Duplication of iron ore mining operation, Yandi mine ML 270SA, Hamersley Range, 90 km north-west of Newman

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BHP Iron Ore Pty Ltd

Report and recommendations
of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 802
December 1995

THE PURPOSE OF THIS REPORT

This report contains the Environmental Protection Authority's environmental assessment and recommendations to the Minister for the Environment on the environmental acceptability of the proposal.

Immediately following the release of the report there is a 14-day period when anyone may appeal to the Minister against the Environmental Protection Authority's report.

After the appeal period, and determination of any appeals, the Minister consults with the other relevant ministers and agencies and then issues his decision about whether the proposal may or may not proceed. The Minister also announces the legally binding environmental conditions which might apply to any approval.

APPEALS

If you disagree with any of the contents of the assessment report or recommendations you may appeal in writing to the Minister for the Environment outlining the environmental reasons for your concern and enclosing the appeal fee of $10.

It is important that you clearly indicate the part of the report you disagree with and the reasons for your concern so that the grounds of your appeal can be properly considered by the Minister for the Environment.

ADDRESS

Hon Minister for the Environment
12th Floor, Dumas House
2 Havelock Street
WEST PERTH WA 6005

CLOSING DATE

Your appeal (with the $10 fee) must reach the Minister's office no later than 5.00 pm on 22 December 1995.

Environmental Impact Assessment Process Timelines

Date	Timeline commences from receipt of full details of proposal from proponent for public review	Time (weeks)
28/8/95	Proponent document released for public comment	
25/9/95	Public comment period closed	4
3/10/95	Issues raised during public comment period summarised by EPA and forwarded to the Proponent	2
15/11/95	Proponent response to the issues raised received	6
8/12/95	EPA reported to the Minister for the Environment	4

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Summary and recommendations

The Environmental Protection Authority herein reports on the proposal by BHP Iron Ore Pty Ltd (the proponent) to develop a second open-cut iron ore mining operation on its Mineral Lease 270SA. Known as the Central Mesa 1 and 2 operation, the new proposed mine site is located in the Hamersley Ranges of the Pilbara Region of Western Australia (119°4'E, 22°43'S, RL 550-575 m AHD).

The Environmental Protection Authority has previously assessed an existing open-cut iron ore mining proposal, known as Yandi E2, on BHP's lease and found it to be environmentally acceptable. Environmental conditions were set on Yandi E2 by the Minister for the Environment (Appendix 5), including the requirement to prepare and implement an Environmental Management Programme, and the mine has been in operation since 1991. The proponent proposes that a lease-wide Environmental Management Programme be developed and apply to both the Central Mesa 1 and 2 mine, the Yandi E2 mine and future operations on Mineral Lease 270SA.

The Environmental Protection Authority notes that the environment at both the existing Yandi E2 mine, the proposed Central Mesa 1 and 2 mine and for Mineral Lease 270SA is the same or similar. It is considered that a lease-wide Environmental Management Programme could be easily applied to the whole of BHP's Mineral Lease 270SA and would enhance mine planning and as a consequence environmental management throughout the lease.

The Environmental Protection Authority has assessed the environmental acceptability of the Central Mesa 1 and 2 proposal and the lease-wide Environmental Management Programme approach.

A number of environmental topics generated by the proposal were considered by the Environmental Protection Authority. From these, the Environmental Protection Authority has identified the major environmental issues requiring detailed evaluation as:

- impacts of mining on the groundwater and those elements of the environment dependent upon it; and
- the preparation and implementation of a lease-wide Environmental Management Programme.

Following evaluation of the major issues, the Environmental Protection Authority has concluded that the proposal is environmentally acceptable subject to the proponent's commitments and the recommendations in this assessment report.

Summary of recommendations	
1	That the proposal is environmentally acceptable.
2	That the proponent prepare and implement a lease-wide Environmental Management Programme for Mineral Lease 270SA.
3	That the proponent should prepare and implement a plan which describes the process for decommissioning and rehabilitation of the lease and which manages salinity in the mined out pits and any regional effects from mining the aquifer, including development of a walk away solution.

Contents

Contents (cont)

Figures

Tables

Appendices

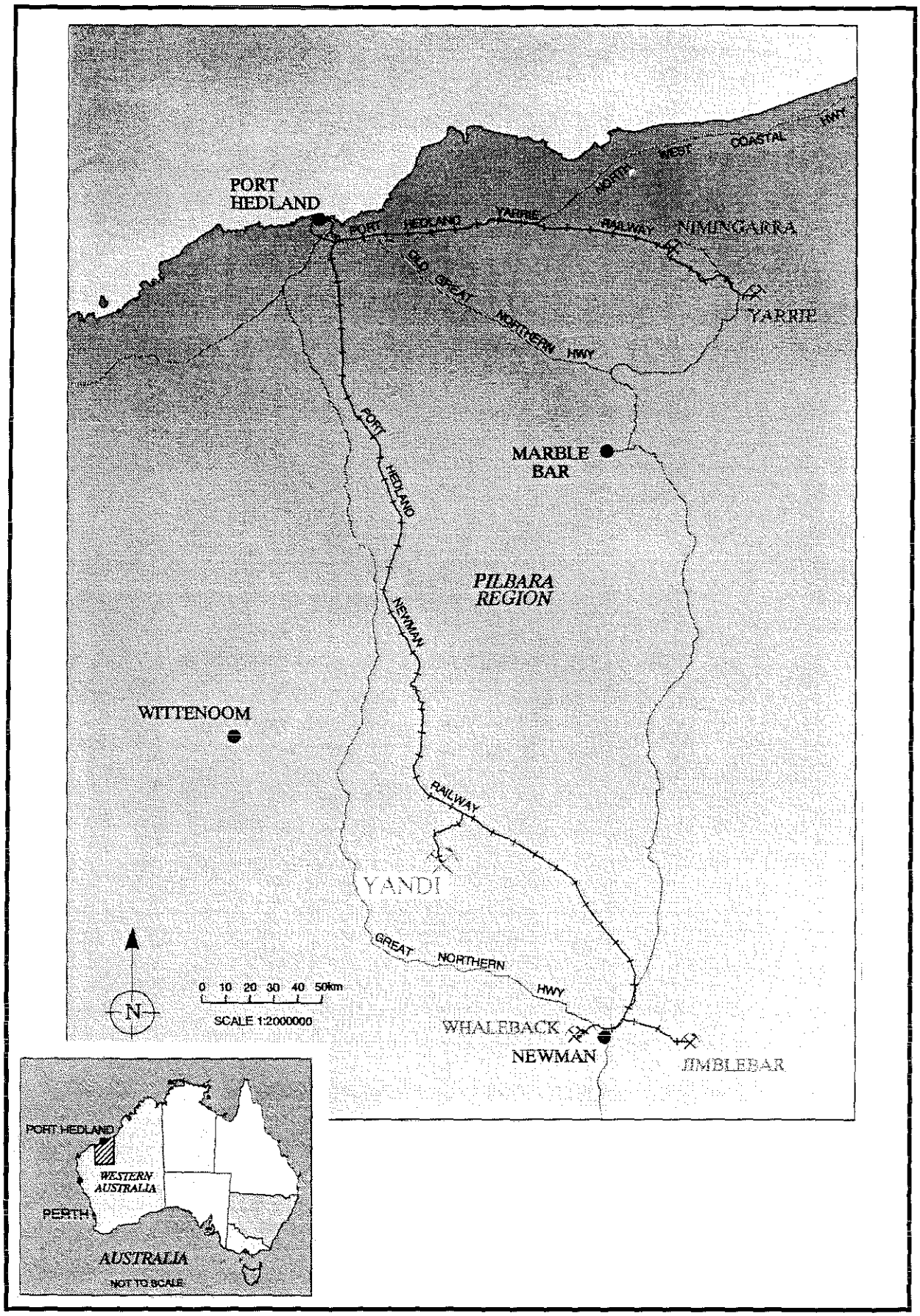

Figure 1. Location plan. (Source: Woodward Clyde, 1995a)

1. Introduction and background

1.1 Purpose of this report

This report and recommendations provides the advice of the Environmental Protection Authority (EPA) to the Minister for the Environment on:

- the environmental acceptability of a proposed second open-cut iron ore mining operation on Mineral Lease (ML) 270SA; and
- the environmental acceptability of a lease-wide Environmental Management Programme being prepared and subsequently implemented.

1.2 Background

BHP Iron Ore Pty Ltd (BHP) is the nominated proponent for the project. BHP proposes to develop a second open-cut mining operation on its Mineral Lease 270SA.

Environmental approval for the first iron ore mining operation on ML 270SA was given to BHP for its current Yandi E2 mine by a previous Minister for the Environment following EPA assessment of BHP-Utah Minerals International's 1987 Public Environmental Review (BHP-Utah Minerals International, 1987). Mining commenced in 1991. In 1992 and 1994, the EPA assessed modifications to the original proposal which involved increased rates of production (EPA, 1992 and EPA, 1994).

The new mine proposed on the lease, known as Central Mesa 1 and 2 (C1/C2) will be mined simultaneously with the current Yandi E2 pit as an integrated operation (Woodward Clyde, 1995a).

In view of the substantial scale of the proposal, the requirement for dewatering during construction and operational phases, the potential for rare and endangered flora and fauna and the uncertainty of impacts to the environment in the long term associated with the decommissioning phase of the project, the EPA determined that the proposal should be formally assessed. BHP submitted a Consultative Environmental Review (Woodward Clyde, 1995a) following guidelines provided by the EPA. The CER was released for a four week public review period ending 25 September 1995.

The location of the project, shown in Figure 1, is approximately 90 km north-west of Newman and 280 km south of Port Hedland (119°4'E, 22°43'S, RL 550-575 m AHD). Figure 2 indicates the location of the iron ore deposits within ML 270SA.

1.3 Structure of the report

This report has been divided into 7 sections.

Section 1 describes the historical background to the proposal and its assessment. Section 2 briefly describes the proposal (more detail is provided in the proponent's Consultative Environmental Review). Section 3 identifies the environmental issues requiring evaluation and provides an outline of the method of assessment, the submissions received and the environmental topics.

Section 4 contains the EPA's evaluation of the proposal and Section 5 summarises the EPA's conclusions and recommendations. Section 6 contains the recommended environmental conditions, and references are listed in Section 7.

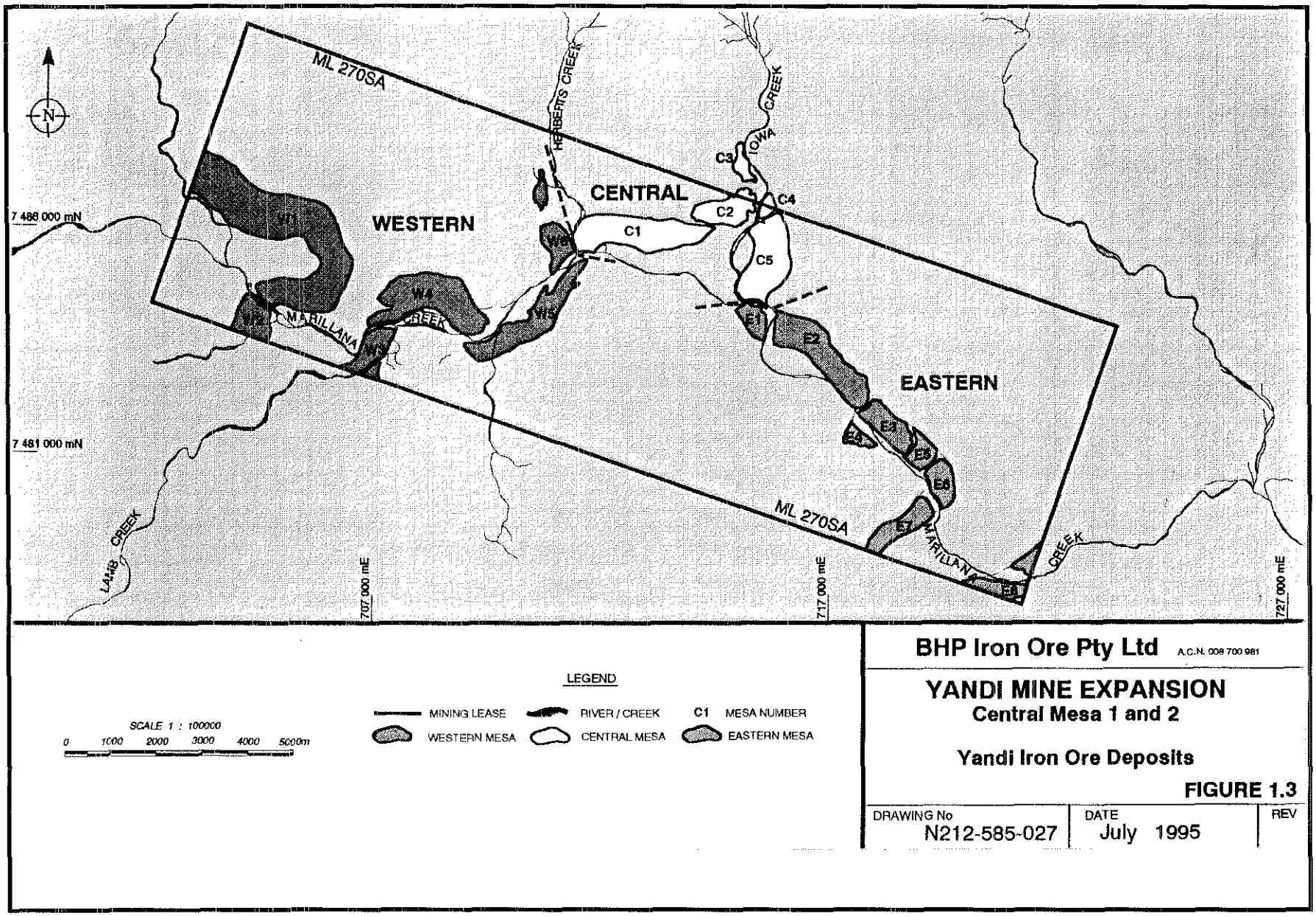

Figure 2. Yandi iron ore deposits. (Source: Woodward Clyde, 1995a)

2. Proposal description

The proposed second iron ore mining operation, Yandi C1/C2, is located on resources totalling approximately 200 Mt. Lowering of the present water table by approximately 40 m is necessary to recover all of the economic ore. The operation will be serviced by an additional rail spur of approximately 10 km length, terminating in a loop. The crushing, screening and trainloading facilities will essentially be a duplication of the infrastructure already in place to serve the existing Yandi E2 operations.

Table 1. Summary of environmental characteristics associated with the mining proposal. (Source: Woodward Clyde, n.d.)

Lease wide characteristics	
Total iron ore resources on ML 270SA	1.2 x 10^9 t
Estimated mining life of ML 270SA	40 years
Yandi C1/C2 proposal	
Iron Ore Resources	200Mt
Mine pit depth	65 m deep (approx.); 40 m below present water table
Dewatering discharge	20,000 m3/day (initial 6 months) reducing to 10,000 m3/day
Total quantity of overburden	80 Mt
Overburden placed out of pit	20 Mt (25%)
Overburden placed in pit	60 Mt
Vegetation impacts from mining and overburden storage	330 hectares
Vegetation impacts from associated infrastructure	180 hectares (approx.)
Vegetation (phreatophytic) impacts from dewatering	70 ha (approx) (assumes no irrigation)
Vegetation (phreatophytic) impacts from decommissioned pits (worst case)	Single pit, Yandi E2 - 40% decline; with Yandi C1/C2 - further 20%
Distance to nearest pastoral station (dust/noise/blasting)	35 km
Distance to Yandi village (mine worker accommodation)	6 km
Marillana Creek catchment area (above Yandi E2)	1,800 km2 (approx.)
Weeli Wolli Creek catchment area (incl. the Marillana/Yandicoogina catchment)	4,150 km2 (approx.)
Fortescue Valley catchment area	31,200 km2 (approx.)
Channel Iron Deposit aquifer, estimated throughflow	2,800 m3/day (approx.)
Shallow alluvial aquifer, estimated throughflow	5 m3/day

BHP (1995) would prefer to manage both the proposed Yandi C1/C2 mine and the existing Yandi E2 mine as an integrated operation. BHP propose to develop a lease-wide Environmental Management Programme (EMP) to assist in the implementation and management of iron ore mining projects within ML 270SA.

3. Identification of environmental issues

3.1 Method of assessment

The purpose of the environmental impact assessment process is to determine whether a proposal is environmentally acceptable or under what conditions it could be environmentally acceptable.

The environmental impact assessment process for this proposal followed the administrative procedures shown in Appendix 1.

The first step in the assessment method is to identify the environmental issues to be considered. A list of topics (or possible issues) was identified by the DEP, on behalf of the EPA, through the preparation of guidelines. These topics were addressed by the proponent in the Consultative Environmental Review (CER) and subsequent documentation.

The proponent's Consultative Environmental Review was available for public comment for a period of four weeks between 28 August 1995 and 25 September 1995. Comments were sought on the proposal from the public, community groups, local and State Government agencies. Four submissions were received from:

- Aboriginal Affairs Department;
- Conservation Council of Western Australia Inc;
- Department of Minerals and Energy; and
- Water Authority of Western Australia.

The responses received were summarised by the Department of Environmental Protection on behalf of the Environmental Protection Authority. This process can add environmental topics which need to be evaluated in terms of the acceptability of potential environmental impacts.

BHP was invited to respond to matters raised in submissions, as summarised by the Department of Environmental Protection. For this project, the Department of Environmental Protection also requested additional information from the proponent. Appendix 2 contains a summary of the matters raised in submissions, including the additional information sought by the DEP, and the proponent's response to those matters.

This information, namely the guidelines, the proponent's CER, the submissions and the proponent's response is then subjected to analysis for environmental acceptability. For each environmental issue, an objective is defined and where appropriate an evaluation framework identified.

Finally, the EPA analysed each of the environmental management issues associated with the proposal against the EPA's environmental management objectives. The EPA considered submissions, and the proponent's responses to submissions and proposed environmental management commitments. Based on this information, the EPA determined, firstly, whether the proposal was environmentally acceptable, and, secondly, whether any modifications were required to make it acceptable.

Limitation

This evaluation has been undertaken using information currently available. The information has been provided by the proponent in the CER and supplementary documentation (in response to guidelines issued by the EPA), by DEP officers utilising their own expertise and reference material, by utilising expertise and information from other State government agencies, information provided by members of the public and industry groups, and by contributions from EPA members.

The Environmental Protection Authority recognises that further studies and research may affect the conclusions. Accordingly, the environmental approval for the proposal is limited.

3.2 Review of topics

Table 1 summarises the EPA's identification of issues requiring evaluation. The topics associated with the proposal are listed, together with the EPA's environmental management objectives. Other columns summarise submissions which relate to the topics listed, and the proponent's responses and proposed environmental management commitments. The final column indicates whether there are any issues not addressed by proponent's commitments or other regulatory processes and which therefore require further EPA evaluation. The issues identified in the final column in Table 1 are evaluated in Section 4 of the EPA's report.

For this proposal the key environmental issues are the local and regional effect on groundwater dependent vegetation, impacts of mining on the groundwater, impacts on Fortescue Valley groundwater system, the preparation and implementation of a lease-wide Environmental Management Programme and decommissioning and rehabilitation.

4. Evaluation of environmental issues

4.1 Impacts of mining on groundwater dependent vegetation

4.1.1 Objective

To minimise the loss of locally and/or regionally significant vegetation associations and habitats.

4.1.2 Technical information

Plants that rely upon the water table for growth and vigour are termed phreatophytes. Phreatophytic vegetation in the Yandi area relies on the shallow alluvial aquifer associated with Marillana creek. Those plants that rely primarily on water held in the unsaturated zone (ie: above the water table) are termed vadophytes. The term xerophyte is given to plants suited to arid conditions (Woodward Clyde, n.d.).

BHP (Woodward Clyde, 1995a) indicate that reduced groundwater levels in the area of Yandi operations due to mine dewatering and pit evaporation (in the longer term) could result in the loss of some phreatophytic vegetation in the riverine vegetation assemblages. The key riverine species are Cadjeput (*Melaleuca argentea*), River Gum (*Eucalyptus camaldulensis*) and Coolibah (*E. victrix*) (Woodward Clyde, n.d.). The phreatophytic vegetation associated with the shallow alluvial groundwater system on Marillana Creek (ie. the mixed stands of Cadjeput and River Gum) rely upon groundwater generally occurring within 2 to 3 m of the surface (Woodward Clyde, n.d.).

Table 1. Issues requiring EPA evaluation

Topics	Proposal characteristics	Objective	Submissions	Proponent response	Identification of issues
			Biophysical		
Changes to landform	Mining of ore will result in the formation of a pit extending approx. 65 m below existing ground level, 40 m of which will be below the present water table; the development of overburden disposal areas (20 Mt or 25% of overburden will be placed outside the pit) and the development of infrastructure to service mining operations.	To ensure the project is managed, during construction, operational and decommissioning phases, to avoid unnecessary impacts and to properly manage unavoidable impacts to an acceptable level.	The potential to share infrastructure (esp. rail) as envisaged in the Pilbara 21 (1992) report has not been examined.	Minimum overburden material to be placed outside of pit (20 Mt). Overburden storage area to blend with surrounding landforms. Monitoring of rehabilitation areas. Commitment that EMP be submitted for operations on lease. Response A3 to submissions.	Addressed by proponent in section 4.4.2 of CER and in response to submissions (Appendix 2). Further EPA evaluation not required.
Impact on vegetation and flora.	Mining activities, such as dewatering, will impact upon vegetation during all phases. Some vegetation will not withstand changes to the watertable and could die.	Rare and priority flora species should be protected. Minimise the loss of locally and/or regionally significant vegetation associations.	Area has significant remnant vegetation. Mulga stands are biologically unique. The flora and fauna of the area are better represented than in the adjacent National Park.	The Steppes/Hill Slopes vegetation association is extensively represented both locally and regionally. Known sites of *Goodenia stellata* (Priority 2 species) are located away from proposed mining activities or will be avoided. Disturbance will be minimised.	Partly addressed by proponent in section 4.5.1 and 4.5.2 of CER and in response to submissions. Local and regional effect on groundwater dependent vegetation is an issue which requires EPA evaluation (see Section 4)

Topics	Proposal characteristics	Objective	Submissions	Proponent response	Identification of issues
Impacts on fauna and habitats.	Mine pit development, overburden disposal area and mine infrastructure will require clearing and disturbance of habitat. Some new habitat, (open water bodies) will form in the decommissioned pits.	Rare and endangered species should be protected.	Rehabilitation should ensure suitable habitat is re-established. Management plan for the Pebble-mound mouse. Ecological changes should be considered.	Minimise area required for construction. Rehabilitation of faunal habitat will occur co-incident with rehabilitation of vegetation.	Addressed by proponent in Section 4.6.2 of CER and in response to submissions A25 - A27, Appendix 2. Further EPA evaluation not required.
Surface water-Marillana Creek, Weeli Wolli Creek system.	Mining activities, such as location of haul roads and bunds, will impact upon surface flow characteristics.	Minimise impacts on the quality and quantity of surface water.	Regional impacts to the Weeli Wolli Creek system and Fortescue Valley system.	Haul road crossing constructed so that there is a minimal change in grade between the upstream and downstream side of the creek. Physical integrity of Marillana Creek (river course as it exists today) to be maintained.	Addressed by proponent in Section 4.2.2 of CER and in response to submissions. Further EPA evaluation not required.
Impact on groundwater.	Mining activities, such as dewatering, creation of voids (the mined out pits), will impact upon groundwater quality, levels, and direction of flow during all phases.	Minimise short and long term effects caused by groundwater use and decommissioned mine pits.	Effect of mining on: • the alluvial, Channel Iron Deposit , and basement aquifers and on the relationships between the aquifers; and • groundwater drawdown, throughflow and salinity.	The regional groundwater model currently under development will allow longer term management options (both during mining and post mining) to be assessed and implemented.	Predicted impacts based on modelling. Further data collection and modelling required to refine long term impacts. EPA evaluation required (see Sections 4.1 & 4.2).
Impacts on Fortescue Valley groundwater system.	The Channel Iron Deposit (CID) ultimately recharges the Fortescue Valley groundwater system. Marillana Creek contributes surface flow to the Fortescue Marsh.	To protect the environment from significant impacts caused by decommissioned mine pits.	Effect on groundwater throughflow and salinity in the aquifer downstream from the decommissioned pit, including the impact on the Fortescue Valley deep aquifer system.	Commitment that an EMP will be prepared. Commitment that regional groundwater model will be developed to assess longer term management options.	Predicted impacts based on modelling. Further data collection and modelling required to refine long term impacts. EPA evaluation required (see Section 4.2).

Topics	Proposal characteristics	Objective	Submissions	Proponent response	Identification of issues
Overburden storage.	Approx. 20 Mt of overburden will be deposited in an overburden storage area external to the Yandi C1/C2 pit.	Maximise the return of overburden to the pits and ensure stability.	The quantity of overburden to be placed in the Yandi C1/C2 pit and the height of the backfill.	Minimum amount of overburden material (20 Mt) will be placed outside of the pit area. Overburden storage will be designed to blend with existing topography.	Addressed by proponent in Section 4.4.2 of CER and in response to submissions. Further EPA evaluation not required.
Pollution issues					
Dust	Mining activities will give rise to dust.	Dust emissions should be controlled so that the environment, including the amenity of nearby residents, is sufficiently protected.		Dust suppression systems will be fitted throughout processing plant. Water tankers will apply water to unsealed roads, haul roads and construction areas.	Management addressed in section 4.8.2 of proponent document. Dust associated with processing facilities covered by works approval and licensing. Further EPA evaluation not required.
Noise	Mining activities will increase ambient noise levels.	To achieve compliance with noise regulations.		A noise monitoring programme will be conducted recording noise levels at the site boundary nearest the mine.	No nearby residences. Management addressed in section 4.9.2 of proponent document and in response to submissions. Further EPA evaluation not required.
Blasting	As part of the iron ore mining operations, blasting will occur at regular intervals during daylight hours.	To protect nearby residences from significant impacts caused by blasting.		Blasting will be conducted during daytime only and at specified times.	No nearby residences. Management addressed in section 4.10.2 of proponent document. Further EPA evaluation not required.
Process water and sewage	Process water and sewage discharge could pollute the environment.	To maintain the environment free from significant pollution impacts.		Covered by DEP works approval and licence conditions, Health Department and DME requirements.	Addressed in DEP conditions, Health Dept. and DME requirements. Further EPA evaluation not required.

Topics	Proposal characteristics	Objective	Submissions	Proponent response	Identification of issues
Social surroundings					
Impacts on Aboriginal sites.	Various activities associated with mining, and increased human presence, could disturb sites.	To manage Aboriginal issues in accordance with relevant State government legislation.	Department of Aboriginal Affairs considers that BHP has shown a commitment to comply with concerns of the Department and the provisions of the *Aboriginal Heritage Act 1972*.	Managed in accordance with relevant legislation. Employee and contractor induction. Consultation and site visits with Aboriginal people.	Managed in accordance with relevant legislation and addressed in sections 3.7 and 4.7.2 of CER. Further EPA evaluation not required.
Regional issues/cumulative impacts.	If approved, the Yandi C1/C2 mine will be the second open cut iron ore mine operating on the Yandicoogina Deposit. Other proposals, including from other proponents, will be proposed in the future and may also proceed. A number of existing and proposed mines also exist in other areas of the Pilbara Region of WA.	To consider the regional cumulative impact of the development on the environment.	The cumulative impact of mining proposals in the region is not being considered.	Cumulative local scale impacts are addressed in proponent response to submissions A1, A2, A16, A27, A38, A42.	Regional cumulative impacts should be considered at a strategic level alongside other regional land use planning issues, and not at the level of the individual proposal. The Pilbara Land Use Planning Group established through the Pilbara 21 Study are undertaking a comprehensive land use strategy for the Pilbara. Further EPA evaluation not required.

Topics	Proposal characteristics	Objective	Submissions	Proponent response	Identification of issues
Environmental monitoring					
Environmental Management Programme (EMP).	BHP propose to develop an EMP to include all aspects of environmental management and monitoring for the combined operations at Yandi.	To ensure the project is managed, during construction, operational and decommissioning phases, to avoid unnecessary impacts and to properly manage unavoidable impacts to an acceptable level.	EMP should be part of the CER.	Proponent has provided a commitment to prepare and implement a lease-wide EMP.	Although the proponent has provided a commitment, the issue of a lease-wide EMP rather than the more standard project specific EMP requires EPA evaluation (see Section 4.3).
Decommissioning					
Decommissioning and rehabilitation.	Residual longer term impacts at the completion of mining operations at Yandi will be mainly associated with the stabilisation of post-mining landforms and hydrological impacts.	To ensure an acceptable rehabilitation and decommissioning programme is put in place which incorporates a "closure strategy" agreed to by the WA Government.	Concerns regarding mining companies walking away from mine sites at decommissioning without fulfilling environmental responsibilities eg: Wittenoom.	BHP has long term commitment to the Pilbara region, backed by a substantial investment in established and committed infrastructure. Proponent has provided a commitment to prepare and implement a lease-wide EMP, including the development of a walk away solution.	To ensure there is no long term liability left to the State, EPA evaluation of this issue is required (see Section 4.4).

Muir Environmental (1995) indicates that River Gum and Coolibah are not generally restricted in their occurrence along the Creek and thus cannot be considered as being true phreatophytes but as vadophytes, ie: primarily unsaturated soil dependent. The table in Appendix 3 provides the possible responses of key species to long-term changes in water availability.

BHP indicate (Woodward Clyde, n.d.) that short term impacts on the local surface hydrology arising from mining the channel iron deposit are likely to arise from two areas:

1. Dewatering

   Enhanced flow in Marillana Creek will occur in the vicinity of the dewatering discharge point. The quantity of flow and the distance it persists downstream will depend on a number of variables including quantity of discharge, saturation of the Creek alluvials, precipitation and rates of evapotranspiration.

2. Engineering

   Works are ongoing to divert minor drainages in order to prevent surface flow into mine areas following rainfall. The current strategy for Marillana Creek is to maintain normal surface hydrological conditions to the greatest extent possible.

BHP (Woodward Clyde, n.d.) indicate that dewatering discharge will cease following the completion of mining and suggest that the ecosystem established in response to greater water availability will return to approximately those occurring pre-mining. BHP (Woodward Clyde, n.d.) also indicate that the dewatering discharge point for the existing Yandi E2 mine will be relocated 2.5 km further downstream and be combined with discharge from the proposed C1/C2 mine and that this will result in the drying out of the existing semi-permanent water body at the current Yandi E2 discharge point.

4.1.3 Comments from key government agencies

The Department of Minerals and Energy indicated that the extent and significance of impacts to phreatophytic vegetation caused by changes to the hydrology was not adequately addressed in the CER.

4.1.4 Public submissions

Submitters are concerned that water bodies forming in the mined out pits will change the ecology of the area.

4.1.5 Response from the proponent

The following information has been provided by the proponent, in an addendum to the Consultative Environmental Review (Woodward Clyde, n.d.), following the public review of its CER:

- short term impacts during mining are small as water dependent species are normally irrigated (Commitment 4, Appendix 4);

- preliminary groundwater modelling predicts that groundwater levels in the proximity of the decommissioned pits will decline to levels that will not be accessible to the existing phreatophytic vegetation associated with the Creek alluvials. A single pit alone at Yandi E2 will be sufficient to cause the decline of around 40% (by area) of the mapped mixed Cadjeput/River Gum community occurring along Marillana Creek. The addition of pits at Yandi C1/C2 is predicted to cause the decline of a further 20% (by area);

- groundwater drawdowns away from the channel iron deposit and alluvial aquifers will not impact on the xerophytic plant communities established there;

- loss of the phreatophytic vegetation community (ie: the mixed Cadjeput and River Gum woodland) in the area of Yandi E2 and C1/C2 will represent between 4 and 10% of confirmed locations in the Pilbara where Cadjeput (*M argentea/leucadendra*) occur. However, taking into account the probable occurrence of Cadjeput in the many other areas where permanent water occurs in the Pilbara region this percentage is likely to be considerably less;

- the Cadjeput occurrence along Marillana Creek represents one of 11 confirmed occurrences of *M argentea* in the Pilbara Region. *M leucadendra* have been mapped at another 15 locations and it is considered these are likely to be the same species of Cadjeput found along Marillana Creek (ie: *M argentea*). In addition, it is considered that Cadjeput occurs at many of the permanent water pools of the Pilbara region; and

- observations made during 1995 indicate that the rate of leakage from the alluvial aquifer to the channel iron deposit in response to dewatering is low, in the Yandi E2 area at least. Pit development may not impact greatly on Creek alluvial aquifer water levels in the short term.

4.1.6 Evaluation

The proponent has provided considerable additional information since the release of its CER. The information, in an addendum to the Consultative Environmental Review (Woodward Clyde, n.d.), summarises information from other technical documents which indicates that:

- dewatering of the Yandi C1/C2 deposit is likely to have similar local impacts to that of Yandi E2, ie; there may be a decline in alluvial aquifer water level but it will be possible to offset by irrigation of the Creek vegetation;
- monitoring of vegetation at the Yandi E2 dewatering site, following relocation of the discharge point downstream, will assist in determining whether Creek vegetation can return to a pre-mining ecosystem once dewatering discharge ceases (proponent commitments 1, 4 and 6, Appendix 4);
- BHP has indicated that it may be desirable to discontinue the irrigation of phreatophytic vegetation at Yandi E2 in order to determine whether they will survive, in the longer term, on water within the Creek alluvials;
- 70 ha (60% of total area of Cadjeput/River Gum habitat in the Yandi area) could be affected by groundwater drawdown due to evaporation from the decommissioned Yandi E2 and Yandi C1/C2 pits;
- BHP intends to maintain the physical integrity of Marillana Creek;
- if the phreatophytes (eg: Cadjeput) do not survive the post mining hydrogeological conditions they will probably be replaced by vadophytes such as River Gum and Coolibah; and
- monitoring will need to be on-going during the life of the mining operations to test predictions and refine the groundwater model so that longer term management options can be optimised.

The Environmental Protection Authority concludes that there remains a lack of full scientific certainty regarding the impacts to phreatophytic vegetation from mining the Yandicoogina iron ore deposit. However, the proponent has provided documentation, based on preliminary modelling results and monitoring of the existing Yandi mine, which addresses these concerns. This information leads the EPA to believe that the impacts to vegetation from the construction and operational phase of mining are manageable, for example, through measures such as irrigation (Commitment 4, Appendix 4). The consequence to vegetation from the decommissioning phase of mining is less well understood, although the proponent has put forward some predictions based upon regional groundwater modelling. The Environmental Protection Authority concludes that mining of the Yandi C1/C2 deposit could proceed providing the proponent undertakes further data collection and monitoring during the life of mining

operations to further test these predictions. This should be reported through an Environmental Management Programme (Recommendation 2) and lead to the development of long term management options prior to mine decommissioning (Recommendation 3).

4.2 Impacts of mining on local groundwater systems and the regional Fortescue Valley groundwater system

4.2.1 Objective

To minimise short and long term effects caused by groundwater use and decommissioned mine pits on groundwater quality (salinity), levels and throughflow.

4.2.2 Policy

Previous EPA assessment

The environmental conditions placed on the approved Yandi E2 mine, required BHP to prepare and implement a plan for on-going water quality in the mined out pit at least 12 months prior to completion. BHP (Woodward Clyde, n.d.) indicate that to assist in the assessment of potential impacts on both the regional and local groundwater system, extensive studies have been undertaken since the commencement of mining in 1991 with the objective of determining the inter-relationship between the groundwaters of the different aquifers. Commitment 5 (Appendix 4) indicates that BHP will continue with the development of the regional groundwater model to assess longer term management options.

Government working group

To date, the Government approach to mining below the water table in the Pilbara has been coordinated through an inter-departmental committee, the Pilbara Iron Ore Environmental Management Committee (PIEC), which has the objective of co-ordinating and reviewing environmental management of the Pilbara iron ore industry. In a letter of 29 September 1995 to the Minister for the Environment and the Minister for Mines, the Minister for Resources Development indicated that several Agencies have responsibilities with projects involving mining below the water table in the Pilbara, and that a co-ordinated approach is required to ensure that the impacts are managed on a regional scale in a balanced and consistent manner. As PIEC's role is broader than just mining below the water table in the Pilbara, the Minister considers it appropriate that a working group be established to focus on this specific issue.

The Minister for Resources Development has sought agreement, from the Minister for the Environment and the Minister for Mines, for the establishment of a working group, comprising representatives from the relevant Government agencies, to develop strategy options for mining below the water table in the Pilbara. The working group would consult with industry and interest groups and would make recommendations to Government on how to manage the issue.

Pilbara Regional Water Resources Review

The Pilbara Regional Water Resources Review Interim Report (Water Authority of Western Australia, 1995), indicates that there does not appear to be a lack of water resources in the region that is likely to impede the development of new industries in the Pilbara. However, the final report will address the issue of groundwater and surface water resources further and as such no definitive conclusions can be drawn from the interim report.

4.2.3 Technical information

The technical information below has been provided by the proponent in an addendum to the Consultative Environmental Review (Woodward Clyde, n.d.) and provides a summary of

predicted impacts only. A general description of the hydrology and hydrogeology of the area has been described in Section 3.4 of the proponent's CER (Woodward Clyde, 1995a).

Impacts associated with dewatering of the mines during construction and operational stages and with mine pits left open at the decommissioning stage include:

- initial increase in combined discharges from Yandi E2 and C1/C2 to Marillana Creek may result in more surface water flow in the Creek for a greater distance downstream than presently occurs;
- modelling (worst case scenario) has shown that, at mine closure, evaporation from the Yandi E2 pit alone could result in drawdowns of more than 2 m in the channel iron deposit, alluvial and basement aquifers for an area approximately 5 km upstream and downstream of the decommissioned pit;
- modelling (worst case scenario) predicts that the addition of decommissioned pits at Yandi C1/C2 could result in drawdowns of greater than 2 m for an additional 8 km upstream but would have no additional impact downstream;
- the option of diverting Marillana Creek flow would not fill the pit to pre-mining groundwater levels in a single "average" year, ie: it would take a number of years of consecutive "average" flows (or greater) to achieve this;
- pit waters will become salinised as evaporation will exceed total inflows; even with diversion of Marillana Creek flow;
- the development of multiple pits will mean that water levels would never recover to pre-mining groundwater levels;
- any escape of saline waters from the decommissioned mine pit would occur through density driven processes, where the more dense and saline water would migrate at depth through the groundwater system;
- routine groundwater samples which have been collected from the channel iron deposit aquifer since mining of Yandi E2 commenced in 1991 indicate that water quality both upstream and downstream of Yandi E2 are comparable and potable;
- the Marillana/Weeli Wolli Creek groundwater system discharges to the deeper saline Fortescue Plain aquifer sub-system of the Fortescue Valley and as a result, the addition of future potentially salinised water from the Marillana/Weeli Wolli Creek system would not impact on the water quality of this system; and
- preliminary groundwater modelling predicts that aquifer water levels approximately 5 km downstream of Yandi E2 (and hence throughflow) would remain little changed from that presently occurring; and

4.2.4 Comments from key government agencies

In general, the government submissions considered the CER contained insufficient detail on the magnitude of the permanent changes in groundwater salinity, flows and levels in the Channel Iron Deposit aquifer and Marillana Creek alluvium, which would result from mining the Yandi iron ore deposits. It was considered necessary to quantify local and regional impacts associated with operational (dewatering) and decommissioning (open mine pits) phases of the proposal.

4.2.5 Public submissions

In general, salinisation of aquifers, reduced flow in aquifers and cumulative impacts from exposed water bodies in the mined out pits on the environment were raised in submissions. Protecting the water resource for the long term sustainability of interests other than mining, such as pastoralism, horticulture and tourism and the long term responsibilities of mining companies were also concerns.

4.2.6 Evaluation

The Environmental Protection Authority concludes that there remains a lack of full scientific certainty regarding the impacts to local and regional groundwaters from mining the Yandicoogina iron ore deposit. However, the proponent has provided documentation in the CER which indicates that mining does not appear to be impacting the quality of the groundwater during the operational phase. The consequence to local and regional groundwaters from the decommissioning phase of mining is less well understood, although the proponent has put forward some predictions based upon regional groundwater modelling. The Environmental Protection Authority considers that the effects of the decommissioned mine pits on the groundwater and the local environment in the long term are likely to be irreversible and that the lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to minimise environmental degradation.

The Environmental Protection Authority notes the intention of the State Government to establish a working group to examine this issue on an broader basis rather than at the scale of the individual mine. In view of the pressures placed on the local environment, BHP has an on-going responsibility in its pursuit of sustainable development, to enlist the technologies and financial resources they command to the prevention of environmental degradation. The Environmental Protection Authority considers that the proponent should contribute to the working group through further data collection and monitoring during the life of mining operations to further test long term predictions. A programme for monitoring and reporting should be established through an Environmental Management Programme and lead to development of long term management options (Recommendation 2).

The Environmental Protection Authority notes the potential for future development of this ore body and considers that a coordinated approach to hydrological research across mining tenements will contribute more effectively to the long term management of this area. It is the Environmental Protection Authority's view that the Pilbara Iron Ore Environmental Management Committee (PIEC) should undertake this coordinating role.

4.3 Lease-wide Environmental Management Programme

4.3.1 Objective

To ensure this project and future mines on ML 270SA are managed, during construction, operational and decommissioning phases, to avoid unnecessary impacts and to properly manage unavoidable impacts to an acceptable level.

4.3.2 Policy

In approving BHP's first Yandicoogina iron ore mine, the Minister for the Environment set a condition which required BHP to fulfil the commitments it made. Commitments 1 and 2 of the environmental statement of approval for the Yandi E2 mine state:

1. The proponent will submit an environmental monitoring and management programme with the mining proposals to the State in accordance with the State Agreement Act.

2. Regular assessment of monitoring results and management effectiveness are to be reported as part of the monitoring and management programme. Reports will be submitted to the responsible Minister at intervals specified in the Act.

The EMP required by commitment 1 for the Yandi E2 project was approved by a previous Minister for the Environment on the 10 January 1992.

4.3.3 Technical information

In its CER document BHP (Woodward Clyde, 1995a) has indicated that to achieve maximum operational efficiency and effective environmental management, it intends to manage both the current Yandi E2 and proposed Yandi C1/C2 minesites as an integrated operation. Accordingly, BHP would prefer to operate within its lease area ML 270SA under a lease-wide EMP arising from this proposal.

4.3.4 Comments from key government agencies

There were no comments in relation to this issue from key government agencies.

4.3.5 Public submissions

Submitters expressed concern that the proposed EMP is being established "on the run". Instead, the CER should clearly identify the environmental impacts of the Yandi mine expansion and have in place a management plan that not only addresses BHP's project specifically but also the wider ramifications to the region.

4.3.6 Response from the proponent

Following the release of its CER for the Yandi C1/C2 proposal, BHP has provided the following amended commitments (see Appendix 4):

Commitment 1

BHP will prepare and implement an Environmental Management Programme (EMP) for the operations on ML 270SA to the requirement of the Department of Environmental Protection. The EMP will include the development of long-term management options and walk-away solutions for the site. The EMP will be reviewed and updated as necessary.

Commitment 2

Regular assessment of monitoring results and management effectiveness will be reported as part of the EMP and according to existing arrangements as specified in the Iron Ore (Marillana Creek) Agreement Act, 1991.

A site specific management plan for the Pebble-mound mouse will be included in the revised EMP applying to all Yandi operations.

4.3.7 Evaluation

In responding to submissions (Appendix 2), BHP has indicated that:

- the total iron resources at Yandi on ML 270SA is estimated at 1.2 x 10^9 tonne and it is planned that most of this reserve will be mined eventually; and
- it is anticipated that mining on ML 270SA will extend over the next 40 years.

Based on environmental impact assessment of many existing iron ore operations in the Pilbara, the EPA concludes that the principles and practices for environmental management of proposals within BHP's lease are likely to be the same or similar. It is considered that the environmental issues associated with the Yandi E2 mine will also apply to the Yandi C1/C2 mine and subsequent proposals within BHP's lease. The EPA believes the proposed integration of operations between mine sites, including the implementation of a lease-wide management programme, will assist BHP with its mine planning and rehabilitation and should also increase environmental performance. The EPA concludes that environmental management throughout BHP's lease could be done under one Environmental Management Programme without diminishing environmental protection. The EMP should contribute to the development of long term management options for the lease. The preparation and implementation of a lease-wide

Environmental Management Programme to manage the environment which is regularly reviewed and updated to reflect continuous improvement principles is therefore environmentally acceptable (Recommendation 2).

The Environmental Protection Authority foreshadows that future mining proposals within BHP's lease area, would be likely to be environmentally acceptable if implemented in accordance with an approved lease-wide environmental management programme. The level of environmental impact assessment for future development activities would still need be determined on a case-by-case basis.

4.4 Decommissioning and rehabilitation

4.4.1 Objective

To ensure an acceptable rehabilitation and decommissioning programme is put in place which incorporates a "closure strategy" agreed to by the Western Australian Government.

4.4.2 Policy

There is no definitive policy regarding decommissioning and rehabilitation. However, the following comments are derived from previous EPA reports and provide some guidance.

1. Community expectations for the rehabilitation of mined lands have increased significantly over the last decade. It is recognised that for rehabilitation to be effective it must be integrated into the mining plans, not left to the conclusion of mining (EPA, 1991 Bulletin 547).

2. It is of paramount importance to the State that rehabilitation management does not impose short or long term costs on the community of Western Australia. This is particularly relevant when the success of rehabilitation cannot be evaluated in the short to medium term (EPA, 1994, Bull 766).

4.4.3 Technical information

Residual longer term impacts at the completion of mining operations at Yandi will be mainly associated with the stabilisation of post-mining landforms and hydrological impacts.

BHP indicate in its response to submissions that, partial infilling of the mine pits will occur during mining. However, due to a shortfall of overburden material the pits cannot be completely infilled. As a result, areas of the pits will remain open on completion of mining. Groundwater will flow into the pits and form open water bodies, although BHP (Woodward Clyde, n.d.) cannot be certain to what level 'groundwater' will recover in a backfilled pit. Due to the high evaporation rates in the Pilbara and the open water surface area, pit water levels will not recover to pre-mining groundwater levels. Salinity levels will build up in decommissioned pits. Worst case modelling has indicated that pit water salinity would approach 45,000 mg/l within 100 years of the cessation of mining (Woodward Clyde, n.d.).

BHP in its response to submissions (Appendix 2) reveal that developed longer term management options are conceptual at this stage and are based on modelling predictions. Monitoring will need to be on-going during the life of mining operations to test the predictions and refine the model so that the longer term management options can be optimised.

4.4.5 Comments from key government agencies

In general it was recognised that impacts associated with the decommissioning phase of BHP's mining operations on ML 270SA required further definition.

4.4.6 Public submissions

Submitters consider that the full impact on water tables around the mines will only be seen when the mining companies are long gone. The salinisation of the Goldsworthy pit and reference to other mines where mining occurs or will occur below the water table was also mentioned. Submitters consider that the mining companies must be willing to cover exposed water tables as part of the normal costs of developing a deposit.

4.4.7 Response from the proponent

In responding to submissions (Appendix 2), BHP has indicated that:

- the total iron resources at Yandi on ML 270SA is estimated at 1.2 x 10^9 tonnes and it is planned that most of this reserve will be mined eventually;
- it is anticipated that mining on ML 270SA will extend over the next 40 years;
- BHP has a long term commitment to development in the Pilbara region which is backed by a substantial investment in established and committed infrastructure;
- BHP has adopted a policy of achieving a high standard of environmental management at all of its operations, and to undertake necessary research and development studies to minimise environmental impact;
- it is impractical to infill the mined-out pits to a level which will cover the exposed water table. The amount of material required would greatly exceed available overburden and would need to be sourced from areas that would otherwise remain undisturbed;
- longer term management options following mining are conceptual at this stage and are based on modelling predictions. Monitoring will need to be ongoing during the life to mining operations to test the predictions and refine the model so that the longer term management options can be optimised; and
- an appropriate long term management strategy will be developed based on monitoring and refined modelling during the course of mining operations.

4.4.8 Evaluation

The EPA recognises that

- the hydrology of the local and regional aquifers and surface water systems have been subject to on-going investigation and modelling to determine probable long-term performance during and following mining. However, the ability of the model to predict the performance of these systems and environmental consequences has been limited by data availability;
- a conservative modelling approach (ie: worst case) has been used and all available data (eg: streamflow, rainfall, aquifer transmissivity) has been incorporated to produce estimates of water quality (salinity), levels, throughflow and surface level ranges;
- that mined out pits will become salty. For example, pit water salinity for the Yandi E2 mine once decommissioned would approach 45,000 mg/l within 100 years of the cessation of mining (based on 'worst case' modelling); and
- this information has been compiled into a series of technical reports, which are referenced in section 8 of this report.

Although the principles influencing the hydrology and hydrogeology of the local and regional area have become apparent, much of the work to date must be regarded as indicative of what may be expected. More detailed studies of the groundwater and surface water hydrology of the area should be undertaken to confirm short term and long term interactions between the aquifers comprising the groundwater system, the surface water characteristics and those components of the environment influenced by changes in their characteristics (Recommendation 3).

5. Conclusions and recommendations

BHP (Woodward Clyde, 1995a), indicate that the proposed new commitments have been formulated with the intention of including specific environmental management measures in an Environmental Management Programme which will be periodically revised and submitted for review by the Department of Environmental Protection. BHP considers that this will facilitate a more effective environmental management system as practices can be modified in response to monitoring programmes and any operational change.

The commitments have been reviewed through the assessment process by the Department of Minerals and Energy, the Water Authority of Western Australia and the Department of Environmental Protection. The commitments have been modified as a result of the environmental assessment process and are considered acceptable to the EPA. Where the commitments are at variance with the EPA's views, the recommendations of this report take precedence.

Following review of the proponent's CER and supplementary documentation, the issues raised in the public submissions, advice received from government departments, relevant literature and the proponent's environmental management commitments, the Environmental Protection Authority concludes that :

- the proposed Yandi C1/C2 open cut iron ore mine is environmentally acceptable; and
- the proposal to prepare and implement a lease-wide Environmental Management Programme for ML 270SA is environmentally acceptable.

Based on the information currently available, the EPA makes the following recommendations.

Recommendation 1

The proposal is environmentally acceptable subject to the proponent's environmental management commitments and the EPA's recommendations in this report.

Recommendation 2

That within 12 months of any approval being granted for the C1/C2 mine, the proponent prepare and subsequently implement a lease-wide Environmental Management Programme for Mineral Lease 270SA to the requirements of the Environmental Protection Authority. The EMP should detail the procedures and practices for protection of the environment during all phases of mining and include but not be limited to the following:

- **groundwater monitoring and management;**
- **surface water monitoring and management including measures for the protection of the integrity of Marillana Creek;**
- **waste management, including overburden, liquid, solid and gaseous wastes;**
- **pollution prevention measures, including noise and dust;**
- **rolling development of rehabilitation plan for mine sites including, landscape management and environmental performance criteria; and**
- **development of a comprehensive monitoring, management and reporting programme for the above.**

The Environmental Protection Authority foreshadows that future mining proposals within BHP's lease area, would be likely to be environmentally acceptable if implemented in accordance with an approved lease-wide environmental management programme. The level of

environmental impact assessment for future development activities would still need be determined on a case by case basis.

Recommendation 3

Within 24 months following commissioning of the Yandi C1/C2 mine and prior to decommissioning of any mine on ML 270SA, the proponent should prepare and subsequently implement a plan which describes the process for decommissioning and rehabilitation on the lease and which provides for long term management of salinity in the mined-out pits and any regional effects arising from mining the aquifer, and include the development of a 'walk away' solution, to the requirements of the Environmental Protection Authority.

Note: A walk away solution means that the site shall either no longer require management at the time the proponent ceases mining operations, or if further management is deemed necessary, the proponent shall make adequate provision so that the required management is undertaken with no liability to the State.

6. Recommended environmental conditions

Based on its assessment of this proposal and the recommendations in this report, the Environmental Protection Authority considers that the following Recommended Environmental Conditions are appropriate.

PROPOSAL:	DUPLICATION OF IRON ORE MINING OPERATION, YANDI MINE, ML 270SA
CURRENT PROPONENT:	BHP IRON ORE PTY LTD

This proposal may be implemented subject to the following conditions:

1 Proponent Commitments

The proponent has made a number of environmental management commitments in order to protect the environment.

1-1 In implementing the proposal, the proponent shall fulfil the commitments made in the Consultative Environmental Review and in response to issues raised following public submissions; provided that the commitments are not inconsistent with the conditions or procedures contained in this statement.

2 Implementation

Changes to the proposal which are not substantial may be carried out with the approval of the Minister for the Environment.

2-1 Subject to these conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal.

2-2 Where, in the course of the detailed implementation referred to in condition 2-1, the proponent seeks to change the designs, specifications, plans or other technical material submitted to the Environmental Protection Authority in any way that the Minister for the Environment determines, on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.

3 Proponent

These conditions legally apply to the nominated proponent.

3-1 No transfer of ownership, control or management of the project which would give rise to a need for the replacement of the proponent shall take place until the Minister for the Environment has advised the proponent that approval has been given for the nomination of a replacement proponent. Any request for the exercise of that power of the Minister shall be accompanied by a copy of this statement endorsed with an undertaking by the proposed replacement proponent to carry out the project in accordance with the conditions and procedures set out in the statement.

4 Environmental Management Programme

A detailed Environmental Management Programme should contribute to the development of long term management options through comprehensive monitoring and management practices.

4-1 Within 12 months of approval being granted for the C1/C2 mine, the proponent shall prepare a lease-wide Environmental Management Programme for Mineral Lease 270SA to the requirements of the Environmental Protection Authority. The EMP shall detail the procedures and practices for protection of the environment during all phases of mining and include but not be limited to the following:

(1) groundwater monitoring and management;

(2) surface water monitoring and management including measures for the protectionof the integrity of Marillana Creek;

(3) waste management, including overburden, liquid, solid and gaseous wastes;

(4) pollution prevention measures, including noise and dust;

(5) rolling development of rehabilitation plan for mine sites including, landscape management and environmental performance criteria; and

(6) development of a comprehensive monitoring, management and reporting programme for the above.

4-2 The proponent shall implement the Environmental Management Programme required by condition 4-1 to the requirements of the Environmental Protection Authority on advice of the Department of Minerals and Energy, the Water Authority of Western Australia and the Department of Resources Development.

5 Decommissioning

The satisfactory decommissioning of the project, removal of the plant and installations and rehabilitation of the site and its environs is the responsibility of the proponent.

5-1 At least 24 months following commissioning of the Yandi C1/C2 mine and prior to decommissioning of any mine on ML 270SA, the proponent shall prepare a plan which describes the process for decommissioning and rehabilitation on the lease and which provides for long term management of salinity in the mined out pits and any regional effects arising from mining the aquifer, and include the development of a 'walk away' solution, to the requirements of the Environmental Protection Authority.

Note: A walk away solution means that the site shall either no longer require management at the time the proponent ceases mining operations, or if further management is deemed necessary, the proponent shall make adequate provision so that the required management is undertaken with no liability to the State.

5-2 The proponent shall implement the plan required by condition 5-1 to the requirements of the Environmental Protection Authority on advice of the Department of Minerals and Energy and the Department of Resources Development.

6 Time Limit on Approval

The environmental approval for the proposal is limited.

6-1 If the proponent has not substantially commenced the project within five years of the date of this statement, then the approval to implement the proposal as granted in this statement shall lapse and be void. The Minister for the Environment shall determine any question as to whether the project has been substantially commenced.

Any application to extend the period of five years referred to in this condition shall be made before the expiration of that period to the Minister for the Environment.

Where the proponent demonstrates to the requirements of the Minister for the Environment on advice of the Department of Environmental Protection that the environmental parameters of the proposal have not changed significantly, then the Minister may grant an extension not exceeding five years.

7 Compliance Auditing

To help determine environmental performance, periodic reports on progress in implementation of the proposal are required.

7-1 The proponent shall submit periodic Progress and Compliance Reports, in accordance with an audit programme prepared by the Department of Environmental Protection in consultation with the proponent.

Procedure

1 Unless otherwise specified, the Department of Environmental Protection is responsible for assessing compliance with the conditions contained in this statement and for issuing formal clearance of conditions.

2 Where compliance with any condition is in dispute, the matter will be determined by the Minister for the Environment.

Note

The proponent is required to apply for a Works Approval and Licence for this project under the provisions of Part V of the Environmental Protection Act.

7. References

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Forrest R 1995, *Pilbara Regional Water Resources Review Interim Report*, Report to the Water Authority , Report No. WP 205, unpub.

Muir Environmental 1995, Possible long-term impacts of the Yandicoogina Iron Ore Project on riverine species along Marillana Creek, unpub.

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Raff M, *The renewed prominence of Environmental Impact Assessment: "A Tale of Two Cities"*, Environmental and Planning Law Journal , vol. 12, no.4, 1995, pp.241-258

Weston A, Trudgeon M 1995, Vegetation and Flora Survey Marillana/Weeli Wolli Creeks and Paleochannel, unpub.

Woodward-Clyde Pty Limited 1995a, *Yandi Mine Expansion Central Mesa 1 and 2*, Consultative Environmental Review, unpub.

Woodward-Clyde Pty Limited (n.d.), *Addendum to Yandi Mine Expansion Central Mesa 1 and 2 Consultative Environmental Review*, unpub.

Woodward-Clyde Pty Limited 1995, *Marillana Creek Environmental Study*, unpub

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Woodward-Clyde Pty Limited 1995, *Marillana Creek Investigations-Surface Water Balance for the Fortescue Marsh System*, unpub.

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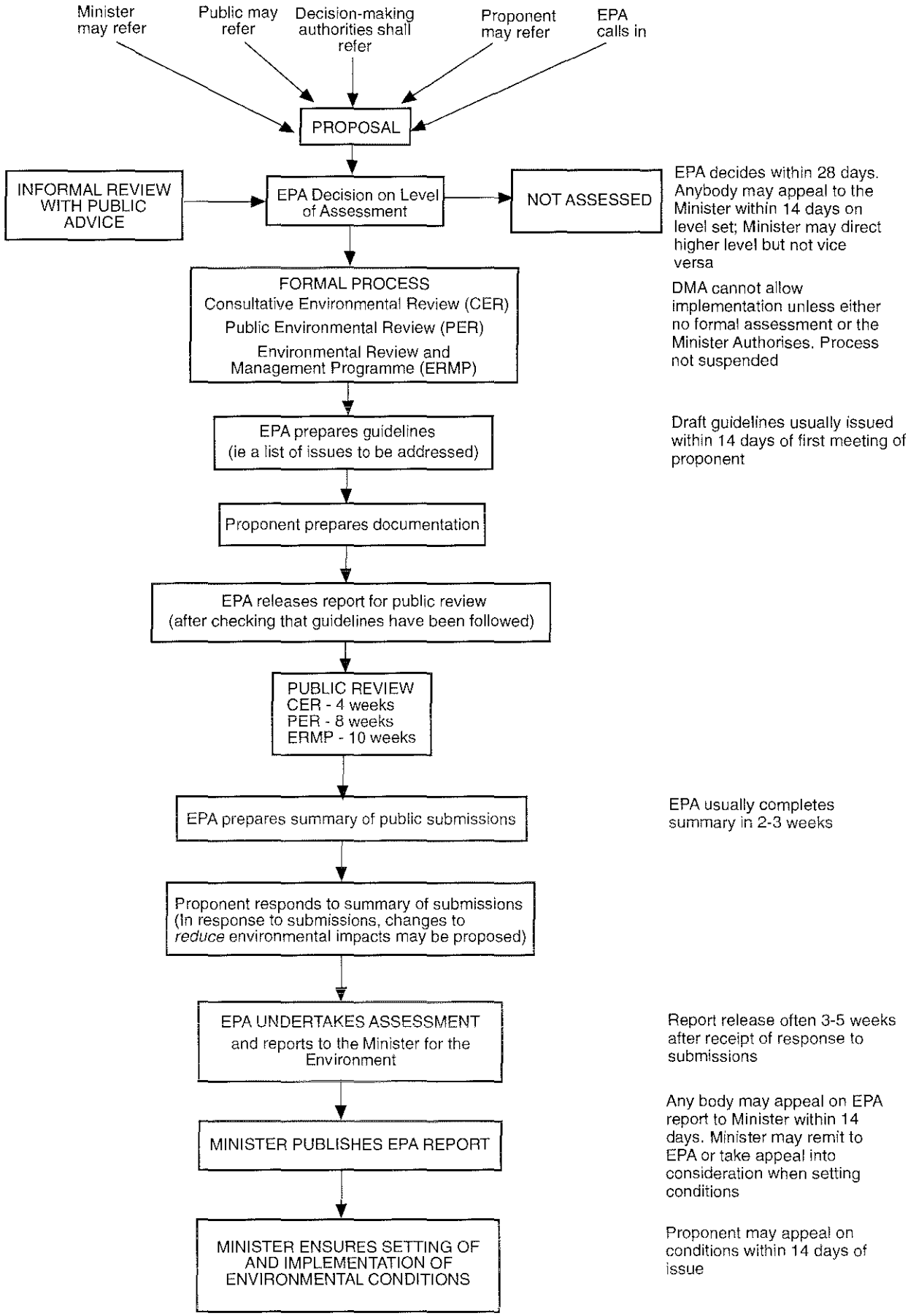
Appendix 1

Environmental Impact Assessment flow chart


Minister may refer
Public may refer
Decision-making authorities shall refer
Proponent may refer
EPA calls in
PROPOSAL
INFORMAL REVIEW WITH PUBLIC ADVICE
EPA Decision on Level of Assessment
NOT ASSESSED
EPA decides within 28 days. Anybody may appeal to the Minister within 14 days on level set; Minister may direct higher level but not vice versa
FORMAL PROCESS
Consultative Environmental Review (CER)
Public Environmental Review (PER)
Environmental Review and Management Programme (ERMP)
DMA cannot allow implementation unless either no formal assessment or the Minister Authorises. Process not suspended
EPA prepares guidelines (ie a list of issues to be addressed)
Draft guidelines usually issued within 14 days of first meeting of proponent
Proponent prepares documentation
EPA releases report for public review (after checking that guidelines have been followed)
PUBLIC REVIEW
CER - 4 weeks
PER - 8 weeks
ERMP - 10 weeks
EPA prepares summary of public submissions
EPA usually completes summary in 2-3 weeks
Proponent responds to summary of submissions (In response to submissions, changes to *reduce* environmental impacts may be proposed)
EPA UNDERTAKES ASSESSMENT
and reports to the Minister for the Environment
Report release often 3-5 weeks after receipt of response to submissions
MINISTER PUBLISHES EPA REPORT
Any body may appeal on EPA report to Minister within 14 days. Minister may remit to EPA or take appeal into consideration when setting conditions
MINISTER ENSURES SETTING OF AND IMPLEMENTATION OF ENVIRONMENTAL CONDITIONS
Proponent may appeal on conditions within 14 days of issue

Appendix 2

Summary of submissions and proponent's response

PREPARED FOR
BHP Iron Ore Limited

November 1995
Project No. A330007\0006
Document R001-B

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BHP IRON ORE PTY LIMITED

YANDI MINE EXPANSION
CENTRAL MESA 1 AND 2

RESPONSES TO ISSUES RAISED IN
PUBLIC SUBMISSIONS ON THE CER

The following addresses issues raised in public submissions on the CER that was prepared by BHP for the proposed Yandi Mine Expansion. The questions are as summarised by the Department of Environmental Protection. However, they have been re-ordered under broad subject headings. References made in responses to the questions are listed in the Addendum to Yandi Mine Expansion Central Mesa 1 and 2 - Consultative Environmental Review.

REGIONAL DEVELOPMENT AND CUMULATIVE IMPACTS

1. The CER does not adequately address regional impacts. The Yandi proposals around Marillana Creek, Yandicoogina Creek take no heed of other regional developments. These being the development proposed by CRA (Hamersley) for the areas surrounding this project namely E47/5, E47/5, E47/620, E47/6, E47/7.

A1. No specific details of mining development proposals have been submitted for any of the above leases. It is therefore not possible for BHP to address all possible future development scenarios. It is presumed that each future development will be subject to an environmental impact assessment by the State Government and that any cumulative impacts relative to existing operations will be addressed as part of this assessment process.

2. Other regional iron ore mines have not been taken into account in the CER and yet in one way or another will have a cumulative impact on the environment of the Pilbara.

A2. See response to question 1.

3. Railway developments were discussed in the Pilbara 21 document. The document does not take into account the proposed rail lines running through BHP's own lease ML270SA or being developed adjacent to ML270SA through E47/5 and the issue of third party rail sharing provisions both as an environmental and economic issue have not been addressed.

A3. The alignment for the Hamersley Iron railway in Attachment D - Map 4 - Land Use Principles for the Central Pilbara of the Pilbara 21 Study document is only schematic. No detailed alignment has been presented by Hamersley Iron, to date. However, it is thought probable that this alignment would be located to the south of ML270SA. As the Yandi railspur proposed in the CER document resides solely on ML270SA it is considered unlikely that a third party will ever seek access to this line.

REGIONAL FLORA AND VEGETATION

4. Which vegetation units will be affected by the proposal, how much will be affected and what is the local and regional significance of the vegetation affected? (CER Section 3.5.1.1)

A4. Section 4.5.1 of the CER on vegetation and flora impacts states that changes to the landform will impact the natural vegetation and flora predominantly in the Steppes/Hill Slopes vegetation associations. This landform category was divided into four sub-categories as follows:

(i) *Triodia basedowii* (spinifex) Dominate Steppes
(ii) *Triodia wiseana* Dominated Steppes
(iii) Mixed *Triodia* (spinifex) Steppes
(iv) *Acacia aneura* Woodlands

These sub-categories are described in detail in section 3.5.1.1 of the CER.

Figure 3.3 of the CER illustrates the occurrence of the vegetation association in relation to the proposed mining area. Direct impacts from mining and overburden storage will permanently affect 330 hectares in the mine area. Associated infrastructure will impact to varying degrees on approximately 180 hectares. Vegetation surveys conducted over these areas did not identify any Declared Rare Flora. The Steppes/Hill Slopes vegetation unit is extensively represented both locally and regionally.

See responses to questions 41 and 47 with respect potential impacts on riverine vegetation.

5. How widespread is the Steppes/Hill Slopes vegetation association and what is the conservation significance of the population within the project area? How much of this association will be affected by the proposal? (CER Section 4.5.1)

A5. See response to question 4.

6. Are there known populations of the Priority 2 species *Goodenia stellata* outside the project area? What is the conservation significance of the population within the project area and will it be affected by the proposal? Will the survey and management of this species be undertaken before development proceeds and on advice of the Department of Conservation and Land Management? (CER Section 3.5.2)

A6. Populations of *Goodenia stellata* have been identified outside of the project area. The Australian Systematic Botanical Society (1981) lists the Gibson Desert as the region of occurrence for this species. The Western Australian Herbarium also contains a collection of this species from 64 miles north of Sandstone towards Wiluna (Ecologia, 1995).

Goodenia stellata was recorded as occurring at low densities at 5 sites during the vegetation survey conducted on the project area (Ecologia 1995). The landforms of these sites include breakaway, plain gorge and minor drainage associated with Marillana Creek.

One occurrence was recorded along Herberts Creek adjacent to the proposed C1 mining area, where disturbance from mining will be avoided. Other recorded occurrences are located further away from proposed mining activities. Section 4.5.2 of the CER states that a detailed survey will be undertaken to determine the distribution of *Goodenia stellata* and four other unidentified species in the C1/C2 area.

7. The area covered by the mines in this area of the Pilbara has significant remnant vegetation, as it has neither been degraded by fire nor pastoral activity (over grazing). The CER fails to comprehend completely the issues of regional biological integrity and its maintenance.

A7. BHP appreciates the conservation value of remnant vegetation of this area of the Pilbara and endeavours to minimise the area impacted by its mining operations. This policy and commitment to protecting the regional biological integrity is also demonstrated by BHP's regional research and management programmes including:

Extensive rehabilitation of degraded pastoral stations;

Initiation of an Environmental Management Programme for the Weeli Wolli Springs area; and

Initiating and maintaining an herbarium of Pilbara plant species.

8. Will the introduced flora species be spread by mining operations and what management of these species is proposed?

A8. Many species of introduced flora occurred in the Yandi area prior to mining development. Care is and will continue to be taken by BHP not to spread introduced flora. However, there are few effective means available to limit the spread of some persistent species.

REHABILITATION

9. How will removal of topsoil be undertaken - all at once? progressive? and is there is plan to optimise its use? (CER Section 2.3.1).

A9. Topsoil, where recoverable, will be removed progressively as the area is required for mining or overburden storage. Because there is only limited topsoil available compared to the disturbed surfaces, it will be selectively used in areas where it is most beneficial for rehabilitation.

10. What rehabilitation measures are proposed where there is not enough topsoil? Will overburden management utilise best soil medium of least contrasting colour on the outside? (CER Section 4.4.2).

A10. Where sufficient topsoil is not available rehabilitation surfaces will be covered with mine overburden material which has been classified as being a suitable vegetation growth medium. Material will also be selected which does not contrast in colour with surrounding landforms.

11. Will seed collected from the local provenance be used in revegetation operations? (CER Section 4.5.2).

A11. Revegetation of overburden dumps and other disturbed areas will be carried out using seed from local native plant species. However, not all seed will be sourced from the local provenances as there are limitations to its availability.

12. What parameters constitute a stable community?

A12. Parameters for determining a stable community in terms of revegetation completion criteria will be established and refined as rehabilitation progresses in consultation with DEP and CALM. A stable community is generally achieved when critical plant species have achieved a desired density and distribution, and are self-sustaining.

13. How long after decommissioning will the progress of revegetated areas be assessed (in years?)

A13. It is difficult to pre-determine the number of years that will be required for assessing the progress of revegetation. It is anticipated that mining on ML270SA will extend over the next 40 years. Areas which have been progressively rehabilitated will be monitored over this period while there is an active presence in the area. Experience gained from this monitoring will dictate how long monitoring will be required past final decommissioning. Monitoring will continue until the future agreed ongoing land use objectives are met.

14. How often will the vegetation be assessed (number of times per year) and what parameters will be assessed? (CER Section 4.5.2)

A14. Riverine revegetation is currently monitored on an annual basis. This monitoring programme will be extended to cover areas affected by dewatering of Yandi C1/C2. Parameters assessed during monitoring include categorised health ratings, foliage density and numbers of seedlings. Photographic records are also maintained. Monitoring is conducted at sites located upstream, adjacent to and downstream of the mining operation and discharge point.

15. What monitoring frequency is proposed, and what action is proposed should impacts be detected, and to whose satisfaction? (CER Section 4.5.3).

A15. Monitoring proposed for riverine vegetation near Yandi C1/C2 will essentially be an extension of the current monitoring programme described in A13. Should any impacts be detected, practical solutions and specific actions will be devised in consultation with the Department of Environmental Protection.

16. How will the impact and financial responsibility in terms of rehabilitation be apportioned around the Weeli Wolli system, should the long term impacts include major environmental degradation?

A16. BHP has a long term commitment to development in the Pilbara region which is backed by a substantial investment in established and committed infrastructure. Mining at Yandi is anticipated to extend over the next 40 years. As part of this commitment BHP has adopted a policy of achieving a high standard of environmental management at all of its operations, and to undertake necessary research and development studies to minimise environmental impact. In the event that long term cumulative impacts were to result in degradation of the Weeli Wolli system, BHP would support co-operative actions agreed with Government for ameliorating such impacts. (It should also be noted in this context, that BHP has previously initiated an Environmental Management Programme for Weeli Wolli Springs which are not located on ML270SA.)

MINING AND INFILLING

17. How much of the Yandi ore body is likely to be mined and over what time frame? (CER Section 2.3).

A17. The total iron ore resources at Yandi on ML270SA is estimated at 1.2×10^9 tonne. It is planned that most of this reserve will be mined eventually.

18. What is the length of the haul road across Marillana Creek? (CER Section 4.2).

A18. The length of the haul road from the exit point of the Yandi C1/C2 deposit to the edge of the overburden storage area is 800 m. The portion of the haul road which crosses Marillana Creek is about 50 m.

19. What percentage of the overburden will be placed outside of the pit compared with in the pit? (CER Section 4.4).

A19. The estimated total quantity of overburden is 80 Mt and it is estimated that 20 Mt will be placed outside of the pit. Therefore, the percentage overburden externally placed will be about 25%.

20. What is the quantity of backfill to be placed in the Yandi C1/C2 pit and the height of the backfill? The proposed final surface level of the backfill in the Yandi C1/C2 pit when mining is completed (Figure 2.5) should be stated in the CER.

A20. Similar to the response to question 18, it is estimated that 60 Mt of overburden will be infilled to mined out areas of the pit. A final surface level for the infill cannot be determined as it will not be uniform throughout the pit.

21. The only option for mining companies is to include in their economic and environmental management plan an inpit design that facilitates complete infill of all pits.

A21. This suggestion is impractical as it would render all developed mines uneconomical and would cause more environmental disturbance than that currently proposed. Infilling will however, be employed as practical. Iron ore is a bulk commodity which represents over 60% of the total material removed from the pit. In order to totally backfill the pits, an equivalent amount of non-mineralised material would need to be mined adjacent to the operations. This would result in extensive disturbance to areas that would otherwise remain undisturbed.

22. How many years following commissioning will the mining be sufficiently advanced to allow direct infilling of the mined out pit? (CER Section 2.3.1).

A22. It is estimated that it will take 4 to 5 years of continuous mining from one area before there is sufficient room available in the pit to allow infilling.

23. What other areas for out-of-pit overburden placement have been evaluated? (CER Section 2.3.3).

A23. All surrounding areas in reasonable proximity to the mining operation were evaluated as possible areas for overburden storage. Taking into account haul distances, access, landform impact and minimum disturbance the proposed area was identified as the most suitable.

24. In regard to re-establishment of pre-existing drainage networks, what is the longer term management strategy? (CER Section 4.12.3).

A24. Mining at Yandi is anticipated to extend over the next 40 years. Diversion of minor watercourses and tributaries to Marillana Creek will be required as mining progresses. This will be done with the objective of avoiding flooding of the mining operation while maintaining flows to areas downstream of the operation. Disturbance of watercourses will be avoided where practical. Following mining, drainage networks will be re-established as dictated by ongoing monitoring and development planning.

FAUNA

25. Although it is expected that many former resident species will return to the project area following decommissioning, will rehabilitation ensure that suitable habitat is created? (CER Section 4.6.1).

A25. Rehabilitation and revegetation using native plant species will provide suitable habitat, where appropriate, for the return of former resident fauna species. Species will begin to return to rehabilitated areas at different times as food, shelter and other requirements are re-established.

26. Has an approved management plan for the Pebble-mound Mouse already been prepared for Yandi C1/C2? (CER Section 4.6.2).

A26. Survey work conducted over the proposed mine area did not identify active Pebble-mound mouse sites. It is estimated that approximately 5% of the identified active mounds in the surrounding area may be disturbed during infrastructure development.

A site specific management plan for the Pebble-mound mouse has yet to be submitted for Yandi C1/C2. It is intended that the plan will be included in the revised Environmental Management Plan applying to all Yandi operations.

27. Cumulatively exposed water bodies will change the fragile ecosystems as mining in the region increases. Exposed water bodies, where they exist, are already creating macro ecological changes in terms of avifauna and laterally, flora by the deposition of avifauna transported seed.

A27. Significant ecological changes within the region are not expected due to exposed water in decommissioned pits. Experience from other decommissioned pits in the Pilbara region suggests that bird usage is relatively low. Permanent surface water is already available in the region in places such as Weeli Wolli Springs and Flat Rocks in Marillana Creek. Ecological changes through deposition of avifauna transported seed are also not expected to be significant as flora species which have been previously introduced by other means have a much greater potential to alter the regional ecology.

DUST AND NOISE

28. In relation to noise and dust issues, how far away are the nearest residences, i.e., the Yandi village and pastoral station homesteads? (CER Sections 4.8, 4.9, 4.10).

A28. The direct distance from the Yandi C1/C2 mining area to the nearest pastoral station, Marillana homestead, is 35 km. The direct distance to the Yandi village is 6 km. The existing mining operation at Yandi E2 is approximately the same distance from the Village.

29. What limits/regulations will be met in relation to dust, noise and blasting? (CER Section 4.9).

A29. Dust, noise and blasting will be controlled in accordance with the current Mines Regulations and subsequently the Mines Safety and Inspection Regulations 1995 when they become effective. The Noise Abatement (Neighbourhood Annoyance) Regulations also apply, as appropriate.

30. What efforts will be made to minimise impact of blasting on nearby vegetation? (CER Section 4.10).

A30. To minimise impacts on vegetation outside of the pit from blasting, the blasts will be designed to initiate toward the pit workings.

The blast energy and fly rock deposited outside of the pit will therefore be minimal. The proposed Yandi C1/C2 mine is located at a substantial distance from Marillana Creek where the main occurrence of larger trees exist which are susceptible to damage from blasting.

COMMUNITY CONSULTATION

31. There is no indication or report in the CER of community consultation. The area is being treated purely as a resource rather than having any community significance or ownership.

A31. Contacts made during community consultation for the Yandi Expansion Project include:

Newman
East Pilbara Shire President and Chief Executive Officer
Newman Chamber of Commerce

Pastoralists
Juna Downs (Hamersley Iron)
Marillana

Port Hedland
Port Hedland Chamber of Commerce
LEAF (Environmental Group)

Aboriginal Groups
Horace Parker-Wittenoom
David Stock-Marble Bar

BHP Iron Ore Employees (through the in-house newsletter)

Government Departments
Resources Development
Environment
Minerals and Energy
Aboriginal Affairs

Media
National, state and regional media

ABORIGINAL SITES

32. Exactly how many and what sort of archaeological and ethnographic Aboriginal sites have been identified in the region of the Yandi C1/C2 mine site? Are any of these considered to be significant? (CER Section 3.7).

A32. Nine Aboriginal archaeological sites may be impacted by the proposed development. These are mainly artefact scatters and are considered of low archaeological significance and are similar to a number of other sites in the area. No ethnographic sites have been identified within areas to be disturbed.

Approval to disturb sites in the vicinity of the Yandi C1/C2 ore body has previously been obtained under Section 18 of the Aboriginal Heritage Act.

GROUNDWATER

33. How far will the mined out pit extend below the ground level (m) and how much of this will be below the original water table level (m)? (CER Section 4.4.1)

A33. The surface of the deposit in the initial mining area is approximately 575 m RL. The level of Marillana Creek directly south of this area is at approximately 555 m RL. The water table level within the channel iron deposit (ore body) for Yandi C1/C2 is at 552 m RL. Mining will extend to the deepest level of 510 m RL. The mine pit will be approximately 65 m deep and approximately 40 m will be below the present water table.

34. What is the minimum pumping rate necessary to achieve optimum mining conditions? (CER Section 4.2.2).

A34. Section 2.3.2 of the CER on Dewatering states that; "the initial six month discharge from Yandi C1/C2 will be approximately 20,000 m^3/day, after which the volume will be decreased and stabilise at around 10,000 m^3/day." This equates to the minimum pumping rate necessary to achieve optimum mining conditions. Actual day to day pumping rates will fluctuate due to seasonal influences.

35. Why is there a need to relocate the dewatering discharge point? (CER Section 2.3.2).

A35. Relocation of the discharge point is necessary as otherwise over 50% of the water discharged to the Creek would be re-pumped by the permanent (downstream) boreline. This "recycling" of discharge waters will be mitigated by the proposed relocation downstream to a point further removed from the CID.

36. It is stated on page 3-11 that extensive studies have been undertaken since 1991 to determine the inter-relationship between the groundwaters of the different aquifers, including regional groundwater modelling study, however, no analysis is present in terms of:

the current effect of dewatering operations on the relationship between the CID aquifer and the present Marillana Creek drainage lines at the Yandi E2 mine;

quantification of groundwater flows and determination of the relationship between the CID aquifer and Marillana Creek alluvium, including quantification of recharge and discharge;

the expected short-term hydrological impacts arising from the development of the Yandi C1/C2 deposit which will be similar to those observed for the Yandi E2 operation. (CER Section 3.3.2.1).

A36. Monitoring bores targeting the alluvial aquifer have not been installed close to the mine. However, monitoring of vegetation along the Creek where it occurs immediately adjacent to the dewatered ore body has not shown indication of water stress.

Recent trenching in the Creek alluvials next to the Yandi E2 pit, undertaken to reinstall reticulation pipe works intersected groundwater less than 0.5 m below ground level (pers. comm. G Clark, Mine Geologist - Yandi, BHP Iron Ore Pty Ltd) whilst the pit water levels immediately alongside were over 30 m lower. This indicates that, whilst there is hydraulic connection between the Creek alluvials and CID during high stages of streamflow, the leakage from the alluvials is probably much lower than the estimated 5 m/d (horizontal) hydraulic conductivity. It is apparent that mine dewatering has had limited short-term impact on the alluvial aquifer system adjacent to the mine.

Dewatering of the Yandi C1/C2 deposit is likely to have similar local impacts to that of Yandi E2, i.e. there may be a decline in alluvial aquifer water level but it will be possible to offset by irrigation of the Creek vegetation.

37. What is the extent and significance of the impacts associated with the movement of the existing groundwater divide upstream following the addition of Yandi C1/C2 discharge?

What is the extent and significance of the impacts associated with dewatering and lowered CID aquifer levels which will extend 10 km upstream from the present Yandi E2 dewatering? (CER Section 4.3.1.1)

A37. The initial increase in combined discharges from Yandi E2 and C1/C2 to Marillana Creek could result in increased recharge to the local groundwater system downstream of Yandi E2. The groundwater divide, then, may move upstream toward the Yandi E2 pit. This situation will be mitigated by moving the discharge point further downstream as is proposed.

See response to question 47.

38. There will be a cumulative effect associated with waterbodies forming in the mined out pits which lay adjacent to the creek systems and palaeochannel adjacent to Marillana Creek, Herberts Creek and Iowa Creek. At no stage have the implications of salinity, water drawdown, or proximity to riverine systems been addressed in terms of the regional impact of the Weeli Wolli Creek System one of the most significant water systems in the region.

A38. Available data indicate that the tributary deposits of CID associated with the Iowa and Herbert's Creek do not form significant aquifers other than where they join the Marillana Creek palaeodrainage CID.

Preliminary numerical modelling (AGC Woodward-Clyde, 1995b) predicts that groundwater level drawdown arising from evaporation from the pits remaining at completion of mining at Yandi E2 and Yandi C1/C2 will not be measurable at Flat Rocks.

39. How far away is the Fortescue Valley groundwater system and what percentage of flow comes from Marillana Creek and the Yandicoogina CID?

A39. The Fortescue Valley is approximately 35 km downstream of the Yandi mining area.

The Fortescue Valley groundwater system consists of two distinct aquifer systems (AGC Woodward-Clyde, 1995b):

A shallow aquifer system associated with creek outwash fans recharged directly from streamflow events and rainfall, and used for stock water supplies.

A deep aquifer system, consisting of two sub-systems (the Plain sub-system beneath the southern portion of the Fortescue Valley and associated with the palaeodrainage of the Fortescue River, and the Marsh sub-system beneath the Fortescue Marsh in the northern portion of the Valley).

It is probable that the Plain aquifer sub-system associated with the Fortescue palaeodrainage is variously recharged by throughflow from upstream, leakage of groundwater from the shallow aquifer system, and possibly by remnant channel iron deposit aquifers where they occur (including the Marillana deposit). On the Fortescue Valley, in the area of the Weeli Wolli Creek outwash fan, goethetic alluvial deposits occur at depth (Mt Newman Mining Co., 1978) and these may be derived from eroded Marillana and Weeli Wolli Creek system channel iron deposit (AGC Woodward-Clyde, 1995b).

The sub-system associated with the Fortescue Marsh is probably recharged by streamflow from the northern portion of the Fortescue Valley (Chichester Range), the Upper Fortescue River (including the Jigalong, Jimblebar and Newman areas), leakage from the Plain aquifer sub-system and from rainfall.

Presently, this deep aquifer sub-system has no identified beneficial use.

Sufficient data are not available to accurately quantify groundwater flow in the Fortescue Valley groundwater system. However, it is likely that inflows from the Marillana/Weeli Wolli Creek system are an order of magnitude less than the total groundwater flow into the Fortescue Valley system (AGC Woodward-Clyde, 1994).

40. What is the combined average flow of the Fortescue River? (CER Section 3.4.1.2)

A40. No westerly flow has been recorded from the Fortescue Marsh since the commissioning of the Goodiadarrie Gauging Station in December 1972. The Marsh is a basin and would require approximately 350 mm of surface run-off over 31,200 km of catchment to fill. It is estimated that the rainfall necessary to cause this run-off would need to exceed 1,200 mm occurring over a one to two month period (AGC Woodward-Clyde, 1995d).

Average annual inflow to the Fortescue Valley has been estimated to be approximately 443 x 10^6 m^3. Inflow varies greatly from year to year as rainfall throughout the catchments is highly variable and only limited data is available.

Recent modelling indicates total average flow to the Fortescue Valley from the Weeli Wolli Creek catchment ranges up to 48 x $10^6 m^3$. This represents up to 11% of the total combined average flow onto the Fortescue Valley. It is estimated that up to one half of this contribution may be sourced from Marillana Creek above the Yandi E2 minesite.

WATER QUALITY
SALINITY

41. It is recognised that evaporation from water in decommissioned pits will result in locally depressed groundwater levels and an increase in salinity. The hydrological monitoring of the Yandi E2 pit and dewatering operations should provide the necessary data to attempt to quantify these impacts in terms of:

the final water level range in the pit;

the final salinity range in the pit;

the effect of backfill on groundwater salinity in the aquifer downstream from the decommissioned pit, including the impact on the Fortescue Valley deep aquifer system;

the extent to which depressed water levels will affect phreatophytic vegetation. (CER Section 4.2.1.2)

A41. Analytical modelling of the Yandi E2 open pit is being undertaken by Woodward-Clyde (AGC Woodward-Clyde, 1995b) to assist in predicting pit water level recovery postmining. Modelling predicts that given an evaporation rate of 7 mm/d, water levels will not recover past the last bench (512 m AHD) as the pit water surface area increases to an extent that additional water will be evaporated.

The modelling process described in Section 4.4.2 has also been used to assist in defining possible rates of salinity build-up in the mine once decommissioned. For example, worst case modelling has indicated that pit water salinity would approach 45,000 mg/L within 100 years of the cessation of mining. This modelling assumed:

an evaporation rate of 7 mm/d.

inflows from groundwater flow and rainfall.

Marillana Creek flow excluded through engineering works.

No base flow in the CID (i.e. the pit traps all groundwater flow).

It cannot be certain to what level 'groundwater' will recover in a backfilled pit as present day aquifer water levels reflect quasi-steady state conditions, i.e. all contributory fluxes are in a state of dynamic equilibrium where recharge processes (infiltrating rainfall and leakage from surrounding aquifers) balance discharge processes (aquifer throughflow and evapotranspiration).

The phreatophytic vegetation associated with the shallow alluvial groundwater system of Marillana Creek (namely *Melaleuca argentea*) relies upon groundwater generally occurring within 2 m of the surface (Muir Environmental, 1995 and AGC Woodward-Clyde, 1992). Numerical modelling of the groundwater system has predicted that, drawdowns of between 2 to 20 m will occur immediately up and down stream of the open pit. Without irrigation it is likely that the local phreatophytic plant community will be impacted in these areas. It is currently estimated that the area of plant community that could be impacted is approximately 70 ha (60% of total area of *M argentea* habitat in the Yandi area).

42. The impacts of groundwater draw down and saline water bodies at this mine have only been addressed cursorily and in isolation. The cumulative impacts and perpetuity have not been addressed either individually or cumulatively.

A42. Any escape of saline waters from the mined out pits will occur through density driven processes where the more dense and saline water will migrate at depth through the groundwater system. Other water inputs (through rainfall infiltration or leakage from other aquifers) into the system downstream of the pit would have a lower salinity and dilute any saline flow that might occur.

Marillana/Weeli Wolli Creek System groundwater discharges to the deeper saline Fortescue Plain aquifer sub-system of the Fortescue Valley (AGC Woodward-Clyde, 1995b). The deeper aquifer system of the Fortescue Valley has no present beneficial use, as groundwater salinities range up to 100,000 mg/L. The addition of future potentially salinised water from the Marillana/Weeli Wolli Creek system will hence not impact significantly on the water quality of this system.

ACIDITY

43. The CER fails to evaluate acidity and pH changes in the regional water bodies.

A43. Acid drainage is not an issue in the Yandi environment as the ore and overburden are oxidised and do not contain sufficient sulphides to give rise to acid generation resulting in pit water or groundwater pH changes.

IMPACTS ON PHREATOPHYTES

44. It is also recognised that the water level decline in these aquifers near to the dewatered Yandi C1/C2 ore body is likely to affect phreatophytic vegetation in areas where groundwater occurs near to the surface. The following issues should be addressed:

the adequacy of irrigation of phreatophytic vegetation to sustain the vegetation in a healthy state (as currently exists);

the identification of these areas in size (ha) and the expected drawdown in these areas;

the areas (in ha) of vegetation likely to be affected during mining operations and on decommissioning of operations.

A44. For the past 9 months, the existing Yandi E2 irrigation system has not been operational due to damage suffered from flooding in early 1995. The *M. argentea* appear to have remained in a similar condition to recent years i.e. they do not appear water stressed (pers. comm. M. Anstey, Environmental Officer, BHP Iron Ore Pty. Ltd.). This indicates that short term impacts of mine dewatering are difficult to measure and leakage rates from the Creek alluvial aquifer to the CID being very low.

(See response to questions 36 and 41)

45. What is the extent and significance of loss of phreatophytic vegetation arising from mine dewatering? (CER Section 4.2.1.1)

A45. (See response to question 44)

46. What is the extent and significance of impacts to the newly established vegetation at the present discharge point when the discharge location is change?

A46. The change of location of the dewatering discharge point will result in a large proportion of the newly established river gums (at the present location) suffering water stress due to decreased availability of water. Some deaths may be expected. However, an equivalent community is likely to become established at the new discharge point.

47. How common is *Melaleuca argentea* (Cadjeput), how will it be affected by the proposal and is this significant? (CER Section 3.5.1.2)

A47. The Cadjeput occurrence along Marillana Creek represents one of 11 confirmed occurrences of *M. argentea* in the Pilbara region. *M. leucadendra* have been mapped at another 15 locations and Muir (1995) considers these are very likely to be the same species of Cadjeput found along Marillana Creek (i.e. *M. argentea).* In addition, Muir (1995) considers it probable that Cadjeput occur at many of the permanent water pools of the Pilbara region .

Preliminary groundwater modelling predicts that groundwater levels in the proximity of the decommissioned pits will decline to levels that will not be accessible to the existing phreatophytic vegetation associated with the Creek alluvials. A single pit alone at Yandi E2 will be sufficient to cause the decline of around 40% (by area) of the mapped mixed Cadjeput/River Gum community occurring along Marillana Creek. The addition of pits at Yandi C1/C2 is predicted to cause the decline of a further 20% (by area).

Loss of the phreatophytic vegetation community (i.e. the mixed Cadjeput and River Gum woodland) in the area of Yandi E2 and C1/C2 will represent between 4 and 10% of confirmed locations in the Pilbara where Cadjeput (*M. argentea/leucadendra*) occur. However, taking into account the probable occurrence of Cadjeput in the many other areas where permanent water occurs in the Pilbara region this percentage is likely to be considerably less.

MONITORING IMPACTS ON PHREATOPHYTES

48. What is the effect on phreatophytic vegetation, in the vicinity of Yandi E2, by mining operations to date.

A48. No adverse effects on phreatophytic vegetation have been recorded in the vicinity of Yandi E2 to date.

49. How will monitoring of riverine phreatophytes be undertaken, what monitoring results will signal action is needed, and will be done if needed?

A49. See response to question 14.

50. How will the need to provide irrigation for phreatophytic vegetation be determined?

The need for irrigation of phreatophytic vegetation likely to be affected by mining at Yandi E2 was conservatively estimated for stands of vegetation upstream and adjacent to the operation.

Further areas which may be irrigated for the development of C1/C2 could be determined through the groundwater modelling.

However, as the water level in the CID will be permanently lowered beyond the reach of the phreatophytes it may be desirable to discontinue the irrigation in order to determine whether they will survive, in the longer term, on water within the Creek alluvials.

HABITATS ASSOCIATED WITH THE RIVERINE ECOSYSTEM

51. What is the extent and significance of the impact to those plant and animal communities that have become dependent upon the hydrological environment, arising from the cessation of dewatering discharge following decommissioning?

A51. Cessation of dewatering discharge following decommissioning will result in the drying out of the permanent water both upstream and downstream of the discharge point, apart from those times following Creek flows.

Plant communities which have become established along the margins of the permanent water-body will suffer stress and many individuals are likely to die. Similarly, animals which have become dependent on the water will either relocate to other areas where there is sufficient water or will die, depending on their mobility.

52. Is there potential for impacts to aquatic habitats/fauna after mining arising from changes in water quality or quantity?

A52. There is one permanent water body in the project area:

Flat Rocks - located within the Marillana Creek system at the western (upstream) end of ML 270SA.

Preliminary numerical modelling (AGC Woodward-Clyde, 1995b) predicts that groundwater level drawdown arising from evaporation from the pits remaining at completion of mining at Yandi E2 and Yandi C1/C2 will not be measurable at Flat Rocks. Water quality at this location, then, is also not expected to change as a result of mining the CID ore body.

53. Will the Olive Python suffer impact as a result of changes to the Riverine vegetation assemblage arising from hydrological impacts caused by dewatering or decommissioned mine pits?

A53. It is the current plan that the physical integrity of Marillana Creek will be maintained. If the local phreatophytes (e.g. *M. argentea*) do not survive post - mining they will most probably be replaced by vadophytes such as *E. camaldulensis* and *E. victrix.*

Animals that have included the riverine habitat as part of their range would be expected to continue to do so post - mining. As a result the food source on which the Olive Python depends (i.e. warm blooded animals) will remain in place.

54. What does minimum disturbance actually mean, and for what duration of time will the integrity of Marillana Creek be maintained? (CER Section 4.2.3)

A54. Minimum disturbance means that mining and associated infrastructure will be designed so that it is located away from the Creek, as much as practicable. Where it is necessary to disturb the Creek, i.e. overburden haul road, this will be done in such a way that surface flows are not interrupted.

The physical integrity of Marillana Creek (river course as it exists today) will be maintained while monitoring riverine local phreatophytes to determine if they will survive with the permanent lowering of the water level in the CID.

55. In relation to aquatic habitats, what is meant by "it is intended to maintain the integrity of Marillana Creek, during and post mining"?

A55. See response to question 54.

MANAGEMENT OPTIONS

56. Anywhere a water table is left exposed, the water in the mined out pit will become more saline through evaporation. No assurance has been given that aquifers can be restored following mining. The mining companies must be willing to cover exposed water tables. This should be seen as part of the normal costs of the developing a deposit.

A56. Similar to the response to question 20, it is impractical to infill the mined out pits to a level which will cover the exposed watertable. The amount of material required would greatly exceed available overburden and would need to be sourced from areas that would otherwise remain undisturbed.

Options are being considered, however, to use available infill material in such a way that will mitigate hydrological impact.

57. It was understood that a backfill strategy would be finalised for the Yandi E2 pit as the relevant groundwater information became available from the dewatering experience. If so, what is it?

A strategy has not been devised to date.

58. What are some of the longer term management options from the regional groundwater model, are they realistic and is BHP committed to them? (CER Section 4.3.2)

A58. Developed longer term management options are conceptual at this stage and are based on modelling predictions. Monitoring will need to be ongoing during the life of mining operations to test the predictions and refine the model so that the longer term management options can be optimised.

Conceptual management options currently include:

(i) If monitoring shows that alluvial groundwater levels in Marillana Creek are not greatly impacted by pit dewatering the physical integrity of Marillana Creek could be maintained in the long-term by undertaking engineering procedures as mining proceeds at other deposits, e.g.:

A60. The effect of backfill on future groundwater flow through mined out sections of the CID will be considered as described in the response to question 58.

61. How will the mined out pit be modified to minimise water quality changes caused by evaporation, what options exist and to what standard will the required modifications meet?

61A. See response to question 58.

62. Pilbara miners in designing aquifer management plans must start considering their responsibilities to the more permanent industries of pastoralism, horticulture and tourism. Land and water resources must be maintained and protected if these industries are to continue. Protecting the water resource is critical to the long term sustainability of the Pilbara.

A62. BHP will take potential future use of land and water resources into consideration in developing and implementing long term management strategies.

63. How dependent are people/stock on the CID aquifer? (CER Section 4.3.1.2)

A63. The CID aquifer is utilised for stockwater at very few locations in the project area, e.g. at Corktree Bore (downstream of the Marillana - Weeli Wolli Creek confluence). There are no reported potable water supplies established in the CID aquifer, apart from those supplying BHP's Yandi Village and Hamersley Iron's Yancra exploration camp.

Appendix 3

Possible responses of key species to long-term changes in water availability

APPENDIX A

POSSIBLE RESPONSES OF KEY SPECIES TO LONG-TERM CHANGES IN WATER AVAILABILITY

	EUCALYPTUS VICTRIX		*EUCALYPTUS CAMALDULENSIS*		*MELALEUCA ARGENTEA*	
	PERCHED WATER TABLE PRESENT	**NO PERCHED WATER TABLE PRESENT**	**PERCHED WATER TABLE PRESENT**	**NO PERCHED WATER TABLE PRESENT**	**PERCHED WATER TABLE PRESENT**	**NO PERCHED WATER TABLE PRESENT**
IMPACT OF DRAWDOWN	Minimal or none on trees which are well away from river margin and not dependent on access to the regional vadose zone. Damage to trees which are partly dependent on regional vadose zone but would probably adapt fairly readily.	Trees on river margin may be temporarily disadvantaged but would probably rapidly adapt. Trees away from margins would be unaffected.	Damage to trees which are partly dependent on regional vadose zone Degree of survival or recovery after initial impact would depend on level of dependence on the regional water table of individual trees	Trees probably die.	Some damage expected but many may be able to survive on available water within the perched aquifers.	Trees die.
IMPACT OF FLOODING	Extensive utilisation of available water accompanied by prolific growth.	May be some long-term adverse effects caused by intolerance to water logging.	Extensive utilisation of available water accompanied by prolific growth.	Extensive utilisation of available water accompanied by prolific growth.	Extensive utilisation of available water accompanied by prolific growth.	Extensive utilisation of available water accompanied by prolific growth.
IMPACT OF DRYING OUT AFTER LONG-TERM FLOODING*	Initial decline, then trees adapt back to normal conditions.	Trees probably die.	Initial decline, then some trees may adapt back to normal conditions.	Trees die as rate of adaptation back to dry conditions may not be fast enough.	Trees die as rate of adaptation back to dry conditions may not be fast enough.	Trees die.

* Assumes not affected by drawdown in the same area. If drawdown is occurring, then impacts as for drawdown area.

Appendix 4

Proponent commitments

PROPONENT COMMITMENTS

Commitment 1

BHP will prepare and implement an Environmental Management Programme (EMP) for the operations on ML 270SA to the requirement of the Department of Environmental Protection. The EMP will include the development of long-term management options and walk-away solutions for the site. The EMP will be reviewed and updated as necessary.

Commitment 2

Regular assessment of monitoring results and management effectiveness will be reported as part of the EMP and according to existing arrangements as specified in the Iron Ore (Marillana Creek) Agreement Act, 1991.

Commitment 3

Mine operations will be designed to cause minimum disturbance to the surface hydrological environment and the physical integrity of Marillana Creek will be maintained.

Commitment 4

Monitoring of the dewatering effects on the riverine phreatophytes will be undertaken. Management will be affected by irrigation with dewatering discharge.

Commitment 5

BHP will continue with the development of the regional groundwater model to assess longer term management options.

Commitment 6

Baseline monitoring of the riverine vegetation will be undertaken prior to commissioning of the Yandi C1/C2 mine and again at regular intervals thereafter, to assess the potential impact arising from the mining operations.

Commitment 7

Management of the area following completion of mining will be undertaken as follows:

- Pre-existing drainage networks be re-established as best meets the longer term management strategy and as approved by the DEP on advise from other Government agencies.
- Revegetation activities will continue until stable communities are established.

Appendix 5

Statement of Conditions of Approval, Yandi E2

WESTERN AUSTRALIA
MINISTER FOR THE ENVIRONMENT

STATEMENT TO AMEND CONDITIONS APPLYING TO A PROPOSAL (PURSUANT TO THE PROVISIONS OF SECTION 46 OF THE ENVIRONMENTAL PROTECTION ACT 1986)

PROPOSAL: YANDICOOGINA (MARILLANA) IRON ORE PROJECT (069/712)

CURRENT PROPONENT: BHP IRON ORE LIMITED

CONDITIONS SET ON: 25 MAY 1988

Condition 1 has been amended to read as follows:

1A Proponent Commitments
In implementing the proposal, including the increased production rate of 10 million tonnes per year, the proponent shall fulfil the commitments (which are not inconsistent with the conditions or procedures contained in this statement) made in the Public Environmental Report (1987). (A copy of the commitments is attached).

1B Detailed Implementation
Subject to the conditions in this amended statement, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal. Where, in the course of that detailed implementation, the proponent seeks to change those designs, specifications, plans or other technical material in any way that the Minister for the Environment determines on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.

The original condition 6 is deleted and a new condition 6 is inserted as follows:

6. Proponent
No transfer of ownership, control or management of the project which would give rise to the need for the replacement of the proponent shall take place until the Minister for the Environment has advised the proponent that approval has been given for the nomination of a replacement proponent. Any request for the exercise of that power of the Minister shall be accompanied by a copy of this statement endorsed with an undertaking by the proposed replacement proponent to carry out the project in accordance with the conditions and procedures set out in the statement.

Bob Pearce, MLA
MINISTER FOR THE ENVIRONMENT

19 MAY 1992

Published on

20 MAY 1992

18th FLOOR, ALLENDALE SQUARE, 77 ST GEORGE'S TERRACE, PERTH, W.A. 6000 TELEPHONE 325 9422 FAX 325 5621

MINISTER FOR ENVIRONMENT

STATEMENT THAT A PROPOSAL MAY BE IMPLEMENTED (PURSUANT TO THE PROVISIONS OF THE ENVIRONMENTAL PROTECTION ACT 1986)

YANDICOOGINA (MARILLANA) IRON ORE PROJECT

BHP - UTAH MINERALS INTERNATIONAL

This proposal may be implemented subject to the following conditions:

1. The proponent shall adhere to the proposal as assessed by the Environmental Protection Authority and shall fulfil the commitments made (copy of commitments attached).

2. The proponent shall undertake regular monitoring of creek bed vegetation and sediment movement in the Marillana Creek system to assess any changes that occur as a result of the mine water discharge and shall ameliorate adverse effects to the satisfaction of the Environmental Protection Authority. The monitoring programme shall be to the satisfaction of the Environmental Protection Authority and shall be prepared prior to commissioning the mine. Results of this monitoring shall be reported through regular reporting mechanisms required under the Agreement Act.

3. At least 12 months prior to the completion of this project the proponent shall prepare and implement a plan for on-going water quality management in the mined-out pit, to the satisfaction of the Environmental Protection Authority.

4. During all project phases, including construction and contract mining as well as on-going mining by the proponent, the proponent shall restrict caravans to a managed caravan park incorporating adequate sewage and other waste disposal facilities.

Published on 27 MAY 1988

7th Floor, May Holman Centre
Phone (09) 325 4122

5. The proponent shall refer any proposal he may develop to establish a new townsite in the Yandicoogina area to the Environmental Protection Authority for assessment.

6. The proponent shall refer any proposal to increase the mining rate beyond 5 million tonnes per year to the Environmental Protection Authority.

B. Hodge.

Barry Hodge, MLA
MINISTER FOR ENVIRONMENT

25 MAY 1990

WESTERN AUSTRALIA

MINISTER FOR THE ENVIRONMENT

STATEMENT TO AMEND CONDITIONS APPLYING TO A PROPOSAL (PURSUANT TO THE PROVISIONS OF SECTION 46 OF THE ENVIRONMENTAL PROTECTION ACT 1986)

PROPOSAL:	YANDICOOGINA (MARILLANA) IRON ORE PROJECT (069 / 712 / 875)
CURRENT PROPONENT:	BHP IRON ORE PTY LTD
CONDITIONS SET ON:	25 MAY 1988
CONDITIONS AMENDED ON:	19 MAY 1992

Condition 1A is amended to read as follows:

1A Proponent Commitments

The proponent has made a number of environmental management commitments in order to protect the environment.

In implementing the proposal, including the increased production rate of 15 million tonnes per annum reported on in Environmental Protection Authority Bulletin 738, the proponent shall fulfil the commitments made in the Public Environmental Report (1987), provided that the commitments are not inconsistent with the conditions or procedures contained in this statement. (A copy of the commitments is attached).

The following conditions and procedure are inserted following condition 6:

7 Decommissioning

The satisfactory decommissioning of the project, removal of the plant and installations and rehabilitation of the site and its environs is the responsibility of the proponent.

7-1 At least six months prior to decommissioning, the proponent shall prepare and submit a final decommissioning and rehabilitation plan to the requirements of the Department of Minerals and Energy in consultation with the Environmental Protection Authority.

7-2 The proponent shall implement the plan required by condition 7-1.

8 Compliance Auditing

In order to ensure that environmental conditions and commitments are met, an audit system is required.

8-1 The proponent shall prepare periodic Progress and Compliance Reports, to help verify the environmental performance of this project, in consultation with the Environmental Protection Authority.

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1 JUN 1994

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Procedure

1 The Environmental Protection Authority is responsible for verifying compliance with the conditions contained in this statement, with the exception of conditions stating that the proponent shall meet the requirements of either the Minister for the Environment or any other government agency.

2 If the Environmental Protection Authority, other government agency or proponent is in dispute concerning compliance with the conditions contained in this statement, that dispute will be determined by the Minister for the Environment.

Kevin Minson MLA
MINISTER FOR THE ENVIRONMENT

3 * MAY 1994

YANDICOOGINA (MARILLANA) IRON ORE PROJECT

ENVIRONMENTAL MANAGEMENT COMMITMENTS

1. The Proponent will submit an environmental monitoring and management programme with the mining proposals to the State in accordance with the State Agreement Act.

2. Regular assessment of monitoring results and management effectiveness are to be reported as part of the monitoring and management programme. Reports will be submitted to the responsible Minister at intervals specified in the Act.

3. The Proponent will comply with the provisions of all relevant Government Acts and Regulations that may apply to the operations.

4. An Environmental Officer will be responsible for all environmental monitoring and management activities for the Project.

5. Environmental awareness programmes will be provided for all construction, contractor and operational workforce.

6. During the construction phase minimum alteration to the existing topography will be achieved. Once construction is complete, areas no longer required will be contoured, slopes stabilised, topsoil replaced and revegetated.

7. Borrow pits, where possible, will be located in areas not visible from the accommodation sites or access roads. The pits will be reshaped and revegetated. Drainage control will be employed to reduce surface water ponding.

8. Erosion will be managed by contouring, stabilising and vegetation.

9. Minimisation of disturbance to archeological sites will be achieved by reducing any operations on the sites. Where a site may need to be disturbed, the Proponent will comply with any conditions imposed by the Minister for Aboriginal Affairs.

10. The area of disturbance will be reduced by using overburden for bund walls, fill for borrow pits and by returning overburden and waste ore to the mined out areas of the pit.

11. Surface dumps of overburden including bund walls, refilled borrow pits and the main overburden dump area will be stabilised to minimise wind and water erosion. The final waste dump will be constructed as to conform with the existing topography.

12. Revegetation of the mine dumps will be achieved using the most successful vegetation techniques available. The revegetation programme will be monitored intensively during the mining phase, and routinely following decommissioning.

13. Mine dewatering will be affected by pumping the minimum amount of groundwater to achieve optimum mining conditions.

14. Mine dewatering discharge will be fed into Marillana Creek and used as irrigation water to support phreatophytic vegetation.

15. No contaminated process water from the operation will be allowed to discharge to the creek system or to the groundwater. A detailed water quality sampling and analysis programme will be adopted as part of the monitoring programme.

16. The removal of waste materials, ie. oils, sewage, etc. will be undertaken in accordance with Health Department and Local Authorities' requirements.

17. Monitoring of the dewatering effects on the riverine phreatophytes will be undertaken. Management will be effected by irrigation of affected areas with mine dewatering discharge.

18. Occupational and ambient dust levels will be managed by controlling dust emissions at their source. Dust monitoring programmes will be implemented, and dust emissions controlled by water spraying.

19. Seasonal vegetation surveys will be undertaken during mining.

20. During construction, caravans will be restricted to a managed caravan park.

21. As part of the general monitoring and management programme, the following mosquito control practices will be adopted:

- identify and control potential mosquito breeding sites;
- monitor mosquito species to assess disease potential; and
- carry out necessary fogging, spraying and baiting should it be required.

22. Management of the area following completion of mining will be undertaken:

- Pre-existing drainage networks will be reestablished where applicable.
- Revegetation activities will continue until stable communities are established.
- The mined out pit will be modified to minimise water quality changes caused by evapoconcentration.