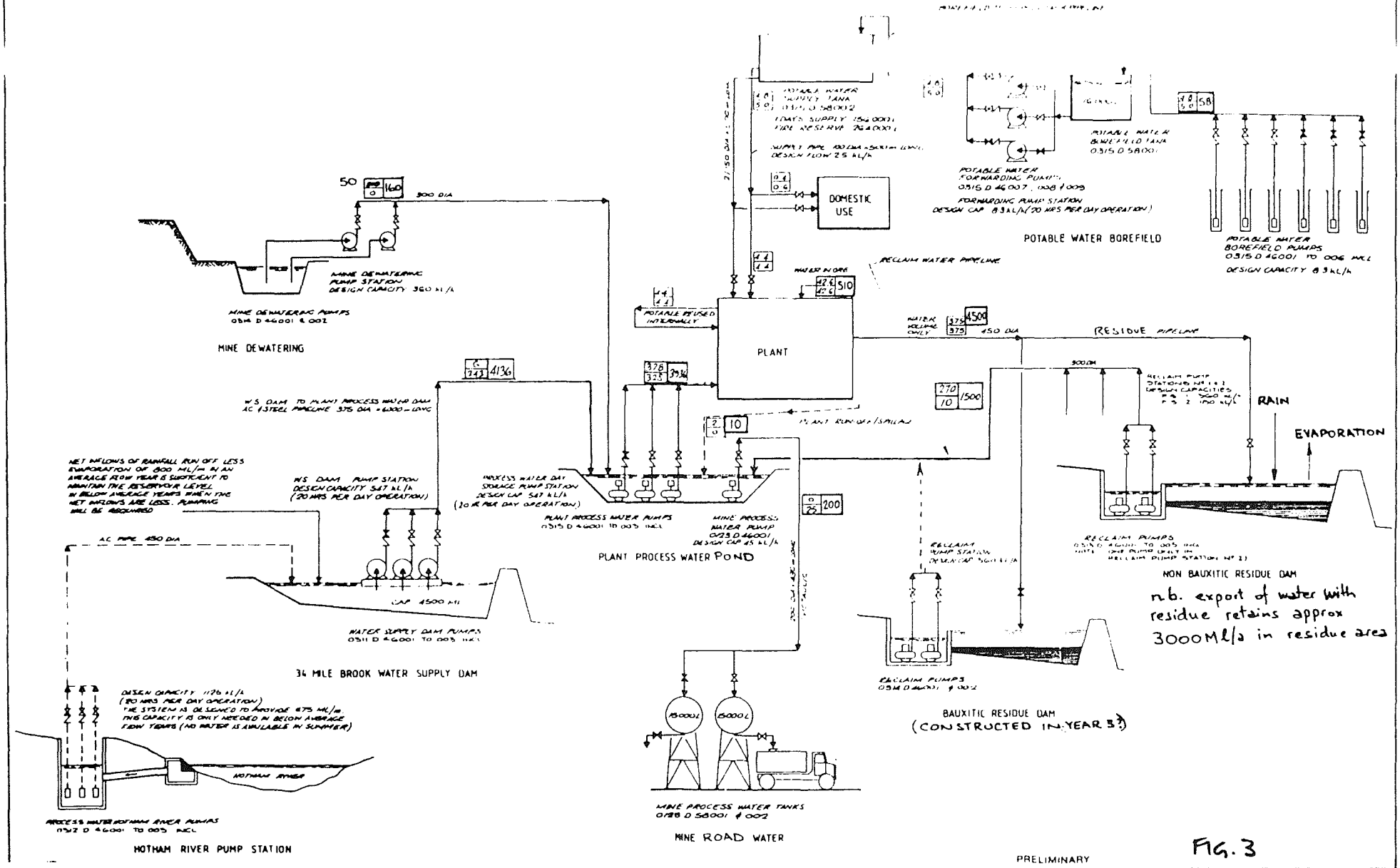

N
CATCHMENT BOUNDARY
NON BAUXITIC RESIDUE FACILITY 0352
BAUXITIC RESIDUE FACILITY 0351
SERVICE CORRIDOR TO RESIDUE DAMS
132 kV POWER LINE
PLANT SITE FACILITY 0200
STREAM GAUGING POINT 1
420 kl POTABLE AND FIRE WATER TANK
ELECTRICAL DISTRIBUTION
136 kl TANK AND FORWARDING PUMP STATION
MINERALIZED AREA BOUNDARIES
STATE FOREST
MINE HAUL ROADS
320 kl HEADER DAM
PIT OUTLINE
STREAM GAUGING POINT 2
WATER SUPPLY RESERVOIR FACILITY 0311
MINE GRID ORIGIN
DELIVERY MAIN TO PLANT
OLD SOLDIERS ROAD REALIGNMENT
WATTLE
DELIVERY MAIN TO WATER SUPPLY RESERVOIR FROM HOTHAM RIVER
HOTHAM RIVER PUMPING STATION FACILITY 0312
ALCOA
WORSLEY

FIG. 3



LEGEND

Typical flow in a winter month

Typical flow in a summer month

ANNUAL FLOW : Ml/a

PRELIMINARY

FIG. 3

WORSLEY ALUMINA PTY. LTD.
OTHER MINERALS OPERATION 1000000 t/a BODDINGTON PROSPECT PROCESS AND POTABLE WATER FLOW DIAGRAM & WATER BALANCE

J.L. IRISH, 07 SEP 1995
Civil Engineer/Hydrologist

SOIL SALT PROFILES AND STORAGES IN THE BODDINGTON GOLD MINE PROJECT AREA.

**** DRILL HOLE AT 6,377,159.00N 438,972.00E **** DRILLED 82-08-26
**** ZONE OF CATCHMENT ** 34 ML 3K **** TOTAL DEPTH OF HOLE 35.00 M

COLLAR ELEVATION 305.20 M DRILLER'S COMMENTS W8R079

BASEMENT HOLE

DEPTH FROM	DEPTH TO	SAMPLE NUMBER	TSS (G/KG)	CHLORIDE (G/KG)	PH	CL/TSS	LITHOLOGY	GRAPH OF TSS AN * = 0.1 UNITS
0.00	1.00	WB02895	0.057	0.009	7.0	0.157	GRAVL	I*
1.00	2.00	WB02896	0.038	0.009	6.7	0.237	GRAVL	I*
2.00	3.00	WB02897	0.038	0.016	6.4	0.422	H'CAP****	I*
3.00	4.00	WB02898	0.050	0.016	6.3	0.319	B-ZNE****	I*
4.00	5.00	WB02899	0.065	0.018	6.2	0.279	B-ZNE	I*
5.00	6.00	WB02900	0.328	0.240	4.7	0.731	B-ZNE	I***
6.00	7.00	WB02902	1.028	0.709	4.4	0.689	B-ZNE	I**********
7.00	8.00	WB02903	1.192	0.819	4.0	0.687	CLAY****	I**********
8.00	9.00	WB02904	1.254	0.860	4.0	0.686	CLAY	I**********
9.00	10.00	WB02905	1.254	0.889	4.5	0.709	CLAY	I**********
10.00	11.00	WB02906	1.441	1.000	4.2	0.694	CLAY	I**********
11.00	12.00	WB02907	1.190	0.819	4.0	0.688	CLAY	I**********
12.00	13.00	WB02908	1.538	1.000	3.9	0.650	CLAY	I**********
13.00	14.00	WB02909	1.969	1.300	3.8	0.660	CLAY	I**********
14.00	15.00	WB02910	1.831	1.199	3.7	0.655	CLAY	I**********
15.00	16.00	WB02912	1.826	1.300	3.8	0.712	CLAY	I**********
16.00	17.00	WB02913	1.859	1.300	4.1	0.699	CLAY	I**********
17.00	18.00	WB02914	1.813	1.300	4.3	0.717	CLAY	I**********
18.00	19.00	WB02915	1.874	1.300	4.1	0.694	CLAY	I**********
19.00	20.00	WB02916	1.698	1.199	4.1	0.706	CLAY	I**********
20.00	21.00	WB02917	1.636	1.199	4.1	0.733	CLAY	I**********
21.00	22.00	WB02918	1.536	1.100	4.2	0.716	CLAY	I**********
22.00	23.00	WB02919	1.341	0.930	4.3	0.693	CLAY	I**********
23.00	24.00	WB02920	1.121	0.750	4.6	0.669	CLAY	I**********
24.00	25.00	WB02922	1.100	0.750	4.7	0.682	CLAY	I**********
25.00	26.00	WB02923	1.160	0.770	4.7	0.670	CLAY	I**********
26.00	27.00	WB02924	1.024	0.709	5.3	0.693	CLAY	I**********
27.00	28.00	WB02925	0.956	0.600	5.1	0.621	CLAY	I**********
28.00	29.00	WB02926	0.863	0.569	5.3	0.659	CLAY	I**********
29.00	30.00	WB02927	0.678	0.429	5.7	0.602	CLAY	I********
30.00	31.00	WB02928	0.671	0.420	5.9	0.626	CLAY	I********
31.00	32.00	WB02929	0.756	0.470	5.9	0.620	CLAY	I*********
32.00	33.00	WB02930	0.664	0.390	6.1	0.594	CLAY	I*******
33.00	34.00	WB02932	0.331	0.170	6.3	0.514	CLAY	I****
34.00	35.00	WB02933	0.374	0.110	7.1	0.294	CLAY	I*****

TABLE

IN THE BODDINGTON GOLD MINE PROJECT AREA.

DRILLED 82-11-1[illegible]

ELEVATION

BASEMENT ROCK

FROM	TO	SAMPLE NUMBER	[illegible] (G/KG)	[illegible] (G/KG)	--------	CL/TSS --------	LITHOLOGY	GRAPH OF [illegible] TSS EACH * = 0.5 UNITS
0.00	[illegible]	WB12942	0.120	0.025	[illegible]	0.209	NONE	*
1.00	[illegible]	WB12943	0.108	0.023	5.4	0.260	NONE	*
2.00	3.00	WB12944	0.125	0.059	6.3	0.474	CLAY****	*
3.00	4.00	WB12945	0.288	0.160	5.4	0.556	CLAY	I*
4.00	5.00	WB12946	0.743	0.449	6.3	0.604	CLAY	I*
5.00	6.00	WB12947	1.254	0.709	7.1	0.565	CLAY	I***
6.00	7.00	WB12948	1.426	0.790	6.7	0.554	CLAY	I***
7.00	[illegible]	WB12949	1.544	[illegible]	5.1	0.506	CLAY	I***
8.00	9.00	WB12950	1.203	0.649	5.4	0.540	CLAY	I**
9.00	10.00	WB12952	1.695	0.934	5.1	0.554	CLAY	I***
10.00	11.00	WB12953	2.343	1.300	5.0	0.555	CLAY	I*****
11.00	12.00	WB12954	2.533	1.399	5.1	0.552	CLAY	I*****
12.00	13.00	WB12955	2.220	1.300	5.0	0.585	CLAY	I****
13.00	14.00	WB12956	2.549	1.379	4.9	0.542	CLAY	I*****
14.00	15.00	WB12957	2.331	1.300	4.8	0.558	CLAY	I*****
15.00	16.00	WB12958	2.415	1.399	4.8	0.579	CLAY	I*****
16.00	17.00	WB12959	2.848	1.699	4.8	0.596	CLAY	I******
17.00	18.00	WB12960	2.705	1.600	4.7	0.592	CLAY	I*****
18.00	19.00	WB12962	2.341	1.399	4.5	0.598	CLAY	I*****
19.00	20.00	WB12963	2.072	1.199	4.6	0.579	CLAY	I****
20.00	21.00	WB12964	2.277	1.300	4.6	0.571	CLAY	I*****
21.00	22.00	WB12965	1.954	1.000	4.7	0.512	CLAY	I****
22.00	23.00	WB12966	1.749	0.939	4.8	0.537	CLAY	I***
23.00	24.00	WB12967	1.759	1.000	5.1	0.568	CLAY	I****
24.00	25.00	WB12968	1.456	0.819	5.7	0.562	CLAY	I***
25.00	26.00	WB12969	1.539	0.850	5.8	0.545	CLAY	I***
26.00	26.20	WB12970	1.308	0.709	6.4	0.542	CLAY	I***

TABLE 2. Typical "monotonically-increasing soil salt profile (BGM).

information on the impacts of agriculture on stream salinity and from information on soil solute concentrations and stream flow data determined by the JV, should provide quantitative estimates of the effect of the total clearing for the mining and ancillary works on the stream flow volumes and salinities at the inflow to the Water Supply Reservoir. The calculations should be performed for a range of rehabilitation practices both vegetative (eg pasture, pasture and forest, or forest) and physical (eg drainage diversion). As part of these studies a detailed review is required of the progressive interaction of the mine pits with stream flow, groundwater flow and salt movement. A discussion of the nature of the final pit water relations would be necessary.

RECOMMENDATION

The JV should provide the State with quantified estimates of the effects of clearing for the project and various rehabilitation alternatives on stream flow volumes and salinities of the inflow to the Water Supply Reservoir. This should include a review of the progressive interaction of mine pits with stream and groundwater flow and salt movement from commencement through to cessation of mining.

The JV have undertaken to monitor water quality so that definitive data can be collected to determine salinity effects of the project. Monitoring should include both surface and groundwater quality, stream flows and piezometric levels. In particular groundwater monitoring would be required adjacent to the mine sites to provide an early warning of potential stream salinity effects.

RECOMMENDATION

The JV should develop and carry out a surface and groundwater monitoring programme acceptable to the State particularly in relation to residue disposal, Water Supply Reservoir, mine and downstream areas.

This should include a discussion of the effectiveness of the various project and downstream management systems and any management changes proposed, for State approval.

5.4 DOWNSTREAM WATER SUPPLY

The continued value of 34 Mile Brook as a stock and recreational water source is to some extent dependent on the maintenance of flows from the northern forested part of the catchment, particularly in summer and early autumn when saline base flows are possibly the major contributors to stream flows on cleared land. The beneficial uses of water downstream from the residue impoundments, particularly downstream of the water supply reservoir need to be considered by the JV. The Joint Venturers have resolved to release up to 50 ML of water from the WSR in the early summer and late autumn to extend the existing flow and quality period if it is shown to be necessary. Stream flow and quality monitoring would be carried out by the JV to assist in this decision making.

The WSR may cause a rise in downstream water tables and a consequent increase in salinisation. Water quality monitoring and water release would need to take this into account.

5.5 REHABILITATION

On the 250 ha of the mine pit area, the native forest ecosystem would be destroyed and soil environment profoundly altered. The mine pit would form an upland clay floored depression in what was freely draining convex topography. The pit would have a completely new soil type in the forest and would require intensive rehabilitation treatment to control erosion and bring its appearance and productivity up to acceptable standards.

The JV plan to directly replace fresh overburden and topsoil from areas being developed for mining onto mined out areas being prepared for revegetation. Rehabilitation would be progressive to a land use suitable for ensuring that the longterm water quality of 34 Mile Brook at the WSR is maintained. The water should be a viable source for public water supply at the completion of the project.

RECOMMENDATION

The JV should conduct progressive rehabilitation to a land use suitable for ensuring that the water quality of the Water Supply Reservoir is such that it would be a viable source for public water supply at the completion of the project.

The JV have proposed that the rehabilitation will be developed in consultation with the Department of Conservation and Land Management and Bunning Bros, attempting to re-establish vegetation in a structural as well as floristic sense. Because of wider interests in the quality of rehabilitation, the EPA should periodically review this work.

Consideration is being given by the JV to the development of pasture on the private land. From an apicultural viewpoint it would however be desirable, in suitable areas, for rehabilitation to a Eucalyptus Wandoo woodland to replace that lost during the project. Further, it may be necessary to reconsider pasture, planting trees to ensure that salinity is not an ongoing problem.

As the bauxitic residue would ultimately be reclaimed as feed for the Worsley Alumina Refinery, rehabilitation is proposed to provide erosion control, whereas the non-bauxitic residue storage area would be rehabilitated to the long term land use.

Rehabilitation should only be regarded as completed when the land manager is satisfied that the vegetation can be maintained and when the State is satisfied that rehabilitation will cope with the salinity risk. Further there should be no toxic or harmful soil components present at this time. In this regard the JV have noted that contouring and drainage would be necessary to avoid the rise of contaminated waters during vegetation re-establishment on the residue disposal areas.

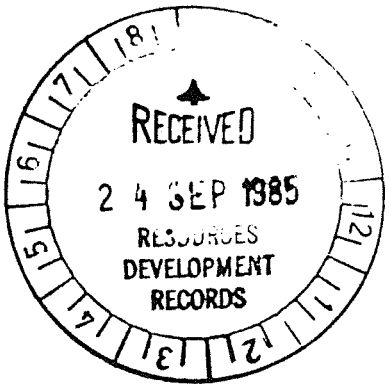
Worsley Alumina Pty Ltd

Incorporated in the State of Western Australia

Worsley Refinery, Worsley, Western Australia P.O. Box 344, Collie Western Australia 6225

CDJ/AMF/1111a

20 September 1985



The Co-ordinator
Department of Resources Development
SGIO Atrium
St George's Terrace
PERTH W.A. 6000

Attention : Mr G.H.C. White

Dear Sir,

BODDINGTON GOLD MINE - ERMP PROCEDURE

In response to your request of 16 September 1985 for additional information to provide to the Environmental Protection Authority, we are please to submit the attached paper.

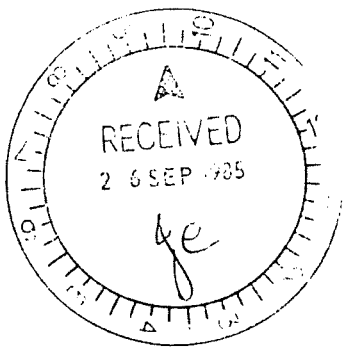
We believe that we have appropriately addressed the matters raised in your request, and trust that our submission meets the State's requirements.

We would be grateful if you would transmit the submission to the Environmental Protection Authority on our behalf.

Thank you in anticipation.

Yours faithfully,
WORSLEY ALUMINA PTY LTD

N.T. CHAPLIN
General Manager



WORSLEY ALUMINA JOINT VENTURERS

BODDINGTON GOLD MINE

SUBMISSION TO ENVIRONMENTAL PROTECTION AUTHORITY - SEPTEMBER 1985

INTRODUCTION

This submission has been prepared as an addendum to information previously provided as part of the ERMP procedure for the Boddington Gold Mine, and deals with requests for information transmitted through the Department of Resources Development on 16 September 1985.

The submission addresses four major questions raised by the EPA (residue containment, stream salinity, residue consolidation and vegetation, and commitment to respond appropriately to eventualities perceived as environmentally hazardous). It also addresses planning and management of the construction camp proposed for establishment near Boddington.

RESIDUE CONTAINMENT

Previous submissions have described the proposed sub-aerial deposition of residues from the process into dammed natural valleys in the upper part of the catchment of 34-Mile Brook, but information has been specifically sought in relation to the subsurface pathway of potentially-contaminated leakages of liquor from the residue storage areas.

Groundwater flows in the storage areas are typical of those of Darling Range areas with similar rainfall (approximately 840 mm per annum). Deep water tables exist some 15-20 metres below natural surface (see Figs 1 and 2), with perched aquifers in winter being the major source of stream flows (cf. I.C. Loh and R.A. Stokes : Predicting Stream Salinity Changes in Southwestern Australia - Land and Stream Salinity Seminar Paper, November 1980). The lack of significant baseflow (deep groundwater) contribution to stream flows in 34-Mile Brook is evidenced by the fact that, even in wet years, the stream is generally dry during summer and early autumn. Perched aquifers in the Boddington Gold Mine area, including the residue storage areas, have been regularly encountered during exploration drilling and test excavation work in winter.

Fig. 1 shows the results of preliminary geotechnical work carried out in 1984 as part of the feasibiliity study for the Boddington Gold Mine project. The four drill holes involved in this work were located at the site of the dam proposed for containment of bauxitic residues (see Fig. 3), and thus are a direct demonstration of the existence of a groundwater table which generally follows the topography at a depth of 15-20 metres.

Fig. 2 shows data derived from drilling logs for transects of exploration holes across both the bauxitic and non-bauxitic areas: the approximate locations of the transects are shown on Fig. 3. Although the data are not derived from activities specifically aimed at hydrogeological investigation, and are therefore not as accurate as the data in Fig. 1, Fig. 2 does demonstrate the existence of a groundwater table which generally follows natural surface, again at a depth of some 15-20 metres.

For the non-bauxitic area, Fig. 2 also indicates that groundwaters in this area have an hydraulic gradient of some 2-5 metres per kilometre. This figure is derived by comparing groundwater levels on the upstream and downstream transects. Given the relatively imprecise nature of the data, this figure can only be regarded as indicative, but in at least a qualitative manner it does suggest a predictable groundwater regime, similar to those of other areas of the Darling Range.

In the improbable event of significant and potentially-hazardous leakage of liquor from the residue storage areas, the proposed network of monitoring/recovery bores, engineered according to the findings of future detailed geotechnical work in the area, will be an appropriate method of detection, containment and diversion. The similarity of hydrogeological situations at the Worsley Alumina Refinery and the Boddington Gold Mine means that the principles of the bore monitoring system currently operating at Worsley can be applied to the Boddington Gold Mine.

Perched aquifer pathways in the Boddington Gold Mine residue storage areas will not be contiguous with those of the surrounding terrain, as the residue areas will be surroumded by diversion channels excavated through the comparatively permeable surface horizons: fresh water flows in these channels will be directed to 34-Mile Brook. At the dam walls in the residue areas, potential flows through these relatively permeable horizons will be prevented; a number of standard engineering options are available to the Joint Venturers, including grout curtains, filter drains to purposely collect flows in a sump and

return them to the storage areas or to process, and construction of a lined trench through comparatively permeable horizons across the valleys immediately downstram of dam walls. The actual method adopted will be determined after the detailed geotechnical work to be carried out in the area after commitment to the project has been made. The design of the installations would be reviewed by the Western Australia Water Authority as part of the licensing procedure under the Rights in Water and Irrigation Act.

STREAM SALINITY

The Joint Venturers have been requested to provide data which would evidence the possible effects on stream salinity of the clearing proposed as part of the Boddington Gold Mine. As noted in the Joint Venturer's submission of August 1985, an exhaustive search of the available literature has not revealed any information which would directly and unequivocally permit prediction of these effects. While a great deal of research has been carried out in Western Australia to attempt to quantitatively predict these effects of clearing, none is considered directly applicable to the Boddington Gold Mine project area.

Moreover, the Joint Venturers believe, for the reasons set out in their submission of August 1985, that clearing for Boddington Gold Mine project activities is most unlikely to cause significant increases in the salinity of 34-Mile Brook. Additionally, rehabilitation programmes will have as one of their key criteria the management of soil salt and water balances.

Notwithstanding the above, and recognising that hypothetical assessment of risks of salinisation following clearing involves a considerable degree of subjectivity and application of "conventional wisdom", the Joint Venturers will, in consultation and co-operation with the State through the Department of Resources Development, determine the need for and, if necessary, undertake a reasonable and appropriate hydrogeological monitoring programme in the area of mine pits developed for the Boddington Gold Mine.

RESIDUE MANAGEMENT : CONSOLIDATION AND DRYING

The Joint Venturers have been asked to provide details on residue consolidation and drying supplementary to those provided in the ERMP submitted in January, 1985 (pp 37-41), and in subsequent requests for data.

As part of the feasibility study carried out in 1984, two Perth-based groups of consulting engineers evaluated possible methods for residue storage and management. Based on examination of topography, settling and consolidation properties of the residues, and meteorological conditions, it has been determined that residues from the Boddington Gold Mine can be managed by storage in the areas delineated in the January 1985 ERMP document (see also Fig. 3 attached).

One of the prime determinants of the feasibility of the residue management concept so developed is the high net annual evaporation at the Boddington Gold Mine. Rainfall is estimated at 840 mm, and lake evaporation (0.9 x pan evaporation) at 1540, with net annual evaporation therefore being 700 mm. Utlilising this high evaporative demand, the residues will be managed by a sub-aerial system involving deposition in thin layers in a progressive manner from the perimeter of the storage areas. After decantation (with decant waters being returned to process), consolidation and drying of residues by evaporation are, based on laboratory testwork, predicted to provide accessible residue surfaces prior to deposition of subsequent volumes of residue. Allowing for the winter period when rainfall exceeds evaporation, the areal and volumetric capacity of the residue storage areas has been determined to allow appropriate decantation, consolidation and drying throughout the year. A third potential consultant engineering group, with experience in consolidation and drying of similar residues by sub-aerial methods in a number of projects, including one in Canada in an area with a much smaller net evaporation than exists at the Boddington Gold Mine, have advised that Joint Venturers that the proposed sub-aerial method of storage should permit the decommissioning of the facility within a year of the end of operations. These consultants also note that bearing capacities permitting access to residues should be achieved within about a month of cessation of deposition.

As part of their meeting licensing requirements under the Rights in Water and Irrigation Act, the Joint Venturers are naturally committed to carrying out detailed design of the residue management system. This work will be carried out in consultation with the Western Australian Water Authority under the auspices of the Department of Resources Development.

Should ultimate operation and decommissioning of the residue management system reveal unexpected problems which would hazard the integrity of the system, the Joint Venturers are committed to modify the system and/or its operation to the reasonable satisfaction of the State, through the Department of Resources Development.

RESPONSE TO UNFORESEEN EVENTS

The Joint Venturers have been requested to satisfy the EPA that, in the event of unforeseen or improbable events taking place, they will take advice from the State and deal with problems to the satisfaction of the State. Examples of such events are dust management on residue areas, management of residue or decant pipeline failures, and the mis-operation of the residue management system (see previous paragraph).

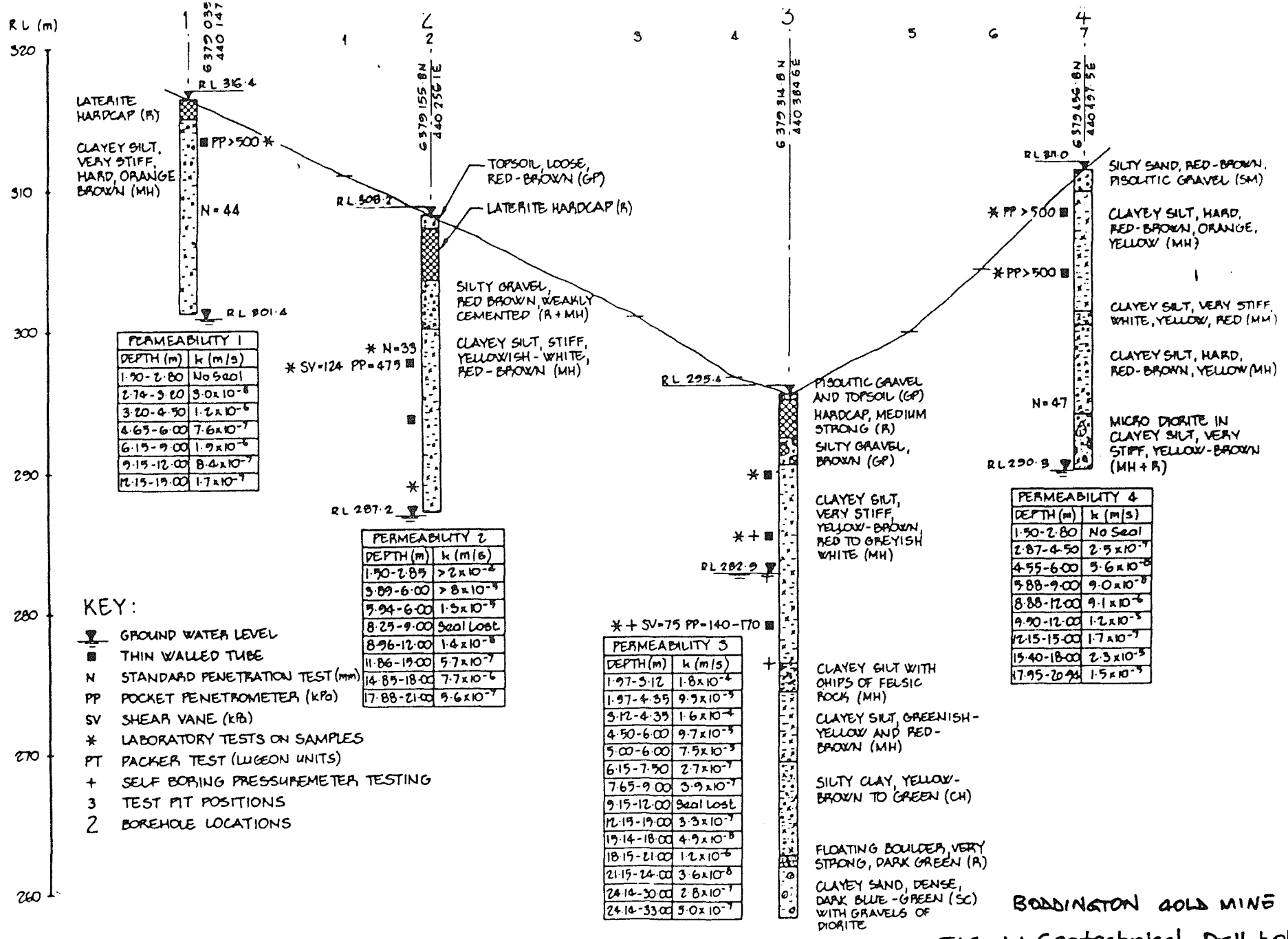
In instances where there is actual or potential risk of environmental impact not already adequately addressed in the ERMP procedure, the Joint Venturers are committed to taking action to the reasonable satisfaction of the State. In this context, the Joint Venturers understand "the State" to mean the Minister for and the Department of Resouces Development, and that disputes on such matters would be managed according to the arbitration provisions (Clause 28) of the Alumina Refinery (Worsley) Agreement, 1973-1982.

CONSTRUCTION CAMP

The Joint Venturers have been asked to detail plans for the location and duration of the construction camp for the Boddington Gold Mine, and to outline proposed methods of dealing with variations from these plans.

The construction camp for the Boddington Gold Mine is, on current planning, to be located on private property (Bunning Bros), as shown in Fig. 3. The camp, which will be equipped with its own sewage treatment plant, will be established, operated and de-commissioned in accordance with the appropriate State and local government statutes and regulations.

It is currently planned that the camp will be operated for the duration of project construction (estimated at 18 months), and then de-commissioned. Any variation from this plan would take place only after consultation with the Department of Resources Development, the Shire of Boddington and any other authority judged by the Joint Venturers and the Department of Resources Development to have an involvement.



PERMEABILITY 1	
DEPTH (m)	k (m/s)
1·90 - 2·80	No Seal
2·70 - 3·20	3.0×10^{-6}
3·20 - 4·50	1.2×10^{-6}
4·65 - 6·00	7.6×10^{-7}
6·15 - 9·00	1.9×10^{-6}
9·15 - 12·00	8.4×10^{-7}
12·15 - 19·00	1.7×10^{-7}

PERMEABILITY 2	
DEPTH (m)	k (m/s)
1·90 - 2·85	$> 2 \times 10^{-4}$
3·89 - 6·00	$> 8 \times 10^{-5}$
5·94 - 6·00	1.5×10^{-5}
8·25 - 9·00	Seal Lost
8·96 - 12·00	1.4×10^{-6}
11·86 - 19·00	5.7×10^{-7}
14·85 - 18·00	7.7×10^{-6}
17·88 - 21·00	9.6×10^{-7}

PERMEABILITY 3	
DEPTH (m)	k (m/s)
1·97 - 3·12	1.8×10^{-4}
1·97 - 4·35	9.9×10^{-5}
3·12 - 4·35	1.6×10^{-4}
4·50 - 6·00	9.7×10^{-5}
5·00 - 6·00	7.5×10^{-5}
6·15 - 7·50	2.7×10^{-7}
7·65 - 9·00	3.9×10^{-7}
9·15 - 12·00	Seal Lost
12·19 - 19·00	3.3×10^{-7}
19·14 - 18·00	4.9×10^{-5}
18·15 - 21·00	1.2×10^{-6}
21·15 - 24·00	3.6×10^{-8}
24·14 - 30·00	2.8×10^{-7}
24·14 - 33·00	5.0×10^{-7}

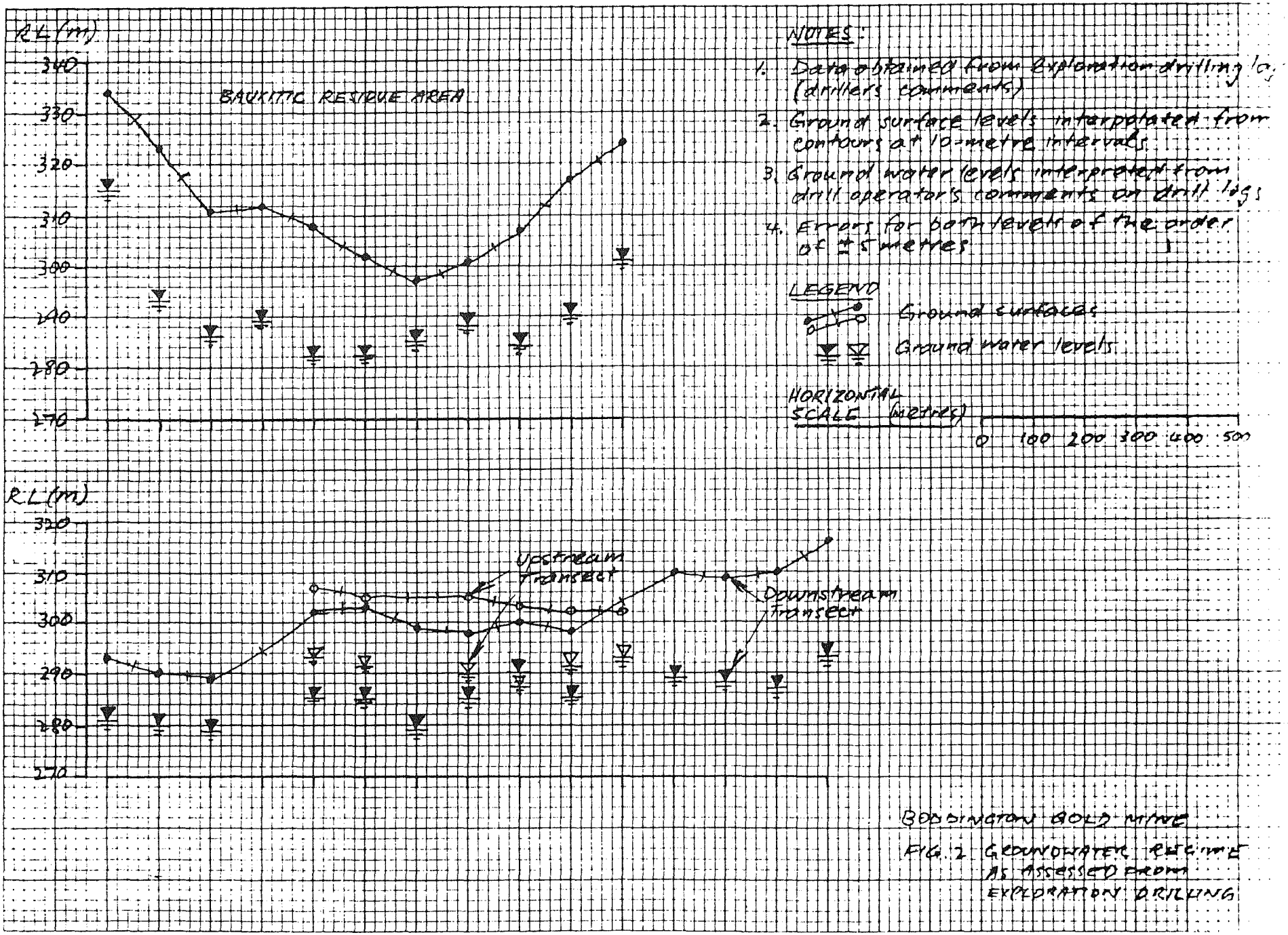
PERMEABILITY 4	
DEPTH (m)	k (m/s)
1·50 - 2·80	No Seal
2·87 - 4·50	2.5×10^{-4}
4·55 - 6·00	5.6×10^{-5}
5·88 - 9·00	9.0×10^{-8}
8·88 - 12·00	9.1×10^{-6}
9·90 - 12·00	1.2×10^{-5}
12·15 - 15·00	1.7×10^{-7}
15·40 - 18·00	2.3×10^{-5}
17·95 - 20·95	1.5×10^{-5}

KEY:

- ▼ GROUND WATER LEVEL
- ■ THIN WALLED TUBE
- N STANDARD PENETRATION TEST (mm)
- PP POCKET PENETROMETER (kPa)
- SV SHEAR VANE (kPa)
- * LABORATORY TESTS ON SAMPLES
- PT PACKER TEST (LUGEON UNITS)
- \+ SELF BORING PRESSUREMETER TESTING
- 3 TEST PIT POSITIONS
- 2 BOREHOLE LOCATIONS

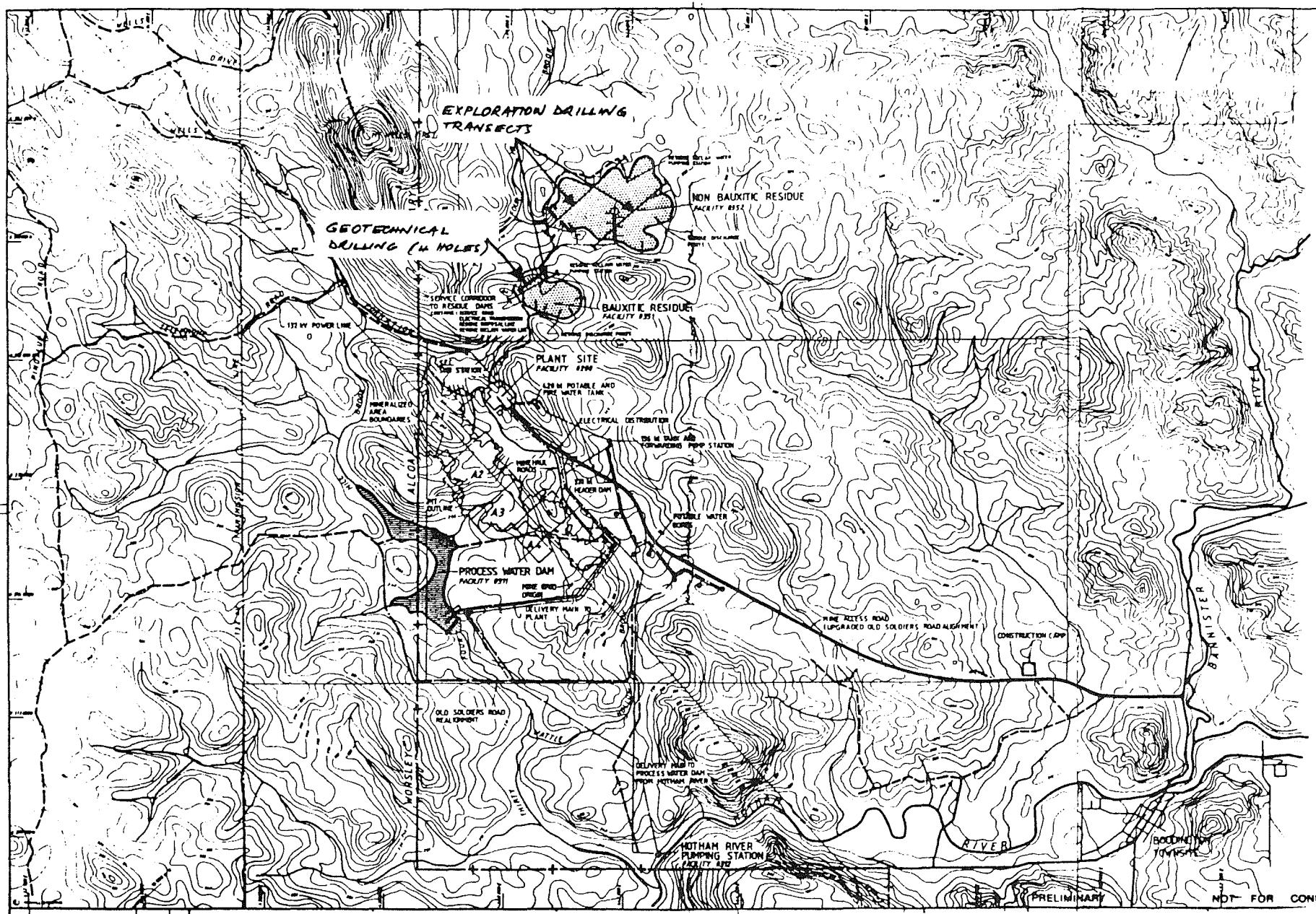
BODDINGTON GOLD MINE

FIG. 1 : Geotechnical Drill-hole Data at the site of the bauxitic residue



BODDINGTON GOLD MINE

FIG. 2 GROUNDWATER REGIME AS ASSESSED FROM EXPLORATION DRILLING



BODDINGTON GOLD MINE

Fig. 3. Project General Arrangement, Including Construction Camp Location

APPENDIX 2

SUMMARY OF COMMITMENTS TO ENVIRONMENTAL MANAGEMENT

The following represents a summary of commitments made by the Joint Venturers in respect of environmental management of the Boddington Gold Mine.

The Joint Venturers will:

(1) Comply with the requirements of applicable Acts and Regulations including:

Clean Air Act (1964)
Hearing Conservation Regulations (1983)
Aboriginal Heritage Act (1972-75)

(2) Establish programmes for the regular monitoring of: bores around the residue areas; the chemical quality of 34-Mile Brook downstream of the Water Supply Reservoir; the Water Supply Reservoir itself and its tributaries;

(3) Maintain a capacity to expeditously pump from recovery bores in the event of seepage of pollutants from the residue storage areas;

(4) Monitor the biological status of 34-Mile Brook both up and downstream of the Water Supply Reservoir;

(5) Take reasonable steps to prevent damage by water runoff, including erosions, and design and operate a water quality, drainage and stormwater management system which will minimise the discharge of turbid water or tailings spills into nearby streams;

(6) Minimise clearing of land consistent with safe and efficient operations;

(7) Control fugitive dust from the Project Area;

(8) Monitor faunal populations and movements in the Project Area;

(9) Monitor noise levels in the Project Area and its surrounds;

(10) Advise nearby populations of likely blasting times;

(11) Apply sensible dieback hygiene constraints to activities;

(12) Utilize requisite safety equipment and procedures in the handling and storage of hazardous chemicals;

(13) Restrict human and non-avian faunal access to potentially hazardous areas by fencing and incorporate avifuanal deterrents in the design of pollutant-containing water bodies;

(14) Ultimately return impacted areas to appropriate and practicable land uses in accordance with agreements with Bunning Bros and prescriptions developed in consultation with Forests Department and/or Department of Agriculture;

(15) Monitor and maintain rehabilitated pits, waste stockpile and reside disposal areas until such time as it is agreed that the objectives of such rehabilitation have been met;

(16) Develop a sanitary landfill area for the disposal of office and domestic wastes generated by the project;

(17) Provide accommodation for the construction workforce in a camp to be established on private property.

(18) Prevent potential flows through residue dam walls;

(19) Carry out detailed design of residue management systems;

(20) Monitor and manage the water/residue system until it is decided, in consultation with the State that such activity is no longer required;

(21) Modify residue management system and operations to the reasonable satisfaction of the State if unexpected problems occur.

(22) Take action to the reasonable satisfaction of the State if actual or potential risks, not adequately addressed in the ERMP, occur.

(23) Undertake testwork of residue chemical breakdown and soil amelioration;

(24) Ensure the longterm quality of water in the WSR;

(25) Remove contaminated material and carry out appropriate rehabilitation if a tailings pipeline failure occurs;

(26) Notify downstream users and would monitor cyanide levels if a major tailings dam failure occurred;

(27) Conduct enrichment planting in disease affected forest and staff training to avoid disease spread;

(28) Consider releasing up to 50 ml of water p.a. to downstream users.

(29) Have ongoing liaison with Mines Department for pit safety and face stability;

(30) Progressively rehabilitate mined areas;

(31) Monitor flows in 34-Mile Brook downstream of the WSR;

(32) Develop biological monitoring programmes to assess the success of rehabilitation;

(33) Not blast when weather conditions indicate there would be a noise problem;

(34) Monitor noise levels;

(35) Manage hazardous chemicals by the use of bunding, safety equipment etc;

(36) Apply appropriate forest hygiene strategies for power line and water supply pipeline;

(37) Conduct appropriate contouring and drainage to prevent the rise of contaminated waters in residue areas during rehabilitation;

(38) Provide alternative access to CALM and local Bush Fire Brigades;

(39) Visuallly blend the residue storage areas into their immediate surrounds;

(40) Compensate the State for all clearing of State Forest.