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CONTENTS

Achievements and Challenges for Joint Industry–Government Initiatives in Best Environmental Practice in Mining

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ACHIEVEMENTS AND CHALLENGES FOR JOINT INDUSTRY-GOVERNMENT INITIATIVES IN BEST ENVIRONMENTAL PRACTICE IN MINING

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ABSTRACT

The collaborative program of activities to encourage the adoption of best environmental practice in mining, involving the Commonwealth government and industry, has evinced a high level of interest in and acceptance of issues-based information on best practice techniques. Environmental management is perhaps the most significant parameter by which the Australian public formulates its attitude towards the mining industry, and the performance standards expected and demanded by the public and government must surely continue to increase. With the trend towards greater self-regulation by industry generally, it is important for the mining industry to be seen to embrace both the rhetoric and the execution of best environmental practice. The demonstrated success so far of the joint industry-government best practice program provides a strong basis upon which to build a comprehensive system of information, training, research and access to underpin the further transfer of best practice environmental management techniques to the Australian mining sector. The possibility also exists for closer co-operation in developing a policy agenda which satisfies both sectors, developing a commercial framework to provide long-term support to the best practice program; and developing an effective system of capturing the commercial opportunities to the Australian mining industry from its improving international image as a leader in environmentally responsible mining.

INTRODUCTION

Protection of the environment is an issue of equal significance to both industry and the government. Increasing public awareness and knowledge of the environment have meant that both sectors must now consider the ramifications of their actions and decisions in the context of the principles of sustainable development and inter-generational equity. The tendency towards increased pressure on land access and use, and the growing propensity for legal challenges based on actual or potential loss of rights, require both sectors to develop cautious attitudes towards legal liability in relation to mining. Whilst this liability lies mainly with the private sector during the mining phase, the liability may extend well beyond mine closure, and apply to both the private and public sectors.

Table 1: BPEM booklets produced so far

• *Overview of Best Practice Environmental Management in Mining.*
Overviews the program and the attributes that go towards achieving best practice. Outlines the potential problems that can occur as a result of mining activities, and some operations that have achieved recognition for the quality of their environmental work. Also canvasses the financial benefits to mining operators of instituting best practice.

• *Mine planning for environment protection.*
Planning is the key to identifying and minimising the environmental impacts of mining. This booklet examines how mine planning for environment protection can help in developing projects that meet community expectations for minimal environmental impacts. It outlines the considerations that shape mining methods and the design of environmental safeguards. These include: air, water and noise quality; transport; biological resources; social and economic factors; surrounding land uses; and heritage places and artefacts.

• *Environmental impact assessment.*
This booklet introduces the background and purposes of environmental impact assessment (EIA). It covers briefly the legislative requirements within Australia, the key components of EIA, and the different levels of assessment that exist. The relationship of environmental management plans, monitoring and environmental management systems to environmental impact assessment is discussed.

• *Community consultation and involvement.*
The expectations and needs of communities affected by mining proposals are covered in this booklet. The processes involved in preparing for the consultation process are discussed in detail and the key community consultation techniques are described. The booklet focuses on a community-centred rather than a project-centred approach to community consultation and involvement.

• *Environmental management systems.*
This booklet outlines the role and key components of an environment management system (EMS) as one tool to use in achieving the company's environmental objectives and targets. It explains how to operate, implement and maintain an EMS within daily operations, from exploration to mine closure.

• *Environmental monitoring and performance.*
Subjects covered include: the objectives of monitoring programs; selection of indicators; measurement methods; data collection and analysis; and reporting. Monitoring of water, air, dust, flora and fauna are covered. The linkages between environmental monitoring and performance and environmental auditing and environmental impact assessment predictions are discussed.

• *Planning an environmental awareness training program.*
This booklet explains the importance of planning a work-force environmental awareness training program to achieve an enduring and improving environmental culture. Corporate commitment is important to a successful program. A framework is provided which can be used in planning a work-force environmental awareness training program and evaluating its success.

• *Tailings containment.*
Planning, designing, constructing, operating and monitoring tailings disposal facilities are covered. The factors to consider in selecting suitable sites and the various disposal options for tailings are explained. The monitoring and control methods that can be used to minimise environmental impacts are discussed.

• *Rehabilitation and revegetation.*
The principles and practices of mine rehabilitation are outlined. Particular emphasis is given to the restoration of natural ecosystems, especially the re-establishment of native flora. Topics covered include rehabilitation objectives, soil handling, earthworks, revegetation, soil nutrients, fauna return, maintenance, monitoring and success criteria.

• *Environmental auditing.*
Auditing is shown to be an important tool for any mining operation to measure its performance against current and expected regulatory requirements, improve its credibility with the public, assess its level of risk exposure, and access loan capital. A range of audit types is described and examples given of audit checklists.

• *Onshore Exploration.*
Significant environmental damage can result from ground disturbance, clearing of vegetation and careless handling of materials such as drilling fluids, lubricants, fuel etc. Techniques are described to avoid damage, such as consultation with local people, alternatives to widespread bulldozing, earthworks to minimise erosion, rehabilitation of drill holes, and safe handling of contaminants.

• *Managing sulphidic mine wastes and acid drainage.*
At many metal and coal mines, acid drainage poses the most significant risk for off-site environmental impact. This can last for many years after mine closure. Management techniques aimed at identifying, classifying and treating potentially acid-producing material are described. However, the long term effectiveness has yet to be demonstrated and much more research is needed to fully understand how to manage the problem.

• *Hazardous materials management, storage and disposal.*
Common hazardous materials used in exploration, mining and processing are described and methods for safe transport, handling, storage and disposal suggested. Proper management planning, documentation and training are essential components of an effective strategy.

While the bases for potential liability claims are extensive, in mining the most significant basis is on environmental grounds. This is because environmental impacts can persist for very long periods of time or may extend well beyond the mine project area (e.g. for acid drainage, impacts may last for hundreds of years after mine closure, or extend tens of kilometres off-site).

Industry and government must now apply best practice and commit to continual improvement to conform with community expectations. This paper examines progress on the joint industry-government Best Practice Environmental Management in Mining program (BPEM), and discusses how the opportunities which the program is generating may be captured to the benefit of the shared interests of both the private and public sectors.

BPEM PROGRAM - PROGRESS SO FAR

Initiatives are under way in the production of booklets, databases, newsletters, and access information; and in the stimulation of research and training.

BPEM Booklets

Thirteen booklets have been produced so far (Table 1), and fourteen are in the pipeline (Table 2). Preparation of the booklets is overseen by a Steering Committee made up of representatives from industry peak bodies (Minerals Council of Australia, AMEEF), State regulators (Chief Inspectors of Mines), professional organisations (AusIMM), industry-representative government agencies (Bureau of Resource Sciences of DPIE), non-government environment organisations (ACF), research organisations (CSIRO) and Environment Australia.

Table 2: Booklets in progress

- Water management and wetlands
- Cleaner production in mining
- Landform design and surface water control
- Control of noise and vibration
- Cyanide management
- Dust control
- Mine decommissioning and closure
- Management of atmospheric emissions
- Contaminated site clean-up
- Environmental emergency procedures
- Environmental risk management
- Managing social impacts
- Indigenous people
- Energy efficiency

The booklets are written by experts in the field, preferably by mining practitioners, with a view to giving practical advice against a background of the basic principles relevant to each topic. Each booklet includes several case studies drawn from Australian mines, supported by photographs of best practice applications, and key references for further reading.

Extensive links have been developed throughout the industry during the production of the booklets, especially in relation to generation of the case studies, where a wide selection of geographically and technically diverse examples is aimed for. Draft texts are refereed by a review panel selected from the Steering Committee and by industry-based consultants.

Databases

A set of nested databases is under development to provide a value-added information resource for mining industry practitioners. Four databases will provide information on:

- technical references
- case studies / best practice sites
- technical expertise
- training courses and workshops

The database system is linked through the classification of all entries into 66 environmental issues, and so inquiries will eventually be able to be made on an issue by issue basis across the four subject areas, as well as by browsing within each subject area. Each database is to be updated annually, and mechanisms for this are currently being investigated. The structure is designed to highlight gaps in information or measure client needs through a user feedback mechanism, so that appropriate responses can be developed (e.g. no known recent technical references on a particular issue; additional training courses needed to meet current level of interest).

The first database, on technical references, is being launched at this conference.

Research

Environment Australia is sponsoring the Australian Centre for Minesite Rehabilitation Research (ACMRR) to stimulate the level of research into the long term strategic environmental issues in mining. Recently initiated research projects assisted by this sponsorship are listed in Table 3.

Table 3: Strategic research projects initiated by ACMRR in 1996/97

- National Survey of Acid Mine Drainage;
- Inoculating VA Mycorrhiza Fungi into Mine Soils;
- Indicators of Ecosystem Rehabilitation Success ;
- Managing Sulphidic Wastes - Stage 1;
- Definition of Research Needs for the Management and Rehabilitation of Tailings;
- National Review of Waste Rock Dump Design;
- Case Study of Final Voids as a Basis for Assessment of Models for Void Water Quality Prediction;
- Management of Sulphidic Wastes - Stage 2;
- Co-disposal of Tailings and Waste Rock;
- Management of Environmental Impacts of Metals in Mining.

Since the commencement of this partnership, the amount of strategic research in mining and environment conducted through ACMRR has about doubled in terms of projects commenced, and increased 440% in terms of research funding expended or committed. Industry has contributed about $3.50 to strategic research for every dollar contributed by Environment Australia.

The partnership is expected to continue for a five year period, with a view to building a sustained higher level of funding by industry to support long term research into strategic environmental issues.

Training

The Environment Australia/ACMRR partnership also extends to support for constructing a sustainable, self-funding facility to provide vocational training to industry practitioners on key environmental issues. Recent short courses and workshops undertaken with government sponsorship are listed in Table 4. A full-time training manager has been appointed, and training activities are on track to become fully self-funding within the term of arrangement between the two organisations.

Table 4: Training courses and workshops run by ACMRR in 1996/97

- Post-mining Landform Stability & Design
- Native Seed Biology for Revegetation
- Mine Rehabilitation in Tropical Environments
- Indicators of Ecosystem Rehabilitation Success
- Management of Cyanide in Mining
- Environmental Monitoring and Testing
- Rehabilitation of Quarries and Land-fill Sites

Access and networking

Finding out which is the best agency or person to contact is a problem we all face from time to time. Whilst individually we gradually build up a network of contacts, you only have to look at the career move columns in mining magazines and corporate reshuffle articles in the newspapers to realise how difficult it is to keep up to date. AMEEF and Environment Australia have recently made an arrangement to develop a generic framework for identifying appropriate organisations active in the mining/environment field in Australia (Figure 1). The key aspects of each organisation will be presented, including name, address, telephone/email numbers, website address, principal contacts, fields of expertise and activity.

The scheme is to be made available on the Internet, and if it proves successful consideration will be given to further developing it as a front-end gateway to additional information on detailed activities, technical materials, technological solutions etc.

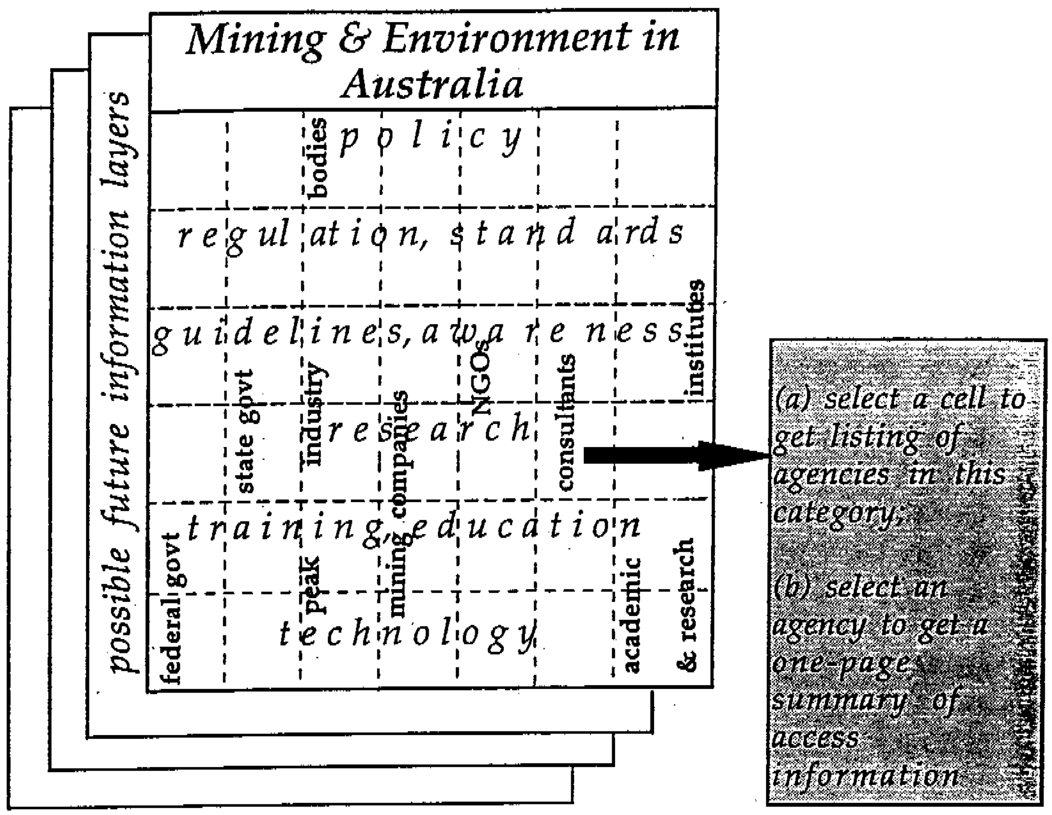

Figure 1. Conceptual matrix for information system to access contacts in the mining and environment field in Australia.

OUTCOMES TO DATE

The number of booklets distributed throughout Australia, and the positive feedback indicated through questionnaire responses and inquiries at conference booths indicate a high level of acceptance; over 6000 sets have been distributed in this country, and new requests for additions to the mail-out list average consistently about 50 per month. Whilst not widely promoted overseas, many requests are received for copies of the booklets, and copies have been distributed to over 60 countries. In response to requests for translation into other languages the first nine titles are now also available in Bahasa Indonesia, Mandarin Chinese, and Spanish (languages chosen because of the presence of, or potential for, Australian mining companies in those language areas).

Increased levels of research and training under the auspices of ACMRR suggest that a substantial improvement in the understanding of, and skills in, a range of environmental management issues will develop in future years. The success of the database systems will be judged in the next few years, but a promising sign is the increasing willingness of industry to work with the environmental arm of government to develop and implement these systems.

However, there are limits to the levels of success which can be achieved by the BPEM program, and these relate to the availability of expertise, funding, and the lack of systems to capture the potential benefits of the program. Development of high quality products requires access to a wide range of leading expertise throughout the industry. Access to adequate expertise ultimately governs the quality of the product, and at present this is obtained through consultancy arrangements with selected experts in each field. The government is committed to funding the program, but the duration of this is limited and ultimately subject to the test of "user pays" to determine the actual value of the program's outputs to the industry, and to gradually transfer full responsibility to the private sector.

The regard for the success of the BPEM program in developing a fruitful collaboration on mining and environment issues has stimulated the Environment Protection Group of Environment Australia to reorganise part of itself along sectoral lines. The intention is to foster greater interaction on both program and policy matters: a "best practice" section will attempt to emulate the BPEM success story across a wide range of industry sectors.

OPPORTUNITIES

An opportunity now exists to develop the BPEM program into a commercially sustainable operation. Some might argue that the mining industry should regard such exercises as the BPEM program as an investment in the future sustainability and viability of the Australian mining sector, and provide up-front financial support. However, the industry does not have a good track record in this approach, and prefers to allow projects to survive or perish on the basis of their ability to "deliver the goods" on a direct fee for service basis. Others might argue that the government should continue to support the program at past levels, but this is not possible because of diminishing budgets, a desire to instigate similar programs for other sectors, andthe attitude in government that the private sector should pay its own way for services of direct benefit to it.

Over the next year, options for partially funding the BPEM program will be explored on a cost recovery basis - for example, possibly charging for the booklets and for access to or placing entries in the BPEM databases. A successful outcome here will be evidence of the value of the BPEM products by industry practitioners, and will be the most appropriate way for the products to be renewed and maintain their usefulness into the future.

Another and very significant opportunity is to build on the closer understanding and working relationships which have developed between industry and the environmental arm of government as a consequence of the BPEM program. One of the key aims of the program has been to demonstrate the substantial level of common interest between government and industry in improved environmental performance. The common interest is in improving the level of acceptance by community and government of the ability of the industry to operate within acceptable levels of environmental impact, and improve the efficiency and certainty of procedures to do with assessment of mine proposals, regulation and monitoring of mining operations, mine closure, rehabilitation, and subsequent land status and re-use. The opportunity now exists for this closer level of understanding to be explored through closer co-operation in strategic policy forums within both sectors, and to set an environmental policy agenda which will cement the Australian industry's place as a world leader in environmentally responsible mining.

CHALLENGES

The challenge for the industry is to respond to the opportunities flowing from the BPEM program. The responses could include:

- assistance in identification and provision of expertise to assist the program;
- demonstrating commitment to the continuance of the BPEM program through up-front or fee-for-service funding;
- co-operation in program planning and its commercialisation;
- development of industry and/or government mechanisms to capture the commercial opportunities flowing from inquiries for information and assistance to the BPEM program (including from overseas);
- collaboration with government in strategic policy forums relating to mining and the environment;
- demonstrating commitment to best practice environmental performance, e.g. through awards systems linked to the industry code of environmental of practice.

Introducing Environmental Planning and the Environmental Performance Review Process to the Christmas Island Phosphate Mine

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INTRODUCING ENVIRONMENTAL PLANNING AND THE ENVIRONMENTAL PERFORMANCE REVIEW PROCESS TO THE CHRISTMAS ISLAND PHOSPHATE MINE.

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Introduction

When considering the icons of environmental management in the Australian mining industry there is a tendency for the community to think first of the more striking and well known examples and these are often the bad apples in the barrel. Such places as Rum Jungle, Mount Lyell and Captains Flat are frequently brought to our attention, especially in this forum. Another location that has previously been regarded as a bit of a horror story is the phosphate mining operation on Christmas Island out in the Indian Ocean. In recent years the mining industry as a whole, through this event and other means, has tried to introduce improved standards of environmental management that reflect the growing community expectations and concerns in the area (Hore-Lacey, 1992; EPA, 1995). Introduction of better environmental management practices has been set as a target by both operator and regulator on Christmas Island and their joint commitment to the pursuit of excellence in this area will hopefully be demonstrated in this account of recent events.

This paper sets out to tell how a re-born, worker-owned mining operation has worked in partnership with the regulating authorities to raise environmental protection and management standards from a historically low base towards a level that it is hoped will be the envy of many others in the industry.

Background

Christmas Island is an Australian Territory in the Indian Ocean, approximately 365 Km south of Jakarta and 2600 Km west of Darwin (Figure 1). About two thirds of the 135 sq Km island is national park, and a marine park zone extends 50 metres out to sea from the low water mark around most of the island (Figure 2), (Gray, 1981). This presents special concerns which the mining company has to manage effectively (Needham et al, 1996). The coast is mostly 10-25 metre cliffs with few beaches. The interior rises through a succession of terraces to a plateau between 150 and 360 metres above sea level. The national park protects a rainforest habitat and some unusual flora and fauna, notably the migratory red land crab and rare and endemic birds such as the Abbott's Booby and the Christmas Island Frigate Bird (ANCA, 1994a and 1994b).

Mining began on Christmas Island with an extensive exploration program in 1887, and the first commercial phosphate shipment left the Island in 1895. The first phase of mining lasted from this initial shipment until 1987 (apart from a break during World War Two). During these times the majority of the deeper, higher grade resources were removed and the lower grade material stockpiled in heaps around the Island. Ownership had been private until 1948 when the Christmas Island Phosphate Company sold out to the Governments of Australia and New Zealand (Woodmore, 1996)

Phosphate mining operations ceased in 1987 as a result of a decision by the Commonwealth to place the Government owned Phosphate Mining Corporation of Christmas Island into liquidation. After lobbying by the Union of Christmas Island Workers and the local community the mine was reopened in October 1990 as a employee owned commercially operated business (Phosphate Resources NL), now known as Phosphate Resources Limited (PRL) trading as Christmas Island Phosphates (CIP). PRL is permitted to recover resources from the existing stockpiles and carry out limited in-situ mining within previously mined areas, provided no rainforest is cleared. The lease areas cover about 20 sq Km or 15% of the Island and are scattered across the Island, including excised areas within the National Park. The park was declared before the current mining phase began. The mining company also recovers dust from the product at the dryers which is then bagged at a plant on the wharf and sold into various markets in Asia where it is popular with smallholders.

PRL has until recently been operating under a ten year lease to conduct mining operations, granted by the Commonwealth on 26 September 1990 (Phosphate Resources NL, 1995). To enable PRL to plan and establish long-term mining operations with confidence, and maintain customer confidence, the company has recently negotiated a new lease with the Commonwealth Government. This re-negotiated lease will allow PRL to recover phosphate ore from existing stockpiles and in-situ resources within the existing mining areas until at least 2014 (CIP, 1996).

Production has increased from less than 64 000 tonnes in 1990-91 (56 480t of rock and 7 129t of bagged dust) to 421 906 tonnes which were shipped in 1994-95 (Phosphate Resources NL, 1995).

Involvement of the Office of the Supervising Scientist

When the mine recommenced there was no effective legislation to control any aspect of the operations. The Commonwealth Government decided to adopt West Australian legislation and enact it as Commonwealth law. This was achieved through the introduction of the Christmas Island Act of 1992. Amongst the Acts adopted but not yet applied at this time were the Mining Act and the Environmental Protection Act. Carriage of particular elements of the former, primarily OH&S issues, was to be given to the WA Department of Minerals and Energy under a service delivery agreement and negotiations were put in place. The environment protection legislation lay with no agent to enforce it until 1995. In June 1995 production at the mine was increasing and so was the potential for environmental impacts.

With much of the infrastructure old and tired and few notions of what was required the mine began to receive complaints about a range of impacts. These complaints were also sent to the Federal Minister for the Environment. As a consequence, in July 1995, OSS was requested to examine the situation and recommend actions required to normalise the situation with respect to mainland Australia.

The visit identified a number of outstanding environmental issues. Dust levels in the loading operations area were very high and potentially hazardous, management of waste and fuels and oils was mostly haphazard, and the overall level of environmental housekeeping poor. The company knew it had to improve its environmental management performance had sought help. The use of short term consultants was expensive and also lacked consistency and continuity.

OSS also noted that the mine was not the only site on the island with these sorts of problems but they were the most obvious and potentially the most important in terms of community impact. Many environmental issues were identified and the recommendation made to appoint a Commonwealth Environmental Officer to the island. This person was to be not only a regulator but also a resource point for information so that the community and other organisations could be assisted in their efforts to improve environmental management and pollution control.

Preliminary Environmental Audit

As a prelude to the appointment of the Environmental Officer, an independent preliminary environmental audit was undertaken to indicate the scale and range of environmental management problems being encountered at the mine and elsewhere. The audit confirmed that there was little active environmental management planning, and although the mining company was aware of the problems they were not certain how they should proceed to manage and improve the situation (Brown, 1995).

Over the next few months the PRL developed an outline strategy for identifying and managing environmental issues, and the Environmental Officer drew up the first environmental licences under the legislation. As a "prescribed premises" the mine was required to comply with a series of requirements mostly relating to alleviation of the dust issue.

Introduction of the EPR Process

During the preliminary environmental audit it became apparent that the community was concerned about developments with respect to improved environmental performance in all aspects of the island's life. Drawing on the experience, and success, of the processes introduced into the uranium mines of the Alligator Rivers Region (OSS, 1995) it was decided that the same program of environmental performance reviews (EPR) would appropriate to monitor progress and improvements in environmental management as well as providing the opportunity for community consultation (Needham, 1996a). The EPR process is essentially a periodic environmental audit which is followed up by a reporting meeting at which the community is encouraged to attend and participate. All the EPR documents are bound and deposited with public libraries on the island where they are available to the whole community (OSS, 1996, 1997).

In essence an audit protocol specific to the operator, in this case PRL, is prepared and distributed two weeks before the EPR interview and inspection when the proponent is asked to formally answer the questions and provide supporting documentation or evidence supported by an inspection. A summary report is prepared containing the audit completed protocol and an assessment based on the information provided and observations from the inspection. The summary report is signed off by the company and the audit team as a fair and accurate record. The report is a review of the period since the previous EPR and a snapshot of the situation at the time of the EPR and emphasises. improvements made, regulatory infringements and areas where improvements are required. The function of the EPR team is not to command and control the operation but observe and report. The concept of the EPR is in accord with the tenets of the ISO 14000 series of standards and reflects closely the process set out in ISO 14035. The history and operation of the EPR process have been described previously in detail by Needham (1995, 1996b).

Development of the EMP

The mining company, in response to the findings of the initial EPR in May 1996, recognised the need to prepare a comprehensive plan that identified the key environmental issues facing the operation and provided appropriate solutions. At the same time negotiations were under way with the Commonwealth regarding the new lease and the issue of minimising environmental impact was high up on the list of concerns.

It was clear that a comprehensive environmental management plan (EMP) was necessary to adequately address all environmental concerns. The company decided to create the position of a full time Environmental Manager in order to facilitate its preparation and implementation. The EMP was completed in December 1996 and then adopted as an annex to the new lease, thus ensuring a legal imperative for its implementation (PRL, 1996a).

The EMP provides details of all aspects of PRL's operations and the environment in which it operates. It details the environmental management strategies, including targets which will be implemented over the following 3 years to ensure that environmental impact is minimised and environmental protection programs are developed and implemented. performance indicators for each strategy have been developed and will be evaluated as the plan progresses.

Achievements and Progress to date

The primary area of concern with regard to environmental impact which has been identified repeatedly is dust. PRL inherited an infrastructure that was, in parts, at least 30 years old. A further 3 years of inactivity had seen extensive deterioration of plant and equipment. The company has made a commitment to bring all of its operations up to the current standards for dust emissions within the next two to three years. To this end the PRL prepared a detailed dust removal plan which was presented to the Commonwealth Minister for Territories on the 5th September 1996 (PRL, 1996b).

The major achievement to date has been the installation of state of the art shiploader chutes which have almost eliminated dust emissions during ship loading. Before the installation of these chutes it was frequently impossible to see the ship during loading due to the plumes of dust generated when the product dropped into the ship's hold. Also this dust cloud settled on the sea and sank to the reef below with probable adverse impacts. Now there is effectively no deposition on the sea from the ship loading operations.

Other achievements so far include purchase of a large vacuum truck to collect dust spills, and a start on upgrading the 6 Km long conveyor system. Early work on the conveyor has included changing the angle of the conveyor rollers to better contain the product and replacing damaged cladding on structures to contain dust at transfer points. Other work includes replacement of damaged and missing cladding at the rock bins (product storage sheds) on the wharf and throughout the buildings in the dryer complex. PRL has also implemented a comprehensive dust monitoring program and a marine monitoring program to determine the effect of dust on the reef adjacent to the ship loading facilities and to study recovery of the marine ecosystem.

PRL is attempting to upgrade its operations with regard to all environmental concerns, not just dust emissions, and has improved in many areas such as fuel storage and management, waste management, energy conservation, heritage and the protection of native flora and fauna, including rehabilitation of new and old minefields.

Rehabilitation

At present, Parks Australia manages the Christmas Island Rainforest Rehabilitation Program (CIRRP) in conjunction with PRL. The company pays a rehabilitation levy of $1.50 per tonne of bulk rock phosphate shipped from the Island. Parks Australia has managed the CIRRP operation since 1989 (ANCA, 1996) and is currently rehabilitating approximately 10-15 hectares per year with CIP as the earthmoving contractor. Parks Australia operates a nursery which produces the necessary seedlings of native tree species for use in the replanting program. In the present system of rehabilitation of old phosphate minefields, extensive earthworks are required in order to prepare the sites prior to planting. 'C' grade material a sub-commercial grade of phosphate recovered from stockpiles left from previous mining operations and containing between 5-18% P_2O_5, is used for the earthworks.

The "C" grade is dumped to a depth of 1 metre over the leveled pinnacle fields with the surface left as a series of swales and dales to reduce erosion and runoff and aid in rainwater infiltration. Alternate rows are planted with an introduced species of cover tree, the Japanese Cherry (*Mungia spp*) which provides shade for the intervening rows of seedlings of native rainforest species. Macaranga is also being used as an alternate shade species. The rainforest plants eventually grow through the shade cover and out compete the shade-intolerant supporting species. In the interim the Japanese Cherry provides a valuable food source for fruit eating native fauna until the native species have begun to fruit (P. Bridgewater, pers.com.).

The present rehabilitation program only deals with areas worked out by the previous mining company and concentrates on those areas which are near critical breeding habitat of the endangered Abbott's Booby. With the introduction of the Western Australian Mines Act there will now be a requirement for PRL to rehabilitate the areas in which it will be mining. As a result the current program is being reviewed in order to provide for a more integrated approach to rehabilitation in both old and presently mined areas and to improve rehabilitation.

General Environmental Management

In addition to the phosphate operation the EPR process has been successfully applied to operations as diverse as the Christmas Island International Airport, the Christmas Island Resort and Casino, a range of fuel storage and marketing operations and a supermarket as well as the Shire Council's operations, particularly the waste rubbish tip. Without exception the operators have participated enthusiastically in the six-monthly reviews of their environmental management performance in the year and a half since the EPR process began. All major players have developed EMPs for their operations. It is likely that at one facility the EPR frequency will be reduced to once per year as the EMP has been very effective and environmental management is good.

Apart from the obvious pollution control exercises such as oils and fuels storage, chemical use and storage, various other policies have been implemented such as internal environmental audits, waste minimisation and energy audits. These are processes which, although designed to be effective in cost cutting and improving productivity, also have very positive spin offs for environmental management in almost every case. As a major community member, the mining company also acts where it can to contribute to overall environmental management improvements on the island, often working as a partner.

One example of such a joint program is the scrap car issue. Historically the people of Christmas Island have been able to import cars relatively cheaply from Singapore. So cheap that when major problems occur the cars are often abandoned and replaced rather than repaired. This has led to a stockpile of up to 1500 abandoned vehicles on the island. Also there are substantial quantities of scrap metal from old mining operations and similar activities, including railway rolling stock, bridge frames and locomotives. PRL is also planning to demolish a redundant production plant at South Point which was abandoned by the previous operators. Whilst some examples are to be prepared for preservation as heritage items the majority are only of scrap value. A joint program paid for by PRL and the Commonwealth should see all the scrap metal removed from the island over the next 12 months by a contractor. New provisions will then be put in place to reduce the accumulation of scrap on the Island.

The waste tip has been a cause for concern for some years. It is inappropriate to keep digging holes in an island and dumping waste in a haphazard fashion. The present site has a history and culture from the past which have made the introduction of new and improved management strategies very difficult. A new site has been located which will offer waste separation facilities as well as designated areas for scheduled wastes, which will in turn create opportunities for waste re-cycling through shipment off-island. There is little chance of recycling becoming a profitable exercise, but it has been estimated that it could become cost neutral or at least require little subsidy. Participation of the shipping company is an integral part of this process, as is the support of the community.

Conclusions

The introduction of modern environmental management practices has been successfully initiated on Christmas Island. Progress already made by the phosphate mining company has substantially reduced dust emissions at the ship loading facility and measures and plans are in place which will reduce dust emissions across the entire operation including the wharf storage areas, the conveyors and the dryers. Implementation of the new EMP has been the reason for many of the other environmental improvements seen in the mine's operations. The prognosis is good; within two years the objective to have a modern mining operation with high environmental standards should be well on the way to being fulfilled. The story so far shows how regulators and operators of mining, infrastructure and service industries can work together to achieve improved environmental management in a non-adversarial way.

Acknowledgments

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References

Australian Nature Conservation Agency (1996) Annual Report 1995-96, Australian Government Printing Service, Canberra

Australian Nature Conservation Agency (1994 a) Christmas Island National Park-Plan of Management, Colemans Printing, Darwin.

Australian Nature Conservation Agency (1994 b) Corporate Plan 1994-96, Goanna Print Pty Ltd, Canberra

Brown G (1995) Preliminary Environmental Audit of the Indian Ocean Territories. Report to the Territories Office, Department of Environment Sport and Territories. Canberra. (unpublished)

Christmas Island Phosphates (1996) Dust Removal Project: Project Presentation Folder, (unpublished)

Environment Protection Agency (1995) *Overview of Best Environmental Management in Mining,* module in the series *Best Practice Environmental Management in Mining,* Commonwealth of Australia, Canberra

Gray HS (1981) *Christmas Island Naturally*, Scott Four Colour Print.

Hore-Lacey I (1992) *Mining and the Environment*, Newstyle Printing, Adelaide.

Needham R S (1995) Best Practice Environmental Management in Mining. in *Proceedings of the 20th Environmental Workshop, Darwin NT, 2-6 October 1995.* Minerals Council of Australia, Canberra.

Needham RS, Nicoletti-Lewins C, Waggitt PW & McBride TP (1996a) Mining and National Parks. in proceedings *Mining and the Environment Workshop*, Jakarta, 9-10 June 1996. (unpublished), Jakarta.

Needham RS (1996b) A system of environmental performance assessment and reporting which serves the needs and expectations of operators, regulators and the concerned public, in proceedings *Academy of Science, Fenner Conference on the Environment.* University of New South Wales

OSS (1995) Supervising Scientist Annual Report. Australian Government Printing Service, Canberra

OSS (1996,1997) Environmental Performance Reviews of Phosphate Resources Limited #1,#2 and #3. OSS Darwin, Christmas Island and Canberra. (unpublished)

Phosphate Resources NL (1995).Annual Report 1994-1995. (unpublished)

PRL (1996a) Christmas Island Phosphates Environmental Management Plan. Company Report. (unpublished)

PRL (1996b) Christmas Island Phosphates Dust Removal Plan. Company Report. (Unpublished)

Woodmore FP (1996) *Christmas Island Explorer's Guide*. Lone Island Publications, Christmas Island , Australia.

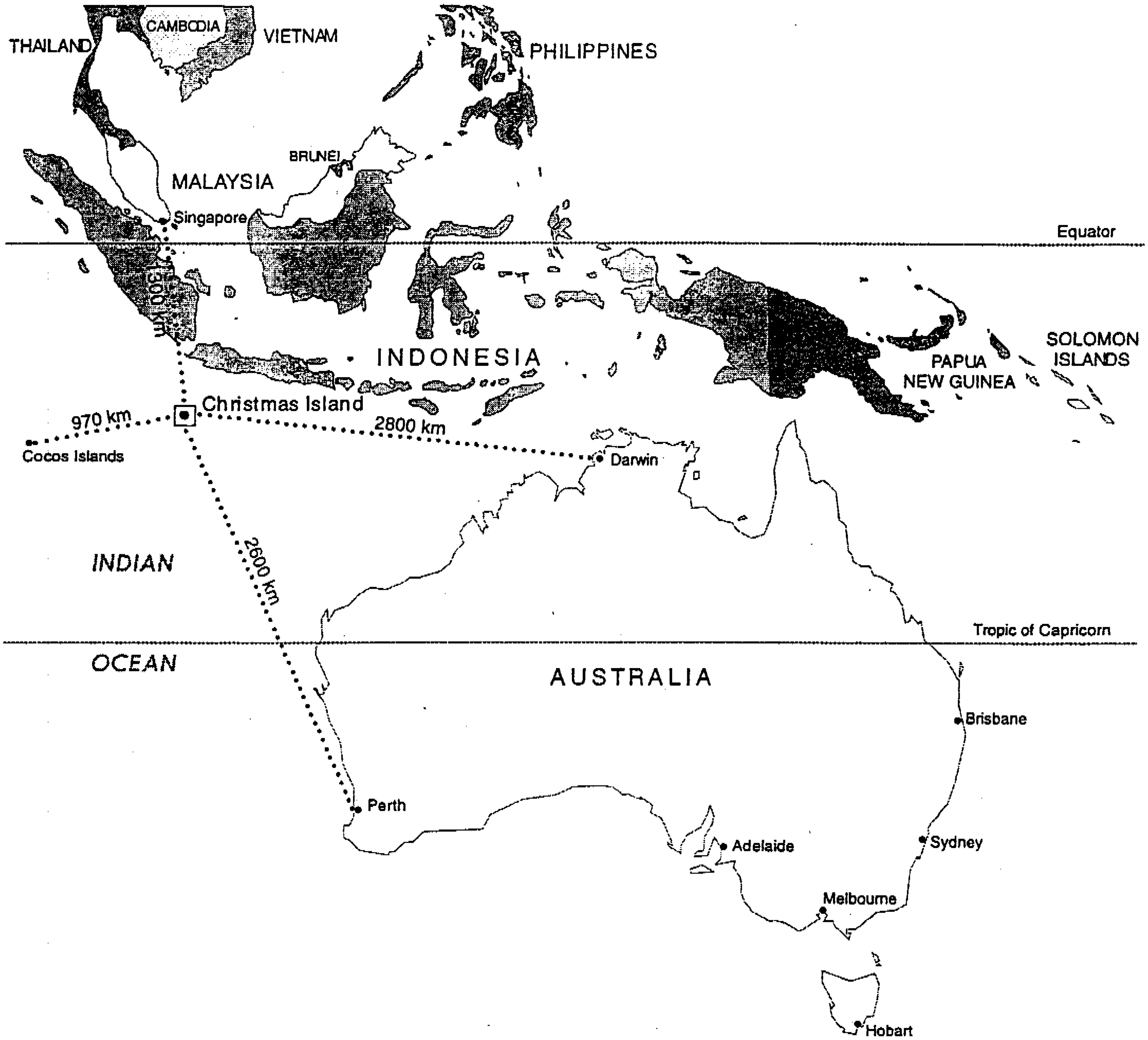
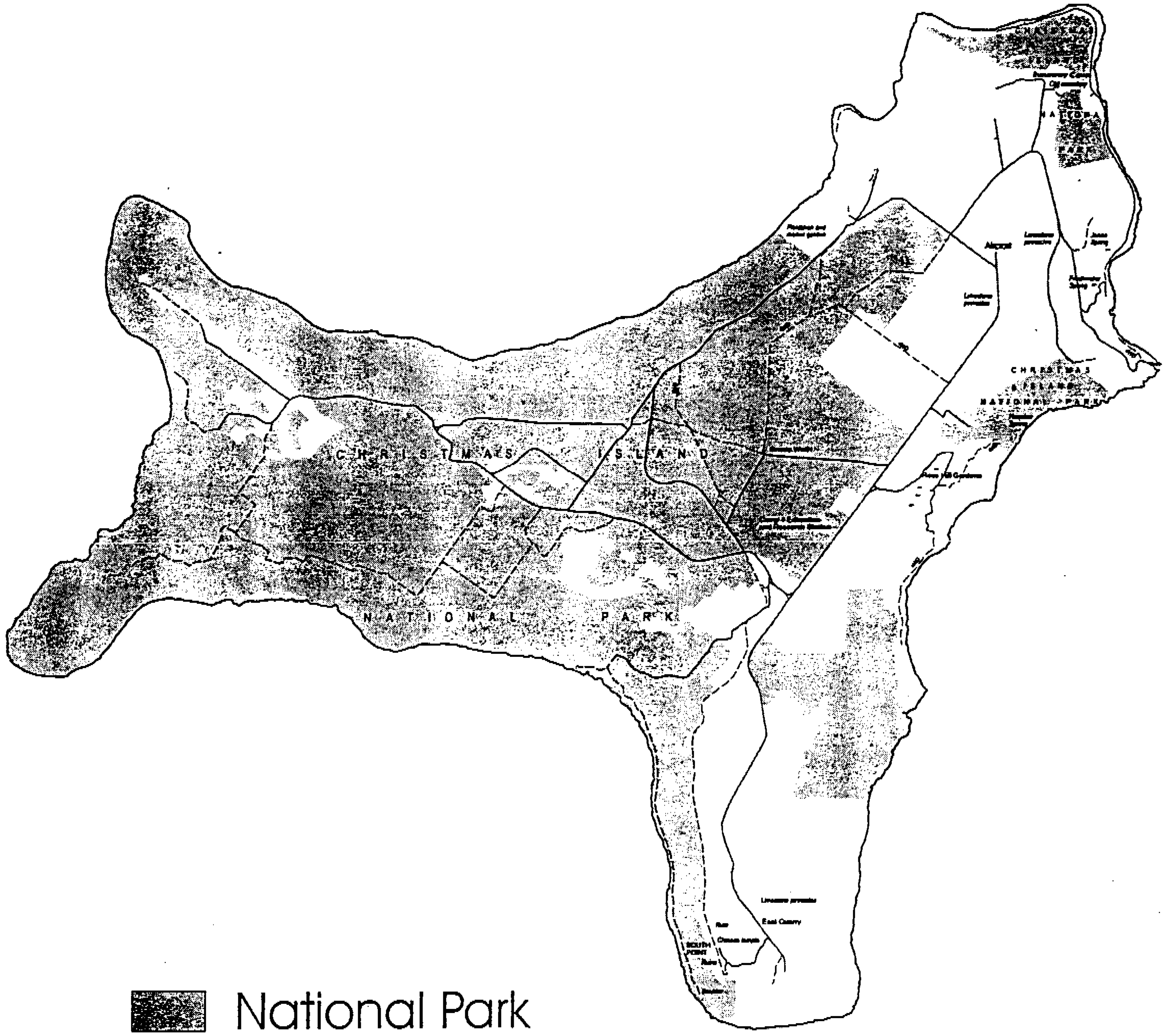


Figure adapted from Auslig Map 94/068

Figure 1 Location of Christmas Island



National Park

0 2
Kilometres

Figure 2. Christmas Island

(adapted from ANCA Tourist Map, 1996)

Evaluating Best Practice Tailings Management

Peter Waggitt

New Technologies and Cost Saving Innovations for Successful Tailings Management Conference

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EVALUATING BEST PRACTICE TAILINGS MANAGEMENT

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Introduction

Throughout all industries the expectation today is for everyone to do more with less. Environmental issues have assumed greater importance in the eyes of the community. The community increasingly demands environmentally friendly products made with cleaner technologies. Environmental quality and lifestyle issues assume greater importance as land pressures increase and the carrying capacity of land, air and water are approaching their limits. Contaminant levels of raw materials are increasing as resources are drawn from poorer quality deposits. Managing all of these factors are some of the essential elements of what has come to be known as best practice.

Best Practice are words that we come to hear more and more frequently in the context of all walks of life. The mining industry and environmental management are no exceptions.

In the mining industry the management of wastes, especially the process wastes we call tailings, is an issue that is of growing significance. The costs, both capital and operating, of waste management, the increasingly stringent environmental standards and regulations and the growing level of public participation in both green and brown environmental issues as well as the increasing public expectations, are all combining to make the safe, efficient and successful management of mine tailings a major priority in modern mining. The mining industry is keen to be seen as being environmentally conscious, to be taking care of the environment, becoming increasingly efficient and reducing pollution.

We are gathered to spend the next two days hearing about successful tailings management, to debate case histories and listen to descriptions of the latest technologies being described by some of the most respected practitioners in our industry. Since the theme is successful tailings management, we will be pushing out the envelope more than a little in places. But success is most frequently judged by results, and what we are trying to achieve is the best so my theme for this first session is evaluating best practice tailings management.

Best Practice

We are all familiar with Best Practice, or are we? The first step must be to agree on a definition and ensure that we are all clear about what it means. Best Practice has been described as "simply the best way of doing things" (Carbon, 1995), but that is possibly an over simplification, for it implies that issues such as cost and community opposition are not considered. In reality what we are often required to consider is something rather different, for example what has been defined as "Best Practicable Technology" (OSS, 1979). In this case we are allowing ourselves to adapt Best Practice by taking account of issues such as cost, location, current technology and social and economic conditions which will result in the final outcome being perhaps better expressed as the best practice that we can implement which is acceptable to all the stakeholders and provides the best possible levels of environmental protection and management.

Best Practice tailings management is described very succinctly in the booklet entitled "Tailings Containment" published by Environment Australia as part of the "Best Practice Environmental Management in Mining" Series (EPA, 1995). But how is this best practice to be evaluated, and by whom? Technical appraisal by peers and regulators is the usual evaluation pathway which is now frequently combined with inputs from community interests. And what is likely to be best practice tailings management? Does it have to be determined for each situation? But first and foremost what are the problems facing the industry in tailings management?

Tailings disposal-the size of the issue

The size of the tailings issue in terms of volume is significant. For example, at just one mine, the Ranger Mine in northern Australia, the annual mill throughput is approximately 1 million tonnes of ore which means that about 1 million cubic metres of tailings are produced. Scale this up by country, by commodity and by varying ore grade and it is apparent that the worldwide annual production of tailings is substantial, certainly thousands of millions of tonnes. Even in Australia we must consider several hundred million tonnes of both previous and current production of tailings from a wide range of metalliferous mines. A waste management issue of sizeable proportions indeed.

Figures are difficult to come by on a worldwide basis but Table 1 gives an indication of the levels of tailings production worldwide for some commodities in 1994. It is apparent that copper is perhaps the metal whose production leads to more tailings than any other enterprise in the mining sector. This list is obviously not exhaustive. There are other commodities that are mined and overall world mineral production is certainly not declining. Also the table does not include output from any centrally planned economies.

Table 1 Tailings Production 1994-Selected commodities

Commodity	Tailings (M tonnes)	Origin
Copper	1500	World
Gold	500	World
Lead & Zinc	130	World
Bauxite	70	World
Potash	120	World
Phosphate	50-60	World
Coal	17(NSW) 24.3 (QLD)	

Source: UNEP, 1996

The number and style of tailings impoundments also needs to be considered, for not all tailings are contained in dams. There are numerous tailings dams around the world. Just to take a few examples, in Western Australia 350, Quebec Province 164 and about 400 in South Africa. In South America, other parts of Africa, Europe and Asia there are probably thousands, maybe tens of thousands more. This is not a small or local issue. Even in the Northern Territory of Australia there are currently several tailings dams in operation and tens of de-commissioned facilities. Worldwide the situation is probably very similar in terms of proportions.

Tailings may be deposited into purpose built structures of various types (Fell et al, 1992), discharged directly into rivers as at Ok Tedi in Papua New Guinea, piped to sites on the ocean floor (Ellis, 1996), placed into old mines (both open pits as well as underground workings), placed in loose piles on flat land, pumped to infill valleys (Ritcey, 1989), or mixed with large size waste rock or other materials. The spectrum of disposal methods is effectively continuous. However, the practice of uncontrolled tailings disposal is coming under increasing scrutiny and is rarely now an acceptable option anywhere.

What are the issues?

The major issues facing mine operators in their tailings management programs begin with the notion that it is a waste disposal situation. The disposal of wastes is a major issue for all industries and mining is no exception. The issue of mining waste (tailings) disposal and management has been a cause of concern as long as there has been mining (Agricola, 1556). It is frequently the subject of papers, books and workshops eg, Williams (1975), Argall (1979), Ritcey (1989) and Waggitt (1994) not to mention this present event.

One possibility has been that the waste from one operation will supply a raw material to another project. A typical example of this would be the old South Alligator Uranium mill tailings which lay abandoned after operations ceased in the late 1960's until about 1986 when another company purchased the tailings to re-work them and extract gold. The tailings in this case were relocated to a more secure storage facility as an integral part of the project. The result was a better containment and overall, an improved outcome for the environment. So the first consideration should be "are the tailings really finished with?". In South Africa most of their uranium comes from re-worked gold tailings and this is taken into account when planning tailings disposal.

However, there are other sides to this sort of tale. In Grand Junction, Colorado, uranium mill tailings were used as a source of sand for construction and bedding for utility lines. Best practice in the 60's was apparently to encourage the re-use of this material with no obvious consideration of other consequences, for example radon emanation. When the enormity of the situation was realised, the remediation work identified over 4000 vicinity properties, houses, shops streets etc affected radiologically by the presence of tailings to the extent that action had to be taken by the authorities. The cost was very high, the overall uranium mill tailings remediation program of the US Department of Energy (UMTRA) has cost over US$1.5 billion so far and they have not really started on ground water remediation yet! Ground water contamination by uranium mill tailings is a serious issue at several sites throughout the central western portion of the USA (UMTRA, 1996). So the need for the proper placement, containment, and management of all types of tailings cannot be over emphasised.

Environmental impacts from tailings can arise in many ways. For example impacts on fauna, such as bird kills on cyanide decant ponds are reported from time to time. Australians will recall the infamous incident at Northparkes a little while back which achieved notoriety through extensive media coverage. In the USA best practice is now to place netting over cyanide decant ponds where they are on migrating bird routes and to employ bird scarers and recovery teams to minimise the possible adverse impacts. At one north Australian mine a water buffalo managed to get into a cyanide pond on a tailings dam and perished by a combination of drowning and poisoning (C McQuade, pers.com). So fencing may be required to keep large fauna out of the water. There is little that can be done to prevent animals drinking tailings pond waters if they are the only source in the area. Some American sites are reputed to have considered placing alternative water bodies near cyanide containing tailings dams to offer a clean safe water supply but no documented case has been found in the literature. Provision of alternative water supplies in this way would be an example of best practice in arid zones. Equally, tailings dams where exposed waters are not contaminated to any significant extent may offer a refuge for wildlife, even a complete new habitat (UNEP, 1996).

Cost can be another major element in the equation. The cost of tailings management is yet another production input. A recent seminar in Western Australia discussed this issue at length. At that event it was appreciated that whilst the direct (operating) costs of tailings disposal and management are relatively easy to calculate, there are other indirect costs which may be even greater. This is especially true in the event of a failure in a tailings storage facility. The seminar was organised by the Australian Centre for Geomechanics and included the examination of case studies of situations such as those at Northparkes and Ok Tedi. Fortunately there have been few major incidents or failures in Australia. However, discussions on overseas incidents, in South Africa and The Philippines, showed that the costs of repairing the physical damage and compensation after a tailings containment failure can be far outweighed by the costs of maintaining or "repairing" public perceptions of the operating company as environmentally responsible (Jewell, 1997). The issue of time for repository life was debated at some length at the same venue and it was decided that until the issue of what is meant by "long term" is resolved, the industry may well be having to face up to very long, even infinite, maintenance periods which could have a serious bearing on the future viability of some operations.

What are the objectives

In terms of tailings final disposal the major factors to consider are:

- containment
- pollution control
- management

If tailings are well contained then the pollution question may be dealt with simultaneously. There are few instances of specific rules for the management of tailings but in the Australian Code of Practice for the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores there is a requirement that uranium mill tailings be contained in structures that will have a design life of at least 200 years and structural life of at least 1000 years. This means the structure will continue to perform its required function without supportive maintenance or renovation for at least 200 years. The structural life requirement of 1000 years means that the basic function will continue to be performed albeit at a reduced level of efficiency, thus this becomes the measure of what might be termed "useful life". If a maintenance and management program are put in place, this life is obviously capable of being extended for very long time periods, but inter-generational equity considerations then come into play. Should we be designing facilities that will place obligations on those who will follow or can we do better now? Isn't that perhaps best practice? I leave it to other speakers over the next two days to provide more information on these issues.

Community safety is another important part of the containment issue. In the past there have been problems of tailings dam failures resulting in property damage and loss of life. Such instances are not everyday events. Five major failures were reported between 1980 and 1996 in the UNEP survey (1996) which lead to a total of 88 fatalities, but there have been significant numbers of failures which concern the community for many years. In the 1972 Buffalo Creek incident in Western Virginia USA, 126 people lost their lives and there was also extensive damage and pollution downstream after coal waste dams failed. Not perhaps tailings in the strictest sense, but a type of material that behaves in a similar way.

If there is no dispersion of tailings then much of the concern related to pollution may be dealt with at the same time. Pollution may occur through a variety of pathways. There may be gaseous emissions, radon from uranium tailings for example or possibly other gases from reactive tailings. These can be contained by covers which may be dry, wet or even water itself. Containment may be maintained by use of an engineered cover, a water cover with surrounding dam walls, by return to underground workings or mined-out open pits, or return to a submarine or subterranean cleft.

Maximising environment protection including protection of the community, containment of tailings materials, reduction of possible on- and off-site impacts especially pollution, and the minimisation of maintenance for the foreseeable future must be the prime objectives. How each is to be achieved in a framework of best practice and in concert with the other objectives is the major challenge.

Site selection factors

When planning for a new mine commences, the issues of waste management and final rehabilitation must be placed on the agenda with everything else. Tailings management is a significant waste management problem in every mine. The selection of a location and methodology which will allow the disposal and containment of tailings in an environmentally safe manner is vital. The location must take into account many factors before a final selection can be made.

First and foremost, are there any local regulations to be taken into account that relate specifically to tailings disposal and management, eg is below ground storage a regulatory requirement, must containments be built to the same standards as water retaining structures? Also what do the community think about a tailings dam being placed in their area? All of these issues will have to be addressed and considered in a best practice evaluation, and that should itself include a hazard identification and risk assessment as integral elements of the process. In the following sections examples are given of the items that need to be included in assessments when selecting sites and methods for tailings disposal.

Site significance to all community groups

Are there any sacred or religious sites in the vicinity such as ancient monuments or burial grounds? Such places are often protected by law and may have buffer zones around them. All areas should be surveyed by appropriate specialists to ensure that there are no unknown or unregistered sites of social, scientific or archaeological significance that might be affected by the proposed tailings storage development. Settlement locations should also be considered, both existing and planned. Whilst the mining company has control over its own development plans, there may be villages or other infrastructure developments which need to be taken into account. In some locations, a new mine may bring with it the opportunity for a squatter colony to become established as the development offers work opportunities.

Ultimately, as Jerry Ellis of BHP said recently (Ellis, 1997), mining companies have to earn their "licenses to operate" from the communities in which they work. Community consultation is an essential part of best practice. All best practice programs and assessments must include a structured and continuing program of community consultation to ensure that stakeholders are informed and have adequate opportunities to exchange information and provide feedback to the mining company.

Meteorology

Building or mine operating regulations may impose standards that require tailings dams to be designed to withstand floods or rainfall events of a specific return period. For example, at Ranger Uranium mine in the Northern Territory the tailings dam has a wet season maximum operating level imposed by the regulating authority which ensures that there will always be sufficient freeboard to accommodate a specified return period of rainstorm. Similar provisions are imposed on a waste water retention pond at the same site in that it must be operated at a level that will enable it to accommodate a 1 in 100 year return 72 hour storm. Equally, the design of a tailings dam should take into account the severity of rainstorms in the area. Many structures are now designed to with stand the flood associated with a probable maximum precipitation event.

Topography

The topography of a tailings repository site is very important. Often a valley in-fill site is preferred as it offers a minimum cost solution to tailings disposal. Equally topography may need to be reviewed in terms of its potential to increase risk, to downstream communities or adjacent wetlands for example. The site should be set out in such a way that drainage does not run off across or accumulate on the site of the tailings. Also, the path of any possible flow following a failure needs to be examined. The camp at the Argyle diamond mine was relocated after it was realised that it lay in the path of the tailings dam should there be a failure as a result of an earthquake.

Surface water

Tailings dams are generally not designed as water retaining structures but most do carry small decant ponds at the surface. The major concerns are to ensure that these waters do not overflow the structure which would present the dual hazards of dispersing contaminants, both solid and liquid, as well as threatening the integrity of the structure with the associated risk of complete failure. Tailings dams are rarely threatened by surface water unless they have been located in a stream course, on a floodplain or in a valley fill site. The concern is almost always what they may release to surface waters.

Groundwater

The commonest concern with tailings in relation to ground water is the risk of contaminants leaching from tailings and passing into the ground water system. This can be minimised or even prevented by a number of techniques. The issue of an artificial liner or waterproof membrane at the base of the tailings storage is a most effective way, albeit rather expensive. Current best practice in the USA for sites of concern is for tailings repositories to be treated as contaminated waste sites and have two liners with a seepage detection system operating between the layers. Experience from the USA at one uranium mill tailings disposal site in the Uranium Mill Tailings Rehabilitation program (UMTRA), and a few Superfund sites suggests that such systems are very difficult to manage unless installation and materials are subject to the most stringent quality control procedures. There may be systems which rely on compacted clay liners or even compacted earth to act as a barrier to seepage leaving tailings. Some facilities have seepage collector systems which vary from open ditches and shallow drains to catch near-surface seepage, to the sophisticated pumped well schemes and reverse osmosis water treatment plants found in some uranium tailings sites of the USA. It is a matter for debate if seepage collection is best practice as it invariably requires very long term intervention and management at a site and arguably best practice means being able to stand back from a completed project. Seepage prevention and retention may be best practice with seepage collection and treatment as an additional precaution. Introduction of modern geotechnical techniques such as membranes, cut-off walls and slurry trenches are seen by some as a way to reduce the risks of groundwater pollution (Cross, 1997).

Foundation suitability

Most tailings containments rely on some form of structure as the retaining device. The foundations of such structures are commonly on the local soils and rocks, particularly in the initial stages of the project development. Later, the tailings impoundment may be built by such methods as upstream construction where the foundation is on previously deposited tailings. But in the first instance there needs to be an accurate and detailed assessment of the foundation conditions by specialist geotechnical staff. Such an assessment must include an examination of the seismic risk.

The conditions of the foundations for tailings dams are a vital consideration in ensuring that containment will be safe and secure for as long as possible, ideally indefinitely. Factors to be considered include ground conditions, geology, seismic activity and climate. High rainfall areas often have greater susceptibility to land slips and similar movements (Murray et al, 1996). Many areas have a seismic history which will require a very thorough assessment of the suitability of the site for a tailings dam. In such areas, there is not only the risk of collapse of structures but also liquefaction of the tailings mass which would enable it to flow off site with possibly disastrous consequences for the community as well as the environment.

Geochemical issues

Should tailings be left exposed to rainfall then there is a potential issue with water percolating through the mass and possibly leaching chemical materials which could be released where the water returns to the wider environment. Some tailings are required to be neutralised before deposition in order to reduce the risk of leaching, eg at Ranger Uranium Mine in Australia. At some locations acid tailings may be discharged to the containment but the natural alkalinity of the host rock is used as a means of neutralising acid leachates passing to the wider environment, eg at Rössing in Namibia where acid tailings are deposited in a area of limestone karst country.

Properties of tailings.

The physical and chemical characteristics of the tailings must be examined to see if they present any special problems which will require particular management strategies to be employed. For example, are the tailings reactive, that is do they contain chemicals which will continue to react and so provide a risk to the environment. The classic example would be sulfide rich tailings and the associated risks of acid rock drainage developing with all the attendant problems of acidity and heavy metal contamination. These issues and management options are explained in the BPEM Booklet "*Managing Sulphidic Mine Wastes and Acid Drainage*" (Environment Australia, 1997). There may also be specific chemicals released from the ore during treatment but not recovered in processing, or processing residues which remain mobile after tailings deposition. In the case of uranium mill tailings there is the issue of radon gas emissions to be considered. Are any emanations of sufficient magnitude that intervention or special management may be required? Finally, there may be a need to consider re-processing of tailings to remove another product.

The physical characteristics of the tailings must also be studied. Is the material free draining or relatively impermeable? Are there large quantities of fine textured materials or slimes present, does the material dry out? Does the grain size distribution of the tailings make them particularly susceptible to liquefaction or slippage during possible seismic events?

All these characteristics should be examined to see if there is any significant increase in risk to the environment.

Australia today

What has happened in the past, how did we get to where we are today? What are the issues and the options to consider for tailings management?

Modern mining is an industry under greater pressure than ever before to perform in all areas, not only economically but also environmentally. Failure to be seen as a good "environmentally aware corporate citizen" may lead to problems with mining enterprises obtaining community support for new projects.

In the past, environmental issues were often not given great importance and there are several examples of where economic and /or political expediency placed environmental protection down the list of priorities. A prime example here is perhaps Queenstown in Tasmania where tailings were discharged to the Queen and King Rivers for over 100 years under legislation that was very outdated. When the operation changed hands in 1995, the new operator stated that modern environmental management standards would be introduced immediately. The construction of a tailings dam was perhaps the most obvious example of this policy being implemented. Tailings are no longer discharged to the river system and other measures are being put in place to ensure that environmental impacts are minimised.

Elsewhere in Tasmania another operation is changing the way in which it manages tailings to reduce environmental impacts. The Renison Bell mine has been undertaking studies designed at reducing the risk of reactive sulfide rich tailings releasing seepage contaminated with acid and heavy metals. The significant item in the study is that the cover for the tailings consists of another form of tailings from the same process plant and water; thus providing a neat disposal method as well as addressing the environmental concern. If the method is as successful as tests indicate, this would have to be considered an element in any future best practice assessment when disposing of reactive tailings (CSIRO, 1997).

At Ranger Uranium Mine tailings are being deposited into the now exhausted #1 pit. Although the system was designed to be a sub-aerial deposition system, the excessive rainfall of the 1996-97 wet season created a sub-aqueous system, which is not generally considered as effective in achieving higher values of settled density. However, by making a few changes to the system the mining company has now found that settled densities exceeding those of the old tailings dam sub-aqueous system and above the minimum values required by the regulating authorities are being achieved. The company are also relocating tailings from the old tailings dam using a dredge into the same mined-out pit. The Environmental Requirements of the Commonwealth stipulate that all tailings from uranium mines in the Alligator Rivers Region should be returned to pits as a final repository.

What is in the future?

So where do we go from here? The future would seem to be reasonably clear in principle. At every opportunity the industry, and stakeholders including government and consumers as well as producers, should be ensuring that best practice is incorporated into all aspects of operations. The concepts of best practice require that the containment of tailings in any situation be carried out with due regard to many factors. Ensuring that the site is appropriate, that the methods of transportation, deposition, management and storage of the tailings are appropriate for the local situation. Equally, the implementation of the selected methodologies has to be effective and timely. The operation has to be adequately monitored and strategies for closure and possible walk-away properly developed and implemented. Above all of this we must be aware of the ever present need to ensure that our plans are dynamic and subject to frequent review. Continuous improvement is an essential part of best practice, technology is advancing daily and the community and industry set higher standards at every turn. There will be eventual limits to best practice I am certain, but I am equally certain that we have plenty of opportunity to improve before we reach those limits.

What are appropriate methods for selecting sites, moving, depositing and managing tailings; what are the best practice monitoring systems that we need, and what does constitute a suitable final closure strategy? These are all issues that will be set out in the papers that will follow over the next two days. The organisers have brought together a wide ranging band of experts from all sides of the mining sector. Stakeholders from industry and government are here to ensure that there is a wealth of up to date knowledge from all operational sides of the industry and regulators.

New technologies are being put forward all the time. Some of the following papers will detail how some of the latest leading edge techniques are being trialed and introduced. Over the next two days we will hear about tailings management issues including reclamation and rehabilitation, water recycling, waste abatement in-plant, toxicity of materials and management of community concerns from some of the leading experts in these fields from across Australia.

I am sure that the promise of this event will be fully realised with these presentations and the discussions that will undoubtedly follow.

References

Agricola 1556 De Re Metallica *in translation Hoover CH & Hoover LH 1950* Dover Publications Inc, New York.

Argall G O (ed) 1978 Tailings Disposal Today - *Proceedings of The Second International tailings Symposium Denver, Co, May 1978,* Miller Freeman Publications Inc San Francisco.

Carbon B 1995 Foreword in *Overview of Best Practice Environmental Management* part of the series *Best Practice Environmental Management in Mining* Environment Protection Agency, Canberra.

Cross M 1997 The application of geotechnical engineering techniques for the prevention and control of pollution. *Land Degradation & Development* Vol 8, 159-177.

CSIRO 1997 Decommissioning sulfide tailings. Interface No 19 July 1997, *CSIRO Coal and Energy Technology Newsletter*, North Ryde, NSW, Australia.

Ellis DV 1996 Regulations controlling submarine tailings disposal in the USA and Canada. in *Building International Partnerships in Environmental Management for the Minerals Industry*, Proceedings of the 21st Annual Environmental Workshop, Newcastle 14-18 October 1996, Minerals Council of Australia, Canberra.

Ellis J 1997 Meeting the Challenges. *Groundwork* No 1 Vol 1 Australian Minerals & Energy Environment Foundation, Melbourne.

Environment Australia 1997 *Managing Sulphidic Mine Wastes and Acid Drainage,* part of the *series Best Practice Environmental Management in Mining,* Environment Australia, Canberra

EPA 1995. *Tailings Containment* part of the series *Best Practice Environmental Management in Mining,* Environment Protection Agency, Canberra.

Fell R, MacGregor P & Stapledon D 1992 *Geotechnical Engineering of Embankment Dams* Balkema Rotterdam.

Jewell, R 1997 Seminar looks at the real cost of tailings disposal. *Landline* Minerals Council of Australia, Canberra.

Murray I, Davies M, Chin B and McLeod H (1996) Design considerations for tailings disposal in tropical high rainfall, seismically active environments, in *Proceedings of the 3rd International and 21st Annual Minerals Council of Australia Environmental Workshop, Newcastle NSW October 1996,* Minerals Council of Australia, Canberra.

OSS 1979 Supervising Scientist Annual Report 1978-79. Australian Government Printing Service , Canberra.

Ritcey G M 1989 *Tailings Management.* Elsevier Science Publishers Netherlands.

UMTRA 1996 Uranium Mill Tailings Remedial Action Project- *Fiscal Year 1996 Annual Report to Stakeholders.* US Department of Energy, Washington DC.

UNEP 1996 *Environmental and Safety Incidents concerning Tailings dams at Mines;* Report for United Nations Environment Program, Paris.

Waggitt Peter 1994. *A review of worldwide practices for disposal of uranium mill tailings.* Technical memorandum 48, Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

Williams R E 1975 *Waste Production and Disposal in Mining, Milling and Metallurgical Industries.* Miller Freeman Publications Inc, San Francisco.

An Australian Initiative to Promote Best Practice Environmental Management in Mining

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Abstract

The Australian government and mining industry are working together on a program to promote the uptake of best practice environmental management in the mining sector. To achieve the higher levels of environmental protection now expected by the community, the industry must perform beyond the levels set down by regulations, which are effectively a "safety net" to ensure that severe impacts on the environment are avoided. A series of booklets is being produced which focus on different environmental issues in mining. Thirteen booklets have been produced so far. They represent a model of the Australian approach to best environmental management in mining, which may be useful to other countries as a guide to determining whether their own practices are consistent with world best practice. To make the information more readily accessible in countries in the Asia-Pacific region, the booklets are currently being translated into Spanish, Bahasa Indonesian and Chinese.

The next stage of the program is under way and will produce a set of inter-related databases which cover 70 issues identified as significant to the environment and mining sector and will include: databases of technical information, best practice practitioners, training courses, best practice sites and case studies, and possibly, new technologies.

Environment Australia is looking at opportunities to develop collaborative programs in environmental protection in mining with other countries to further build on the programs described in this paper.

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PhD in Soil Science 1977 - Sydney University

Work Experience

1967 to 19 72	As Lecturer at Tamil Nadu Agricultural University, India, taug soil science to undergraduate students in agriculture.
1973 to 1976	Completed a PhD degree in soil science from the University of Sydney.
1977 to 1981	As Research Officer in the University of NSW, Australia investigated nutrient deficiencies in beef cattle.
1982 to 1987	As Soil Chemist conducted soil, plant and water analysis and provided advice to the Northern Territory (NT) Government in promoting the development of agriculture in the NT.
1988 to 1989	As Environmental Scientist with the Northern Territory Department of Mines & Energy supervised the regulation of uranium mining industry operations in the NT.
1990 to 1994	As Senior Environment Officer provided advice to the Australi: Government in minimising the environmental impacts of uranium mining operations in the NT.
1995 to the present	As Assistant Director with the Australian Government Environment Department involved in the development of Best Practice Environmental Management in mining booklets and promoted them within Australia and overseas.

Introduction

Globalization is occurring in all industry sectors throughout the world. It is well under way in mining, transportation, communication and manufacturing. The Australian mining industry is now, more than ever, increasingly global in its outlook. Australian companies operate in Indonesia, other countries of Asia (including the C.I.S), the Pacific, North, South and Central America and in Africa. The recent merger between RTZ and CRA (now called Rio Tinto), into a corporate entity of global proportions, illustrates this trend.

Globalization necessarily invites comparison of performance on a world scale, including environmental performance.

Some Australian mining companies are world leaders in mine site rehabilitation, mineral processing and environmental management. For example, Alcoa of Australia is the only company in the world to win the United Nations Global 500 Role of Honour for its excellent work in mine site rehabilitation and revegetation. High levels of environmental performance have been required in order for some mines to obtain approval to operate in areas of particular environmental sensitivity or with high conservation values, such as at the Ranger uranium mine which operates in an area surrounded by the Kakadu National Park, which is on the World Heritage list

Australian companies have developed their current environmental awareness and expertise over a long time and have learned from some very costly past environmental mistakes. The Mt Lyell copper mine in Tasmania, where pyritic tailings were discharged directly into the river system for about 70 years and SO2 from smelting killed vegetation which led to severe erosion around the minesite, is now regarded as an icon of environmental bad practice and represents a management style far from acceptable by today's expectations. Even sites remediated as recently as 15 years ago, such as the Rum Jungle uranium-copper-lead mine in the Northern Territory, are widely regarded as not meeting the best practice standards of today.

Mining will continue to be a mainstay to the Australian economy for the foreseeable future, and it is important for the industry to gain the confidence of the community if it wishes to continue to gain access to resources. Mining no longer has an automatic priority in terms of land use, because proposals have to compete with other interests including conservation and tourism. Therefore there is now emerging in Australia a culture of "best practice" in environmental management, in an attempt to move environmental performance beyond that demanded by regulations. Government regulations now represent a "safety net" below which there is a high risk of severe environmental impact so that penalties are necessary to ensure that this minimum level of performance is met.

"Best practice" is simply the best way of doing things. It is not static but involves continuous improvement. It encompasses the principles of:

- best technology
- continual improvement
- agreed environmental quality objectives
- pro-active planning and research
- independent evaluation of environmental performance
- outcomes focus rather than process focus

- public disclosure
- involvement by local communities affected by mining operations.

Whilst the "safety net" of minimum standards imposed by government remains in place, the traditional approach of government imposing its will coercively upon the industry through the threat of fines is being replaced by a more cooperative approach to encourage a level of performance beyond the minimum requirements. State regulators assist the industry in developing Environmental Management Systems which incorporate environmental quality objectives, and performance is now more frequently assessed through a process of periodic auditing rather than through frequent site visits.

In concert with this move to a more collaborative approach, government has formed a partnership arrangement with several industry sectors to encourage improvement in environmental management. The partnerships commonly also include the participation of community and consumer organisations to ensure that the program objectives are broadly acceptable. This partnership approach is proving to be most effective: industry involvement attracts acceptance by industry peers; government endorsement provides assurance to industry that the initiatives are consistent with government policy directions; and community participation provides a level of certainty that the program outcomes will be acceptable to the wider community.

The partnership dealing with the mining industry is called the Best Practice Environmental Management in Mining Program. The Program recognises that whilst some Australian mining companies are leaders in good environmental management, there are also companies whose performance is relatively poor. It is designed to complement a number of programs under way to encourage continual improvement by industry, such as award schemes for excellence in environmental management run by the industry or by State Government. These award schemes offer a competitive environment for companies, organisations or individuals wishing to demonstrate their achievements, as well as offering financial rewards.

Elements of the Best Practice Environmental Management in Mining Program are:

- production of booklets and videos
- databases to provide easy access to key information
- training programs
- strategic research into environmental issues in mining.

Booklets and video on Best Practice Environmental Management in Mining

This project began in early 1995 following a suggestion from the World Bank that Australia could assist in dealing with a range of environmental issues in mining.

A steering committee was formed to guide and assist with the project. The steering committee members were chosen because of their interest, expertise and contacts on the subject of environmental management in mining. The steering committee included representatives from the peak mining industry organisation (Minerals Council of Australia), an industry-based environmental focus group (the Australian Minerals and Energy Environment Foundation), the principal mining professional body (the Australasian Institute of Mining and Metallurgy), a key mining research organisation (the CSIRO Minesite Rehabilitation Research Group), the State Government based Chief Inspectors of Mines of Australia, and the Australian Conservation Foundation representing non-Government conservation groups.

To date thirteen booklets have been written by leading practitioners of environmental management in the mining industry. The booklets were printed and published after intensive review by a sub-group of the steering committee with input from experts from the mining industry on each subject. In addition a 10 minute introductory video has been produced to illustrate the objectives and concepts of best practice environmental management in mining.

Topics covered by the booklets are: an overview of best practice environmental management in mining; mine planning for environment protection; environmental impact assessment; community consultation and involvement; environmental management systems; environmental monitoring and performance; planning an environmental awareness training program; tailings containment; rehabilitation and revegetation; environmental auditing; onshore exploration; managing sulphidic mine wastes and acid drainage; and hazardous materials management, storage and disposal. Details of these booklets are given in Table 1.

Table 1

The first series of thirteen BPEM booklets

• ***Overview of Best Practice Environmental Management in Mining.***
Overviews the program and the attributes that go towards achieving best practice. Outlines the potential problems that can occur as a result of mining activities, and some operations that have achieved recognition for the quality of their environmental work. Also canvasses the financial benefits to mining operators of instituting best practice.

• ***Mine planning for environment protection.***
Planning is the key to identifying and minimising the environmental impacts of mining. This booklet examines how mine planning for environment protection can help in developing projects that meet community expectations for minimal environmental impacts. It outlines the considerations that shape mining methods and the design of environmental safeguards. These include: air, water and noise quality; transport; biological resources; social and economic factors; surrounding land uses; and heritage places and artefacts.

• ***Environmental impact assessment.***
This booklet introduces the background and purposes of environmental impact assessment (EIA). It covers briefly the legislative requirements within Australia, the key components of EIA, and the different levels of assessment that exist. The relationship of environmental management plans, monitoring and environmental management systems to environmental

impact assessment is discussed.

• *Community consultation and involvement.*
The expectations and needs of communities affected by mining proposals are covered in this booklet. The processes involved in preparing for the consultation process are discussed in detail and the key community consultation techniques are described. The booklet focuses on a community-centred rather than a project-centred approach to community consultation and involvement.

• *Environmental management systems.*
This booklet outlines the role and key components of an environment management system (EMS) as one tool to use in achieving the company's environmental objectives and targets. It explains how to operate, implement and maintain an EMS within daily operations, from exploration to mine closure.

continued.........

Table 1 continued

• *Environmental monitoring and performance.*
Subjects covered include: the objectives of monitoring programs; selection of indicators; measurement methods; data collection and analysis; and reporting. Monitoring of water, air, dust, flora and fauna are covered. The linkages between environmental monitoring and performance and environmental auditing and environmental impact assessment predictions are discussed.

• *Planning an environmental awareness training program.*
This booklet explains the importance of planning a workforce environmental awareness training program to achieve an enduring and improving environmental culture. Corporate commitment is important to a successful program. A framework is provided which can be used in planning a workforce environmental awareness training program and evaluating its success.

• *Tailings containment.*
Planning, designing, constructing, operating and monitoring tailings disposal facilities are covered. The factors to consider in selecting suitable sites and the various disposal options for tailings are explained. The monitoring and control methods that can be used to minimise environmental impacts are discussed.

• *Rehabilitation and revegetation.*
The principles and practices of mine rehabilitation are outlined. Particular emphasis is given to the restoration of natural ecosystems, especially the re-establishment of native flora. Topics covered include rehabilitation objectives, soil handling, earthworks, revegetation, soil nutrients, fauna return, maintenance, monitoring and success criteria.

• *Environmental auditing.*
Auditing is shown to be an important tool for any mining operation to measure its performance against current and expected regulatory requirements, improve its credibility with the public, assess its level of risk exposure, and access loan capital. A range of audit types is described and examples given of audit checklists.

• *Onshore exploration.*
Significant environmental damage can result from ground disturbance, clearing of vegetation and careless handling of materials such as drilling fluids, lubricants, fuel etc. Techniques are described to avoid damage, such as consultation with local people, alternatives to widespread bulldozing, earthworks to minimise erosion, rehabilitation of drill holes, and safe handling of contaminants.

• *Hazardous materials management, storage & disposal.*
Hazardous materials management principles should be consolidated in a simple,

comprehensive and well structured management plan. A review of the hazardous materials typically used at mines and mineral processing plants is presented, and specific examples provided in managing these materials.

•*Managing sulphidic mine wastes and acid drainage.*
The most appropriate prevention/remediation measures are affected by site-specific constraints and the characteristics of the sulphide containing material. A range of strategies and case studies are presented which demonstrate current approaches to achieving best practice in managing acid drainage to minimise its associated environmental impact and long term liabilities.

Authors for the booklets were chosen on the basis of their expertise and industry background. Where suitable authors from companies were not available, consultants from the industry were engaged.

The booklets contain a number of case studies which give examples of how specific components of environmental management programs are being implemented in a range of climatic conditions and mine sites across Australia. They set out how to integrate environmental issues and community concerns through all phases of mining, from exploration through construction, operation and eventual mine closure.

The booklets were launched at the International Association for Impact Assessment conference in Durban, South Africa in June 1995 and in Australia in Sydney and Perth in August 1995.

The booklets and the video have up to now been freely available and over 6000 packages of the first eleven titles and the video were widely distributed to industry, government, teaching institutions, consultants and individuals both in Australia and in over 60 overseas countries.

The objectives of the booklets are to:

- improve the level of environment protection associated with mining in Australia and overseas;
- share Australian expertise in environmental management in mining with people overseas;
- work on a cooperative/partnership basis with industry to promote best practice through all sections of the mining industry; and
- encourage industry to perform better than is required under regulation.

More booklets are planned (Table2). Each will be written by recognised leaders from the industry in their particular fields of expertise. The booklets are not designed to be comprehensive technical manuals giving precise details on what is best practice at a mine site and how to do it. By its very nature, best practice may differ from one site to another, and will evolve over time. The booklets are designed instead to present the philosophy of best practice, with enough supporting factual information, general descriptions of techniques, and case studies containing examples of best practice already in operation. The booklets are therefore designed to convince the reader that best practice is a worthwhile objective. An extension program is being developed to provide more detailed information to encourage the wider adoption of best practice in environmental management.

Table 2
BOOKLETS IN PREPARATION

• Water Management and Wetlands	• Dust Control
• Cleaner Production in Mining	• Mine Decommissioning and Closure
• Landform Design & Surface Water Control	• Management of Atmospheric Emissions
• Control of Noise and Vibration	• Contaminated Site Clean Up
• Cyanide Management	• Environmental Emergency Procedures
• Indigenous People	• Environmental Risk Management
• Energy Efficiency	• Managing Social Impacts

Databases

"EnviroNET Australia" is a network of complementary databases accessible on the Internet (http://www.erin.gov.au/net/environet.html) designed to maximise access to information on Australia's capabilities in environmental management. It was developed and maintained by Environment Australia. In January 1996 it was recognised by the Swedish-based Eco-Network as one of the top 100 Internet environmental sites. The six interlinked databases are described in Table 3.

Table 3

EnviroNET Australia

Cleaner Production Case Studies Database

This database assists small to large businesses to maintain a competitive edge by drawing on case study information about cleaner production methods. Information focuses on production processes which minimise harmful environmental impacts by improving management practices from the beginning to the end of the production process. Cleaner production processes are shown to actually reduce costs to business.

Environment Industry Expertise Database

Lists the environmental expertise of private and public sector organisations who offer technologies, products and services to solve problems in the following categories: air pollution; water pollution; waste management; noise, vibration and radiation; chemicals for environment management; environment monitoring and measurement; and general environment management (such as environmental law, economics, policy, auditing, planning and training).

Environment Education Database

Provides comprehensive information on environmental education and training courses available from Australia universities and other institutions.

Pollution Prevention Research and Development Database

Lists waste management and pollution control expertise and reveals whether a technology currently exists to solve a specific problem, and if not, whether there is current research or scope for such research to fill the gap.

Technology Case Studies Directory

Contains information on 'best-practice' operating solutions to environment problems - for example, innovative sewage treatment processes, technology to recycle green waste, or environment monitoring equipment.

Hazardous Waste Treatment Technologies Directory

An independent source on the status of technologies capable of treating hazardous scheduled wastes in Australia. These are chlorinated hydrocarbons that are toxic, persistent and bioaccumulative.

Environment Australia is also currently developing a similar network of databases to complement the Best Practice booklets which will provide information of direct use to the mining sector. These databases will provide further information on specific issues. The idea is that people will first read the booklets and the databases will provide further support by offering accessible, relevant and specific information to industry practitioners to follow through on their environmental requirements. These databases are structured around a list of environment and technical issues identified as important to the mining industry (eg water management; mine planning; auditing; tailings disposal). These databases will shortly be accessible through the home page of the Office of the Supervising Scientist (http://www.erin.gov.au/portfolio/epg/oss.html) and will comprise:

• *technical information* - up to 5 references to technical information in books, journals, manuals etc which will be chosen on their practicality, currency, and availability

• *expertise* - a list of environmental management expertise in mining-related issues, including the private, government and academic sectors

• *training courses* - upcoming training courses, workshops, and conferences related to mining and the environment

• *case studies of best practice sites* - details of sites where examples of best practice are in operation.

• *new technologies* - planned, funds permitting.

Training programs

There is a high demand for training in environmental management in mining. For training to be effective, courses need to be targeted at all levels of the workforce, from the truck driver and security officer through to senior managers rather than being focussed on environmental management staff. An arrangement with an industry group, the Australian Centre for Minesite Rehabilitation Research (ACMRR), has recently been entered into to identify training needs, with a view to developing an integrated program of training courses to meet these needs. Australia is in a good geographic position to offer access to training through Asia and the Pacific, and so training programs need to cater for situations with various economic, social, climatic and geographic conditions which may differ considerably from the Australian situation. The intention is to design highly specific workshops on key environmental issues in mining for different target groups, and coordinate the availability and timing of these to both the domestic and overseas markets.

Under the Australia Indonesia Government Sector Linkages (GSLP) Program funded by the Australian Agency for International Development (AusAID) six environmental managers from the Indonesian Government received training on Best Practice Environmental Management in Mining during June 1997 in Australia. We are currently developing two more GSLP projects with our Indonesian counterparts.

Courses being conducted by ACMRR during 1996-97 include:

- Post-mining Landform Stability & Design
- Native Seed Biology for Revegetation
- Mine Rehabilitation in Tropical Environments
- Indicators of Ecosystem Rehabilitation Success
- Management of Cyanide in Mining
- Environmental Monitoring and Testing
- Rehabilitation of Quarries and Landfill Sites
- Prevention and Control of Acid Mine Drainage
- Fauna Habitat Reconstruction After Mining

Strategic research

Many areas require further research to determine fully effective methods in environment protection, such as acid mine drainage, management of mining voids, revegetation, and measurement of rehabilitation success. The arrangement with the ACMRR also extends to joint sponsorship with industry of research projects which are strategic in nature - that is, they are of general relevance throughout the industry and will lead to better long term solutions. Research which is more site-specific is funded wholly by the industry.

Some of the current research projects in progress are:

- National Survey of Acid Mine Drainage;
- Inoculating VA Mycorrhiza Fungi into Mine Soils;
- Indicators of Ecosystem Rehabilitation Success ;
- Managing Sulphidic Wastes - Stage 1& 2;
- Definition of Research Needs for the Management and Rehabilitation of Tailings;
- Case Study of Final Voids as a Basis for Assessment of Models for Void Water Quality Prediction;
- Co-disposal of Tailings and Waste Rock; and
- Management of Environmental Impacts of Metals in Mining.

International Collaboration

The role of the Australian Government in the international promotion of 'Best Practice Environmental Management in Mining' is limited to initiating and facilitating that process, and to provide seed funds such as for translation of some of the booklets and for training courses.

The ultimate responsibility however for application of the concepts and ideas espoused in the Best Practice Program must rest with the recipient Government, local mining industry and local communities affected by mining. The Australian initiative has to be transformed and adapted to make it responsive to local problems and requirements. This process of adaptation is best done by local experts and scientists, although Australia may be able to assist through provision of advice and technology.

The application of best environmental practice at individual mines can only be achieved through a sustainable change of behaviour of mine technical and managerial personnel at all levels. It also requires a shift in thinking among government officials, at both the local and federal level. And, last but not least, it requires sensitising, educating and actively involving local communities affected by the mining operations.

The task ahead of us is enormous and will require a concerted effort by all stakeholders. The BPEM products described in this paper are but the first step. To be truly effective, they will need to be complemented by targeted training and awareness raising, by public education and sensitising programs, and by the development of what we would call '2nd Generation' products. These 2nd Generation products will take BPEM to the next level and apply it to the local environment and to the specific conditions and problems which exist in individual mines. They must be written and designed by local specialists to reflect local conditions. Examples here in Indonesia could include: Small Scale Mining, Rehabilitation of Clay Pits, Vocational Training and Training for Mine Inspectors.

Realisation of these ideas and plans will require resources; not very large amounts, but rather carefully planned and focussed activities; not a massive aid program aimed at changing the situation over a couple of years, but rather well thought-out pilot activities which demonstrate that Best Practice can and does work. An important target group are mine managers and we need to convince them that it makes economic sense to be environmentally responsible and to involve local communities.

Indonesia and Australia have started this process. In close consultation with our counterparts in BAPEDAL, the Directorate General of Mines & Energy and, the Bandung Institute of Technology, Environment Australia has begun to engage Indonesian mining industry, their Australian joint venture partners and other multilateral and bilateral donor agencies. Our aim is to interest them in the BPEM program and its adaptation into an Indonesian program and to seek their active collaboration and funding support.

Initial discussions with a number of donors have been successful but much work still needs to be done. An outstanding feature is the early commitment made by the Indonesian Mining Vocational Education & Training Board (IMVET). IMVET has agreed to distribute the booklets translated into Bahasa Indonesia to interested parties throughout Indonesia, and has also indicated a willingness to co-finance 2nd generation products. The fact that industry in Indonesia has agreed to allocated funds and other resources to the promotion of BPEM is perhaps the strongest indicator yet of the relevance of the Australian initiative to the sustainable and environmentally responsible development of the minerals industry in Indonesia.

Conclusions

Community expectations for environmental protection are ever increasing. Since the Rio Earth Summit in 1992 there has been a greater awareness by governments of the need to implement Ecologically Sustainable Development (ESD), and by industry that a good international corporate image is an important ingredient for successful business. ESD symbolises a balance of economic exploitation of resources together with effective environment protection.

The Best Practice Environmental Management in Mining Program is an example of a cooperative partnership between Australian government and industry which is focused on bringing forward solutions consistent with ESD related to the mining sector. The partnership is built around the principle of best practice. The booklets are the first stage of a long term plan to provide a range of resources which will enable the mining industry to improve its general level of environmental performance. Mining is a major activity in Australia, and it is a priority for our country to ensure that mining is able to operate at levels of environmental impact acceptable to the public and compatible with other competing land uses.

Australia also has a responsibility to contribute to improvement in the level of environmental protection in mining internationally, particularly because its own mining sector is active in resource development in many other countries. Translation of the booklets into other languages will facilitate their usefulness internationally. It is hoped there will be an opportunity to develop collaborative programs in environmental protection in mining between Australia and other countries to further build on the program described in this paper.

Creating Transparency: Stakeholder Involvement in Environmental Management of the Northern Territory Uranium Mines

Stewart Needham and Peter Waggitt

2nd Annual Australian Uranium Summit

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CREATING TRANSPARENCY: STAKEHOLDER INVOLVEMENT IN ENVIRONMENTAL MANAGEMENT OF THE NORTHERN TERRITORY URANIUM MINES

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ABSTRACT

Uranium mining, national parks, and Aboriginal rights are all issues of significant concern to many sections of the Australian community. In combination, they create a particularly volatile and emotive mixture. This is well demonstrated by the frequent media exposure of matters relating to the uranium mines in the Kakadu region. The controversial nature of uranium mining in the Northern Territory has necessitated the development of special arrangements to enable the supervising authorities to provide the level of assurance expected by all elements of the community, including other arms of government, that social, environmental and public health issues are adequately addressed. This paper describes a mechanism which has been designed to deliver information, clarity of process and participation in a way which meets the expectations of a broad group of government, community and industry stakeholders. A case history of the Ranger uranium mine, where the system is applied, is presented.

INTRODUCTION

Mining is an industry which often has a negative image in the eyes of the community. Sometimes perceived as a "one time user" of land and a major polluter and despoiler of the natural environment, many members of the industry have been working hard in the last ten years to improve not only the outcomes in terms of environmental management, but also the communication of their improving environmental performance to the wider community. **The mining industry relies on access to land and according to at least one industry leader, is informally licensed by the community.** This is because failure to convince the community that a company is doing a good job environmentally as well as financially, will reduce the chances of that company being allowed access to resources in the future. Thus it has become important for industry members to communicate with the community in an open and transparent manner in order to demonstrate willingness to be accountable for their actions and provide assurances that all the expected standards of protection are being maintained. This is particularly relevant to the uranium mines of the Kakadu region. The stakeholder group is diverse and includes the Aboriginal landholders; local residents; the mining company, shareholders and employees; the managers of Kakadu National Park and park visitors (ie. tourists); Territory and Commonwealth regulators and interested departments of resources, environment, and health; and community environmentalist and anti-nuclear groups. Each of these stakeholder groups focus their attention on different aspects of the mining operation.

These range from financial performance, occupational health and safety of workers and nearby residents, protection of the natural environment, and safeguarding dietary and other risks to Aboriginal people, to reduction of long term risks after mine closure including site rehabilitation and long term containment of tailings. Tensions have developed as a consequence of these different and sometimes conflicting priorities.

At the outset of the "new" uranium mining era in 1979, a body was created, the Alligator Rivers Region Co-ordinating Committee, which was supposed to be a forum for stakeholder groups to exchange ideas and data. In truth the membership was limited and dominated by the mining companies and various government departments with no representatives of other stakeholders apart from the Northern Land Council and a single environmentalist. Also the proceedings were confidential, a requirement of the legislation. These last two factors did little to provide assurances to the community in general or the local stakeholders in particular. Since 1993, a structure has been put in place which involves processes of stakeholder involvement, information sharing, joint problem solving, and public reporting. This structure adds up to a system of high public accountability, and presents an interesting study of how diverse stakeholder group interests and expectations can be accommodated. The process also offers
opportunities for stakeholder opinion to directly influence environmental management decisions. This paper will show how the process was developed and provide a specific example using the Ranger uranium mine as a case history.

THE SYSTEM

The system involves the integration of two main components: environmental performance audits, and stakeholder consultation. These operate on a six month cycle, reflecting the dynamics of the activity, the level of interest/concern, and the extreme pressures that the wet-dry tropical climate can impose upon environmental management at the mine (in particular, water management and disposal of excess water).

Key Features

The key features of the system are shown in Figure 1. Important underlying principles are:

- there are no surprises or no secrets
- the focus is on outcomes rather than process
- continual improvement is encouraged by a shared problem-solving approach which is
- kept apart from regulatory, compliance-focused processes
- as far as possible, all relevant data are released to the public domain
- the process is independently chaired
- key stakeholders are always consulted on major issues
- detailed scrutiny is expected from the broad stakeholder group
- the processes are transparent, predetermined, and frequent.

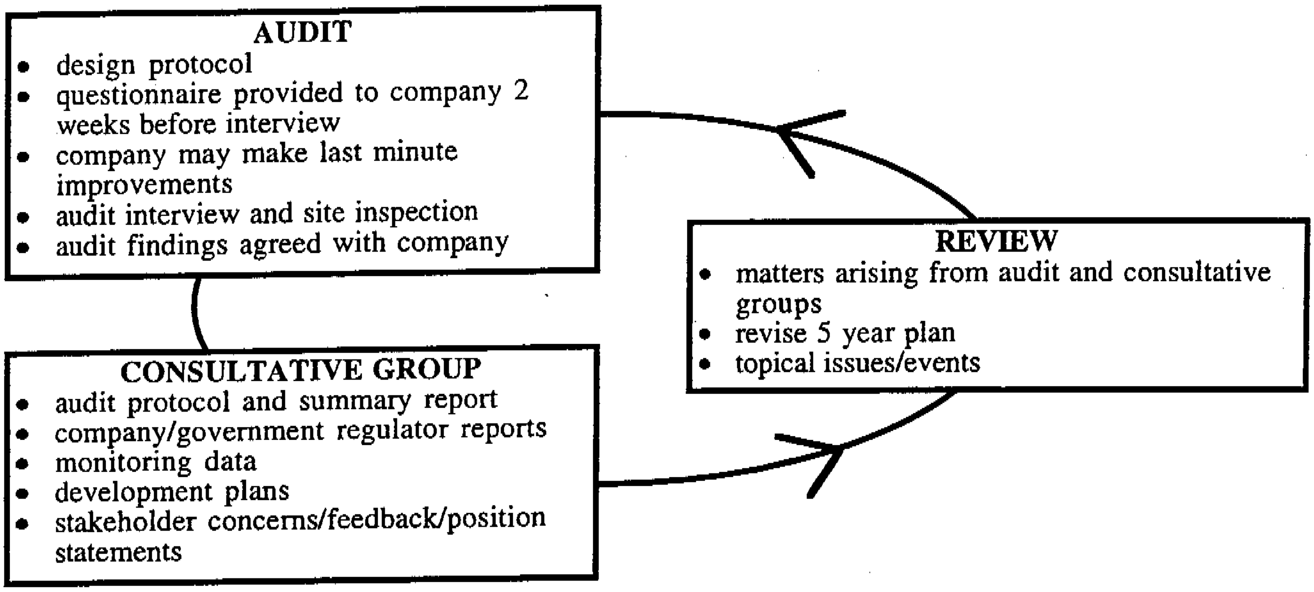

Figure 1: The audit/consultation cycle

Audit Process

Audits of the mine sites are undertaken every six months. Termed "environmental performance reviews" (EPR), they focus on measuring outcomes rather than process, and are not designed to operate as a regulatory compliance tool, although there is a small section devoted to compliance issues. Areas of performance which do not meet the reasonable expectations of the broad stakeholder group are examined to determine possible methods of achieving improved performance. Any issues not resolved at the EPR interview are commonly referred to technical working groups to evaluate options in terms of effectiveness, cost, and acceptability. Non-compliance issues may be exposed and are reported upon, but disciplinary action is pursued through the normal regulatory framework which provides a safety net of minimum acceptable performance. A five-year forward plan of audit focal issues has been developed and is available for adjustment by the broad stakeholder group. The plan recognises the appropriate frequency for issues to be revisited. This is based upon technical assessments of risk and consequences, and public perceptions of risk and consequences as voiced by the broad stakeholder group. The five-year plan is flexible, and accommodates topical issues which may arise for example from unusual rainfall patterns (which may stress the water management system of the mine), infringements, or public interest issues which may arise from time to time.

The audit protocol takes the form of a questionnaire which is provided to the company at least two weeks before the scheduled audit week. There are four major sections: matters arising from the previous EPR; compliance; standard operational issues; and finally the focus issue for the review in question. The protocol includes prompts designed to help the audit team in their work, but which also assist the company to identify particular matters of interest, and documentary evidence required. The company may then prepare for the review by carefully checking relevant data, operational systems (hardware and processes), and ensuring that documentary evidence is accessible. After two years of undergoing this audit process, Energy Resources of Australia (the operators of the Ranger uranium mine), began to prepare fully documented responses to the questionnaire which have considerably assisted in the detail and efficiency of the process.

Question No.	Question	ASSESSMENT Accept- able	Req. further work	Not acceptable	Verification	Comment
2. 1. 4	Has all environmental monitoring been carried out and reported as required by the Authorisation?		✓			Monitoring and reporting acceptable except for two omissions already reported in 2.1.2. Gross alpha monitoring and reporting is a regulatory issue which shall be referred to the MTC. The review team acknowledges the openness of ERA in raising these issues.
2. 1. 5	Has effective interpretation of monitoring results (through quarterly and annual reports) been provided, and have unusual results been highlighted?	✓			Document #3, Monthly and quarterly reports on file	Yes. All monitoring results have been reported and interpreted satisfactorily. One series of anomalous values has been attributed to analytical artefacts.
2. 1. 6	Was water quality in Magela Creek at 009 within receiving water standards during the period?	✓			Document # 8, #9 Monthly Reports on file	Yes.
2. 1. 7	Has DME check monitoring confirmed the accuracy of ERA's monitoring data and agreed with trends described?	✓			Document #9	Results continue to show good agreement.
2. 1. 8	How have the environmental impacts of exploration activities (if any) been managed and reported?	✓				No exploration carried out in the reporting period.
2. 2	**Radiological Monitoring**					
2. 2. 1	Has all radiological monitoring been carried out and reported as required by the Authorisation?		✓		Document #10, #11	Monitoring acceptable with the exception of the omission noted in 2.1.

Figure 2: An example EPR questionnaire page

Following the audit interview, a site inspection is undertaken. This includes areas of routine operational interest as well areas of particular interest, including those where poor performance may have been indicated. This is commonly the first step in discussions to identify possible reasons for poor performance, and the development of options for improvement. Where improvement is indicated, joint technical working groups may be established to develop solutions, and the matter is placed on the agenda for examination at the next review in six months time where progress will be evaluated. A minesite technical committee meeting is held within 6 weeks of each EPR to discuss any technical issues arising from the EPR and the subsequent stakeholder group meeting.

The questionnaire framework is used to develop an audit outcome report, and each item in the questionnaire is assessed as acceptable, unacceptable, or requiring further work. An example page from a recent review of the Ranger mine is shown in Figure 2. A scoring system, for example a mark out of ten, is avoided, because this always implies that for any score of less than 10/10 there is a significant degree of under-performance. This in turn can imply an impact on or risk to the environment. Such an approach is not helpful; for example, it might not appropriately represent situations where insufficient data are available to fully understand an issue, in spite of the fact that more environmental data may be available here than in any other known situation, and the company may already be committed to an ongoing program of investigation.

A summary report of the review is prepared in the same week of the audit process, and is signed by the principals of organisations participating in the review team. The outcomes are therefore agreed, and misunderstandings or differences of opinion are worked through before the results of the review process are presented to the stakeholder consultative group.

The Consultative Process

The stakeholder group meets immediately following the environmental performance review, and is presented with copies of the audit assessment (as in Figure 2), and the summary report - normally only completed late the previous day. This information is made available at least two hours before the meeting commences, so that members may, if they wish, carefully examine it before the meeting. This procedure also ensures that discussion focuses on up-to-date information. Other information provided includes reports by the NT government supervising authority and the Supervising Scientist for the period under review; annual environmental reports by the mining companies; and any additional reports the companies may wish to make available. These may include monthly or quarterly reports of monitoring data, one-off technical reports, and planning documents. The company staff commonly also give brief presentations on recent or planned developments at the mine sites. There is no restriction placed on the distribution of any material presented to the meetings. These reports are distributed as early as possible before the meeting , often up to two weeks in advance.

The stakeholder group is made up of representatives of Aboriginal groups, environmental groups (both national and local), unions, local government, and federal and territory government departments and agencies of resources, health and environment. The stakeholder groups are approved by the federal Minister for the Environment, and the groups are free to select their representatives. Additional members have been added to the group to ensure that the consultative process is truly inclusive of all significant stakeholders.

The committee is independently chaired. Debate is managed so as to focus on environmental protection from uranium mining. Although some representatives have strong positions on whether or not uranium mining should be permitted in Australia, discussion on uranium mining policy is discouraged. `Meeting notes' are taken rather than formal minutes, in order to avoid acrimonious discussion on detail which was common in earlier forums.

CASE HISTORY: RANGER URANIUM MINE

A good example of how the process works was seen during the water management issue of 1995 wet season. From the outset of mining it had been understood that Ranger was a mine designed to release mildly contaminated waste waters that accumulate on site "every few years". For the first 14 years of the mine's life there had been no need to release water. As a result of community concerns about possible environmental impacts of water release it was decided that the frequency should be limited to those years when the rainfall exceeded a 1 year in 10 probability. A mechanism for triggering release was devised by the supervising authorities which was designed to ensure that the releases would only occur "about every ten years". In 1995 it became apparent that the rainfall pattern was such that the trigger would be activated. All the members of the stakeholders' consultative group were duly informed of the possibility of a release. Within days the trigger rainfall level had been achieved and the technical working group began to prepare for the expected release of accumulated mine waste waters.

At this point the aboriginal landowners were informed of the proposed release plan in detail. They chose to legally challenge the water release plan in the High Court of the Northern Territory and the court decided that the release could proceed.

During this period direct consultations took place with the stakeholder group and the traditional land owners were briefed to provide comprehensive information on this issue between the usual six-monthly stakeholder consultative group meetings. These consultations revealed the depth of environmental and social concern felt by some key stakeholders about water releases from the Ranger mine, and as a consequence ERA undertook not to release water, in spite of the court's ruling in its favour.

Therefore, in order to accommodate stakeholder concerns, it was necessary to develop an alternative water management strategy to that under which the mine had operated for the previous 16 years. This strategy had to be based on a "no-release" philosophy. A working party was set up which canvassed all stakeholders for ideas on how to manage waste waters on site, and this rich fund of ideas was considered in an analysis of best practicable tech ology undertaken by the working party. Key stakeholders were kept informed of the progress of the working party through special meetings and site tours where the options for water management were presented and discussed.

An interim plan has been working well since 1994 and the final water management plan should be agreed in 1998. Development of the new water management strategy has been examined in detail by the EPRs, and the outcomes of these examinations have been the subject of extensive discussion and exchange of information at successive stakeholder consultative group meetings. Feedback from the EPRs and consultative group meetings has been fed into further refinement of the water management strategy, consistent with the "continual improvement" cycle represented in Figure 2.

There now appear to be fewer stakeholder concerns about waste water management at Ranger, demonstrated by fewer media reports and stakeholder queries on the subject. Whilst it may be claimed that the process of communication amongst stakeholders about the environmental performance of Ranger mine is not perfect, this example shows how the process was able to deliver a solution acceptable to all of the parties. A key feature of the process was that the stakeholder group members continued talking to each other; the solution thus became a mutually owned solution and avoided a polarisation into "winners and losers". Meetings continue both on a regular and "ad-hoc" basis in an effort to improve standards of communication and to raise levels of trust between the stakeholder groups.

EVALUATION

The performance review approach to environmental audit has engendered a more harmonious working relationship between the company, the supervising authorities and the other stakeholders. This has resulted from a mutual understanding that the special circumstances represented by a uranium mine, surrounded by a national park, in a world heritage area, on aboriginal land, in a region of outstanding biodiversity, warrants special care which may exceed normal regulatory requirements. This improved understanding of the concerns, objectives and values of other stakeholders has helped build an attitude of shared commitment to problem solving rather than apportioning blame. The success of the process relies heavily on trust between the parties, for example trust on the part of the audit team that all relevant data are presented, and are presented objectively by the company; that the company is consistent and committed to pursuing improvement in areas identified as unacceptable or requiring further work; and that all stakeholders will deal with information in an objective and professional manner.

The scope of the audit goes well beyond regulatory considerations, and so regulatory sanctions generally cannot be called upon in the case of this trust-based relationship breaking down (in many respects the system is effectively voluntary for the companies). However, the sensitivity of the mining industry to negative perceptions in the community and government over uranium mining/national parks/Aboriginal issues, and the effectiveness of the stakeholder group as a conduit to expose controversial issues to community groups and government agencies, have to date guaranteed positive mining company participation in the performance review process.

A major benefit of the independent chairing of the consultative forum is the reduced risk of the system being overtaken by any of the political agendas held by some of the stakeholder groups. A close focus on environmental performance has been maintained as the main business of the group, which has improved the maturity and quality of discussion. Access to up-to-date comprehensive environmental data and interpretation, and the opportunity to discuss these in detail with the key information sources, has increased the responsible use and acceptance of this information, and reduced the prior tendency for its selective and sensationalist misuse.

There is further evidence of the success of the process. The EPR/ stakeholder consultation system has recently been introduced into the Indian Ocean Territories, where previously little environmental management expertise or a regulatory framework were available. Unlike the uranium mining application, the objective is to increase the standard of performance to acceptable mainland standards, at which time regulatory mechanisms can be applied. But again a very broad based stakeholder group has to be engaged over a wide range of environmental issues and differing points of view.

The islands face significant environmental problems related not only to mining (mainly dust from phosphate mining and processing operations), but also to solid and liquid waste disposal, sewerage treatment, management of hazardous substances, and general community environmental understanding and behaviour.

The new procedures of environmental performance reviews, stakeholder consultation, and system review are proving effective in raising the level of environmental performance from a very low base. They have been applied effectively to a wide range of sectors (mining, local government, utilities, tourism, service industries and various outposted government departments). In only two years, some operations have lifted the quality of environmental management to mainland standards. A sense of shared commitment and synergy has emerged where the different sectors are exploring opportunities to learn from each other, and looking for efficiency gains such as sharing the costs and benefits from expert consultants and development of new systems.

CONCLUSION

The system of integrated environmental audit, stakeholder consultation and review used for the Alligator Rivers Region uranium mines and for environmental improvement in Australia's Indian Ocean Territories has proven successful in delivering outcomes acceptable to the main stakeholders and the broader community in situations of particular environmental sensitivity and concern to the public. Whilst it may seem contradictory, a significant strength of the system is its voluntary nature, which assists in bringing all parties to the table and fostering mutual understanding between groups with diverse and commonly conflicting views, concerns and agendas. Regulatory mechanisms act as a `safety net' beneath this voluntary system to ensure there is no significant risk of environmental damage. Beyond the realm of regulation lies the community's expectation of "best practice" performance in order to protect the outstanding environmental and human assets of the Kakadu region. The influence of public opinion, and community reaction to performance seen as inconsistent with maintaining the World Heritage status of the region, are powerful sanctions sanction against mediocre performance.

Success of this system depends to a large degree on open exchange of information, development of mutual understanding and trust, clearly defined environmental objectives, and commitment by all parties to continual improvement. It may take several iterations of the audit/consultation cycle to start to generate a trustful relationship. The objective is to develop a shared, open team approach able to accept and absorb differences in position and principles, which is robust enough to maintain its focus through technical difficulties and political influences. The potential rewards include leadership in the fields of community relations and environmental performance, and improved certainty in strategic mine planning.

Planning Mine Closure and Stewardship in a World Heritage Area – Alligator Rivers Region, Northern Territory, Australia

Stewart Needham and Peter Waggitt

US Department of Energy Mine Stewardship Workshop

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PLANNING MINE CLOSURE & STEWARDSHIP IN A WORLD HERITAGE AREA - ALLIGATOR RIVERS REGION, NORTHERN TERRITORY, AUSTRALIA

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ABSTRACT

The uranium mines of the Alligator Rivers Region of Australia's Northern Territory lie in a region internationally recognised for its outstanding natural and cultural values. The high level of community concern based on perceptions of risk to the environment and to human health led to establishment of a complex supervisory regime which has delivered a very high level of environmental performance in terms of mine operation, and in planning for mine closure. The high level of community interest will ensure an increasing focus on rehabilitation and stewardship issues as the mines approach the end of their operating lives.

This paper describes the procedures which have been developed to maximise the satisfactory and orderly close-out of the Ranger uranium mine, due to cease milling operations in 2007, and draws on experience from the nearby Rum Jungle and Nabarlek mines which were rehabilitated in 1986 and 1995. These procedures emphasise the need for early definition of objectives, early planning of remedial works, and continual refinement of these plans, establishment of adequate and secure rehabilitation funds, and definition of roles and liabilities extending beyond closure.

INTRODUCTION

In Northern Australia the coincidence of uranium mining, Aboriginal land, National Park and World Heritage Area presents a particularly challenging situation for mine operators and government regulators. Since before mining began in the region in 1979, outspoken community groups have continually expressed their concern about the potential environmental risks from uranium mining to the outstanding World Heritage listed biological, cultural, archaeological and geomorphological assets of the Kakadu National Park; potential health risks and social disruption to Aboriginals still maintaining traditional lifestyles; and the moral issues surrounding the nuclear fuel cycle. These issues are commonly seen as inter-related by the Australian community, and so they form a potent and at times politically sensitive mix which needs careful management.

Consequently the uranium mines of the Alligator Rivers Region of the Northern Territory are Australia's most closely supervised mining operations. The high level of concern also extends to mine closure and the state of the land after rehabilitation. In particular, a key concern relates to the level and character of rehabilitation, and suitability of the mined areas post-closure for land uses compatible with incorporation into the surrounding national park and access by Aboriginal people to undertake traditional hunter-gatherer activities. It is clear that there will be intense scrutiny of the development of rehabilitation and stewardship arrangements by the many interested stakeholder groups, presenting an exciting challenge to develop arrangements clearly seen to be at the leading edge of best practice in the Australian context.

Four economically significant mineral deposits have been defined in the Alligator Rivers Region, but only two have been mined to date because of the 1982 - 1995 Labor Government's policy of restricting the size of the uranium mining industry. Inclusion of most of the "Alligator Rivers Uranium Field"[1] into Kakadu National Park has also very significantly reduced the areas available for exploration, as no exploration activity is permitted in the park. The two deposits which have been allowed to be developed are Ranger, and Nabarlek.

When development of the Ranger deposit was proposed in 1974, the Federal government established the Ranger Uranium Environmental Inquiry chaired by Mr Justice Fox[2]. The inquiry was established in recognition of the particular environmental values of the area surrounding the Ranger deposit, and proposals to declare a national park in the region. This inquiry was effectively Australia's first comprehensive environmental impact assessment, as environmental impact assessment legislation was still under development at the time. The inquiry concluded that provided a series of arrangements and conditions were put in place, mining could proceed without damaging the integrity of the high natural value of the region. Key arrangements put in place included the creation of the statutory position of "Supervising Scientist", with a mandate to oversee the environmental management and regulatory arrangements at Ranger, assess environmental performance against the expectations of government and the community, and conduct research to develop improved environmental monitoring methods and environmental protection techniques. The Federal Government defined its expectations for environmental protection through a comprehensive list "Environmental Requirements" which were agreed with representatives of the Aboriginal landowners (i.e. the Northern Land Council) and became a legal instrument through attachment to the federal Aboriginal Land Rights Act. The day to day regulation of the mining was delegated to the Northern Territory government, and conformity of environmental legislation between the two jurisdictions was provided for through attachment of the Federal Government's Environmental Requirements to Northern Territory legislation (the Uranium Mining [Environmental Controls] Act).

The Environmental Requirements defined some of the fundamental aspects for rehabilitation of the Ranger mine, including:

- progressive rehabilitation was to be implemented from the earliest opportunity;
- the tailings were to be returned to mined-out pits at the end of operations, unless a better option could be shown to the Supervising Scientist which would ensure that the environment was no less well protected;
- the Goal and Objectives for rehabilitation would have to be agreed within ten years of the mining operation commencing.

In combination, these three points articulate the fundamental position of government that mining will not compromise the future (i.e. post-mining) integrity and functionality of the natural resources of the region. In retrospect, the definition and enshrining in legislation of the principles of progressive rehabilitation, below-grade placement of tailings, and post-mining land use compatible with the national park has proven insightful and progressive. Using these principles as the foundation, the governments' Goal and Objectives for rehabilitation have been determined. Research and planning by government and the mining company have been directed to conform with these principles and the Goal and Objectives for rehabilitation. Evaluation and refining of plans is conducted on an ongoing basis through detailed technical discussions between the federal and territory governments, the Northern Land Council and the mine operator.

GOAL AND OBJECTIVES FOR REHABILITATION

The Broad Goal for rehabilitation at the Ranger uranium mine is defined as:

> "Rehabilitation of the Ranger Project Area should aim to establish an environment in the Area that reflects to the maximum extent that can reasonably be achieved the environment existing in the adjacent areas of Kakadu National Park, such that the rehabilitated area could be incorporated into Kakadu National Park without detracting from Park values of adjacent areas."

The three Major Objectives for rehabilitation are:

1. "To revegetate the disturbed sites of the Ranger Project Area with local native species similar in density and abundance to that existing in adjacent areas of Kakadu National Park, in order to form an ecosystem the long term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the Park.
2. To establish stable radiological conditions on disturbed sites of the Ranger Project Area so that, with a minimum of restrictions on use of the Area, the public dose limit will not be exceeded and the health risk to members of the public, including traditional owners, will be as low as reasonably achievable.

3. To limit erosion in rehabilitated areas, as far as can be reasonably achieved, to that characteristic of similar landforms in surrounding undisturbed areas."

The exact interpretation of some of the terms used in the Goal and Objectives was left to be determined through discussion between the key parties at a later date and as information from rehabilitation research came to hand..

IMPLEMENTATION OF THE GOAL AND OBJECTIVES

Early attempts to determine the details of how the Goal and Objectives would be achieved were unsuccessful. A significant contributor to this was the concern by the company that the demands for rehabilitation were more far-reaching than for almost all other minesites in Australia; a lack of technical and scientific information on rehabilitation and revegetation methods which would be needed to conform the government requirements, and the cost. For many years the company developed plans based on in situ rehabilitation of the tailings in the tailings dam, hoping to utilise an option spelled out in the Environmental Requirements which indicated that, subject to the agreement of the Supervising Scientist, tailings could be disposed of other than by burial in the pits provided that this alternative method was no less protective of the environment. However, after considerable research and field trials, followed by a "best practicable technology"[1] evaluation for final tailings containment, the company elected in 1997 to relocate the tailings from the tailings dam into the pits. Whilst the assessment has not been made public, factors influencing the decision probably included -

- cost (e.g. difficulty in gaining access to the tailings surface to place the cover material because of the low settled density of the tailings may have required the use of expensive geotextiles and excavation of very large volumes of sand from environmentally sensitive areas);

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[1] "Best Practicable Technology" is defined in the Environmental Requirements as:

That technology from time to time relevant to the Ranger Project which produces the minimum environmental pollution and degradation that can be reasonably achieved having regard to:

(a) the level of effluent control achieved, and the extent to which environmental pollution, and degradation are prevented, in mining and milling operations in the uranium industry anywhere in the world;

(b) the total cost of the application or adoption of that technology relative to the environmental protection to be achieved by its application or adoption;

(c) evidence of detriment, or lack of detriment, to the environment after the commencement of the Ranger Project;

(d) the physical location of the Ranger Project;

(e) the age of equipment and facilities in use on the Ranger Project and their relative effectiveness in reducing environmental pollution and degradation, and

(f) social factors including community acceptance and possible adverse social effects of introducing alternative technology.

- uncertainty on the long term behaviour of the tailings mass, in particular from low-density lenses of gels, and its impact on long-term stability and containment of radioactive materials.

Acceptance by the company of the tailings placement option preferred by government now allows improved coordination and collaboration in rehabilitation research between the company and government. In addition research into tailings placement, covering issues such as maximising settled density, capping design to reduce radon flux etc, other research priorities are addressing:

- lack of knowledge on revegetation using native species (for example, many Australian native species have low and/or unpredictable germination rates, and may require heat, smoke, ingestion/excretion, or attrition before they will germinate);
- lack of knowledge on the evolution of mine soil and its ability to support sustainable vegetative ecosystems;
- landscape design to reduce the level of post-closure maintenance, reduce erosion, and provide a result aesthetically not incompatible with the natural local landscape;
- design of low-maintenance wetland filter systems for control of suspended sediment and uranium, sulphate and magnesium in runoff.

CONSULTATION ON REHABILITATION WITH STAKEHOLDERS

An important element in implementing the goal and objectives for rehabilitation is ongoing consultation with stakeholders. As the land is Aboriginal land, there is more than one possible outcome in terms of post-mining land use. It could be incorporated into the Kakadu National Park if the landowners agree to enter into a similar lease-back agreement with the Federal government as currently exists for the park; or the landowners may choose to maintain the area as an excision within the park for agricultural, aquacultural or tourist development - or for Aboriginal enjoyment without intrusion by tourists or park management staff.

Formal consultation occurs through several mechanisms. Twice-yearly environmental audits to assess environmental performance are conducted by the Supervising Scientist and closely linked to a Ministerially appointed stakeholder consultative committee made up of representatives of federal and Territory departments of mines, environment and health, the National Parks service, the local Town Council, traditional land owner associations, the Northern Land Council, the trade union and representatives from environmental NGOs at both local and national level (Figure 1)[3]. The strategic plan of issues to be investigated by the audits is developed with this stakeholder committee, and the audits results presented to the committee for advice and discussion. This arrangement allows for information exchange between, and input into processes from, a very wide group of interested stakeholders. Issues of concern to the group included mine rehabilitation, and consequently the issue of planning for mine closure has become the focus of audit questioning and reporting to the stakeholder group. Exposure of the lack of agreement between the company and the government on implementation of the Goal and Objectives for Rehabilitation at Ranger to the environmental audit and stakeholder committee resulted in the company undertaking in December 1995 to report on it's intentions for tailings disposal within two years. Thus the "Best Practicable Technology" assessment of tailings disposal options as described above, and subsequent resolution by the company to conform with the government's preferred option for rehabilitation of the tailings, came about as a consequence of the linked audit-consultative process.

The emphasis on openness and exchange of information has resulted in greater clarity in the role of agencies, greater understanding of opportunities for collaboration, and greater understanding of potential efficiencies to be gained. The efficiencies can flow from establishing positions and programs discussed and accepted by the stakeholder group, thus avoiding problems with those parties who otherwise may cause delays or complications through legal or protest action etc. A second stakeholder consultative forum identifies research priorities and fosters collaboration and exchange of research information. Recognising the impacts upon Aboriginal society in the region over the last twenty years which have resulted from a range of developments including mining, government and mining company jointly funded a study to identify the social impacts and recommend solutions. The study involved extensive input from local Aboriginal people and organisations, and government and private sector delivery agencies, to maximise ownership both of the problems defined in the study, and the recommended solutions and response mechanisms[4,5].

Currently, thought is being given to develop other, less formal mechanisms for exchange of information with local Aboriginal people who do not have the language skills or are uncomfortable with meeting in the "balanda" (white-fellow) way. Plain English reports are being developed which can be more broadly distributed amongst Aboriginal communities in the region. Rehabilitation planning is also discussed at regular Aboriginal liaison meetings organised by the company, and Traditional Owners are encouraged to visit the minesite a few times each year so they remain familiar with changes in operations and can discuss progress on progressive rehabilitation and research results related to rehabilitation planning.

Whilst there will always be tensions because of the diversity of backgrounds and views amongst stakeholder groups, the inclusive and open approach is allowing more sensible, better informed and better quality decisions to be made in the region. It is important that this inclusive approach is followed in planning for mine closure and post-mine management to ensure that a level of short to long term protection of the environment and human health are delivered which meet the high expectations commensurate with the attributes of a World Heritage Area. the needs of the traditional land owners, and the expectations of the broader public.

Comments from Traditional Owners are important for they are the people who may use the land after rehabilitation is completed. At the Nabarlek mine 60 km northeast of Ranger, which is now in the post-rehabilitation works monitoring and maintenance period prior to walkaway, the Traditional Owners asked for enhanced levels of particular native "bush tucker" species to be incorporated in the revegetation program planted to improve the usefulness of the area to them for traditional hunter-gatherer foraging expeditions. Assessment of revegetation success at Nabarlek will assist in planning at the Ranger site, including whether it is possible to establish "enhanced" native vegetation communities. Research will need to continue to ensure that no health risk arises from eating bush foods from the capped area through accumulation of metals or radionuclides.

REHABILITATION PLANNING

There is a legal requirement for rehabilitation works at Ranger to be completed within five years of the end of mining and milling, and so planning for rehabilitation reflects this requirement. The company is also required to provide funds in trust to cover the costs of rehabilitation. In order to determine the appropriate size of this fund, which is held in trust as cash or government securities, a rehabilitation plan has to be prepared every year which describes the work that would need to be done to rehabilitate the site from the condition it exists at the time of preparing the report. This plan addresses, in broad terms, the costs of a 5 year rehabilitation works program commencing on a fixed date each year. The assumption is that the mine and mill will cease operations and all work is to be completed within 5 years of that cessation date. The plan is drawn up by the mining company in accordance with the requirements of the mining laws and the Environmental Requirements. A draft is discussed between the mining company and the two governments. A final costed version is passed by government to an independent assessor to check that costings are adequate, and the size of the trust fund is adjusted accordingly. Thus the size of the fund varies over time, and in recent years has reduced to reflect the impact of progressive rehabilitation and progressive placement of waste rock consistent with the final landform design. This process ensures that there should always be sufficient financial resources to rehabilitate the mine at any time.

A more detailed plan of rehabilitation is prepared on a rolling 5 year basis. This plan includes detailed plans for progressive rehabilitation works, and also describes recent results of rehabilitation research. Long term research by the company relevant to rehabilitation includes exploration of revegetation options, landforming methodology and final land form shape, erosion of man-made landforms, radiological studies and capping options for tailings deposits.

Rehabilitation research is also undertaken by the Supervising Scientist[6]. Topics being investigated include erosion characteristics of mine soils under differing slope characteristics; long term computer modelling (i.e. to 10 000 years) of erosion of various landform models[7]; evolution of mine soils; and longevity of wetland filters as passive water management systems. Work on revegetation, in particular on seed germination of native species and mechanical and chemical soil treatments to enhance vegetation establishment, has been concluded; the responsibility for this kind of work now rests with the company, in line with common practice elsewhere in Australia.

There is a general understanding that detailed plans for rehabilitation will be gradually developed and refined as results of research come to hand, and as the end of the mine's life draws closer. Whilst it is the company's responsibility to develop the detailed plans, they are submitted to the authorities for evaluation against the agreed Goal and Objectives for Rehabilitation using "Best Practicable Technology" as the assessment principle. Therefore, as more knowledge comes to hand from research at this site or from relevant research elsewhere, there will be an ongoing development and improvement in rehabilitation plans. Also, as further knowledge accumulates, the degree of certainty of rehabilitation success is expected to improve.

STEWARDSHIP

The *special considerations* which apply to the Ranger site require that mine closure and subsequent stewardship arrangements will provide a high degree of certainty that the site will meet exacting expectations. In essence the area will need to be compatible with the landscape and vegetation of the national park, there should be no limitations on access and casual habitation by Aboriginal people, and there should little or no requirement for special aftercare.

When the issue of uranium mine rehabilitation is discussed in Australia, inevitably the *experience of rehabilitation* at Rum Jungle is raised. The Rum Jungle mines lie 225 km west of Ranger, were mined in the 50's and 60's, and rehabilitated in the 70's. The rehabilitation included design of benched, capped and grassed waste rock dumps, and stabilised open pit lakes treated to reduce surface and shallow water acidity, neither of which would be acceptable for a site destined for incorporation into a national park. Regular maintenance is required, for example to remove any trees which start to grow on the waste rock dumps.

A more appropriate example is the rehabilitation of the Nabarlek mine[8], mined and milled between 1979 and 1989 and rehabilitated in the early 90's. At this site, 60 km from Ranger, the orebody was stockpiled in a single intensive orebody extraction program, and progressively milled over ten years. The tailings were pumped direct to the pit. Prior to decommissioning and rehabilitation, the tailings were dewatered using vertical wicks to maximise the space available in the pit and improve stability. Contaminated material from the floor of the evaporation ponds, and mill arisings, were placed above the tailings, and the pit filled with waste rock. The cap was shaped to "natural" slopes and contours designed to minimise the risks of erosion, and a cap designed to reduce radon flux but which would withstand the impacts of revegetation including tree root penetration.

The *measurement of rehabilitation success* is still a developing science, and research sponsored jointly by the mining industry and government is currently being undertaken in Australia to identify and apply ecosystem indicators for this purpose. In the Northern Territory, a company's liability for a minesite ends upon the issue of a Revegetation Certificate by the NT Minister for Mines, and objective information is required to advise the minister accordingly. The Goal and Objectives for Rehabilitation for Nabarlek are, like those for Ranger, conceptual and value-driven, recognising the absence of sufficient information to enable quantitative targets to be set, such as values for biomass, tree canopy cover, successive colonisation of flora or fauna. Therefore an arrangement is in place whereby regular (at least annual) surveys are undertaken by an independent ecological consultant, who is charged with advising the authorities when he considers that the site is reaching the objectives required by the Traditional Owners and the supervising authorities.

The current expectation is that, given growth rates in this region and the speed of mine soil generation from broken rock, and presuming that there are no unforeseen developments, that the expert will make a recommendation leading to termination of further liability for the site by the company within five to ten years after completion of the rehabilitation works.

At the Ranger mine, further work is required to provide certainty of process to the company for planning and executing close-out procedures, and providing a clear path through to removal of company liability for the site. It will be necessary to develop a procedure which recognises and integrates the interests and expectations of both levels of government and the landowners, possibly through appropriate arrangements recognising the progressive stages from mine operation through to and beyond walkaway:

• **Operational mining**

- The company undertakes a monitoring program as specified in legislation; monitoring information is checked by the NT authorities and reviewed by federal authorities.

- Ongoing research into rehabilitation techniques by the company and the federal government.

- Preparation of Annual Rehabilitation Plan and cost estimations to facilitate maintenance of an appropriate sum in the Rehabilitation Trust Fund.

- Ongoing refinement of rehabilitation technologies through consultations with major stakeholders to review probable post-mining land use and evaluation of best practice as it applies to Ranger.

- Progressive rehabilitation, in particular stabilisation and revegetation of disturbed ground, and placement of waste rock to conform with the geometry of the final landform.

• Care and maintenance period

The main environmental risk at Ranger relates to water management, in particular the appropriate containment, treatment and disposal of rainwater which occurs as heavy tropical rains during about four months of the year. This risk will be just as high during any care and maintenance period which may occur between cessation of mining and milling and commencement of rehabilitation works. There all of the above arrangements would need to continue, except for preparation of Annual Rehabilitation Plan. However, in the case of a protracted care and maintenance period periodic review of the plan may be necessary to adjust the size of the Rehabilitation Trust Fund for the effects of inflation etc, and to incorporate any advances in best practice techniques.

• Rehabilitation Works

Major engineering works to decommission the mine infrastructure, relocate tailings from the tailings dam to the pits, fill and cover the pits with waste rock, landscaping and revegetation.

- Appropriate sanctions should apply in the event that the Rehabilitation Works are not completed within the specified five year period.

- Close monitoring by the authorities to ensure that the works are conducted in a manner most likely to meet the Goal and Objectives for Rehabilitation, with emphasis on minimising radon flux, surface erosion (particularly gullying), and seeding with native species.

- Company and government research programs on techniques and standards for rehabilitation works would appropriately cease at the start of this stage, but would focus on finalising techniques for monitoring and maintenance.

• Monitoring and Maintenance

The period during which the success of the rehabilitation works is assessed through monitoring and expert examination.

- Assessment will be through regular evaluation by an independent revegetation expert against the generic criteria contained in the Goal and Objectives for Rehabilitation, or, if agreed by the supervising authorities, the company and representatives of the land owners, more quantitative criteria developed through research and appropriate to the biophysical and climate characteristics of the Alligator Rivers Region.

• **Walk-away**

The point at which the Goal and Objectives are determined as met, and the NT Minister for Mines issues a Revegetation Certificate for the site.

- From this point it would be appropriate for future liability for the site to rest totally with government. Whilst there are no mechanisms in place at this stage, the government may consider placing a charge on the issue of the Revegetation Certificate in order to provide funds for long-term monitoring and maintenance of the site after walk-away. It would be good practice to determine the size of any charge attached to issuing the Revegetation Certificate on the basis of a risk assessment conducted at the conclusion of the Monitoring and Maintenance period, focusing on the probability of risk from higher than targeted radon flux, erosion gullying, and contamination of surface water.

- The long term management of the rehabilitated area is most likely to be a partnership under the primary leadership of the Traditional Owners. The government authorities would probably assume responsibility for maintenance and remedial works, and long term surveillance. It is unlikely that public concern will diminish to the point where an Australian government would be able to walk away completely from a rehabilitated uranium mine site - a perception which appears commonplace amongst the communities of many other nations (e.g. discussions at the Multilateral Exchange meeting and workshop held in Vancouver in June 1997).

CONCLUSION

Stewardship is a new concept in Australia. Because of the high level of community interest in uranium mining, particularly in the Alligator Rivers Region where the mines are adjacent to the World Heritage listed Kakadu National Park, the concept is likely to be developed and refined through the process of close-out planning for the Ranger uranium mine. A central concept applied in the environmental management, regulation and oversight of the mine is that of "Best Practicable Technology". This requires that standards, procedures and plans are continually reviewed and revised to keep abreast of scientific knowledge, technological develops, and stakeholder concerns. Therefore we cannot outline here and now exactly what procedures will be applied at Ranger, but we can say how critical it is to ensure there is open and continued communication between the mine operator, government and the community to ensure that there is broad understanding and ownership of the objectives for rehabilitation, and that the outcomes meet expectations to a reasonably high level. The high natural values of the surrounding region will ensure that the Ranger mine will be rehabilitated to level internationally recognised as best practice for the uranium mining industry, and ideally the site will be reincorporated into the national park. Such high expectations are likely to deliver a result which will present minimal risk and effort to government in its role as long-term steward of the post-mine Ranger site.

REFERENCES

[1] Needham RS, 1988. Geology of the Alligator Rivers Uranium Field, Northern Territory. Bureau of Mineral Resources Australia Bulletin 224. 96p

[2] Fox RW, 1977. Ranger Uranium Environmental Inquiry, Second Report. Australian Government Printing Service, Canberra

[3] Needham RS, 1996. A system of environmental performance assessment and reporting which serves the needs and expectations of operators, regulators and the concerned public. In *Proceedings, Academy of Science Fenner Conference on the Environment.* University of New South Wales.

[4] Supervising Scientist for the Alligator Rivers Region, 1997. Annual Report 1996-97. Australian Government Printing Service, Canberra

[5] Evans KG, Willgoose GR & Saynor MJ 1998. Incorporation of landform evolution modelling in mine rehabilitation planning. In *Proceedings of SWEMP '98: 5th International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production, Ankara, Turkey 8-10 May 1998.* Balkema, Holland

[6] Kakadu Region Social Impact Study (1997a) Report of the Aboriginal Project Committee. Supervising Scientist, Canberra

[7] Kakadu Region Social Impact Study, 1997b. Report of the Study Group - Community Action Plan. Supervising Scientist, Canberra

[8] Waggitt PW, 1998. The decommissioning and rehabilitation of the Nabarlek uranium mine, northern Australia. In *Proceedings of SWEMP '98: 5th International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production, Ankara, Turkey 8-10 May 1998*. Balkema, Holland

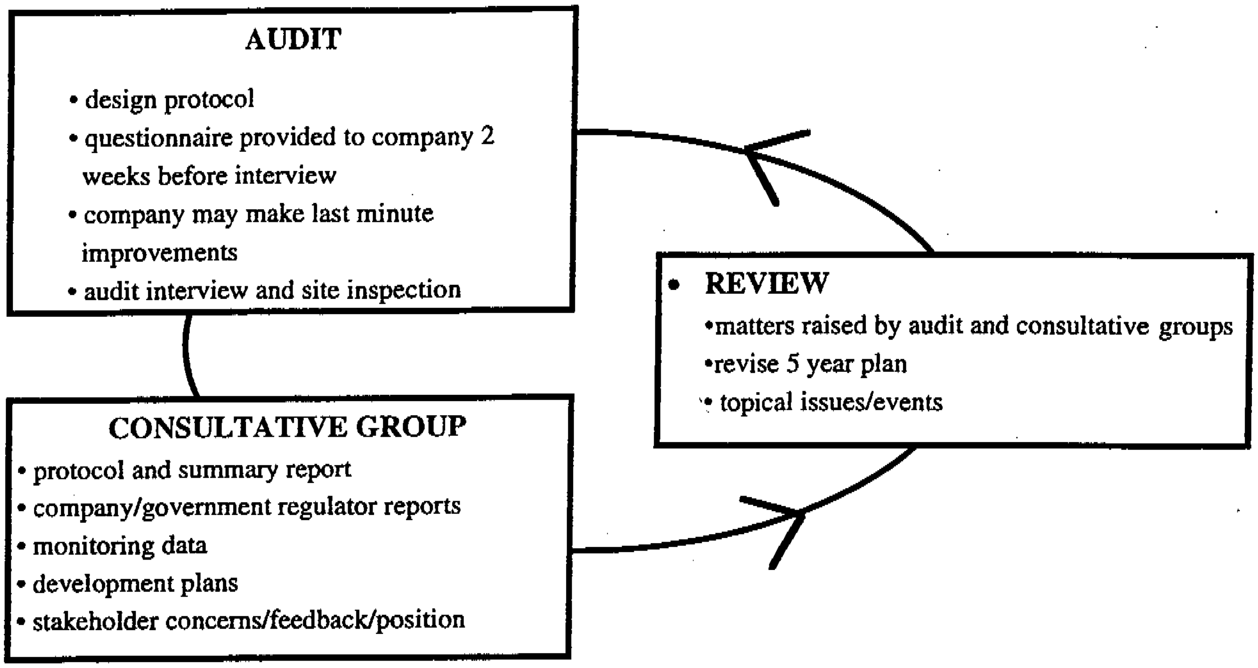

Figure 1. Environmental assessment and communication mechanisms for uranium mines in the Alligator Rivers Region: our "continuous improvement cycle"

Best Practice Tailings Management: Principles and Practice

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BEST PRACTICE TAILINGS MANAGEMENT: PRINCIPLES AND PRACTICE

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INTRODUCTION

In the modern world there is an increasing pressure for everything we do to be the best. Best Practice is a phrase that we come to hear more and more frequently in all walks of life. The mining industry and environmental management are no exceptions. Best Practice Environmental Management in Mining is a concept that is gathering a significant following around the world as the mining industry responds to public opinion through establishing itself as being environmentally aware. Mining is an industry that wishes to be seen as becoming increasingly proficient in reducing pollution and taking care of the environment

In the mining industry the effective management of waste, especially the processing waste we call tailings, is an issue that is of growing significance. This is in part due to the necessity for mines to be working deeper deposits which are often dominated by sulphidic ores. These operations may produce greater volumes of tailings as open cuts go deeper and grades get lower. As these processing wastes are likely to be more reactive they require more careful management to minimise possible environmental impacts.

THE DIMENSIONS OF THE ISSUE

The volume of tailings being produced in the world is substantial. The figures are not easily determined but Table 1 shows what annual production was in 1994 for some commodities. Overall world tailings production could easily be more than 2500 million tonnes annually. Copper mining is the major producer of tailings.

Table 1: World tailings production 1994-Selected commodities

Commodity	Tailings (M tonnes)
Copper	1500
Gold	500
Lead & Zinc	130
Bauxite	70
Potash	120
Phosphate	50-60
Coal (estimated)	1150

Sources: UNEP, 1996, ABS, 1998

The levels of public concern and potential risk to the environment and public health may be significantly higher for some types of tailings, for example uranium mill tailings. The world production rate of uranium mill tailings is probably more than 20 million tonnes each year (IAEA, 1992). In the USA alone there were an estimated 173 million tonnes at active mills in 1982. This is expected to be increase to than 200 million tonnes by the end of the century. In Canada, 130 million tonnes were identified in deposits in 1982 and more mines are scheduled to come on line in the near future (Waggitt, 1994). Other major producers in Namibia, West Africa, the former eastern block and Australia could double the volume of uranium mill tailings globally. Other types of tailings which, under best practice principles, require especially careful management include sulphidic materials, those with extreme pH characteristics and high reactivity, and any tailings likely to give rise to toxic effluents.

Equally significant is the total number of mine sites that have tailings to manage. No comprehensive list has apparently ever been assembled but over 90% of mining sites would have tailings or waste in some similar form, and that must be a very large number. There are many small sites, sole operators and so on, that fall through the mesh of national surveys but even medium sized mines are often neglected by enumerators when assembling statistics. In Australia alone there are over 500 recorded minesites currently operating; worldwide the number must be many times greater.

The safe, efficient and successful management of mine tailings is a major priority in modern mining. All wastes from mining, especially tailings, must be managed so as to prevent any possible future pollution and degradation of the environment or any other risk to the community. The issues that must be addressed include costs of waste management, both capital and operating, increasingly demanding environmental standards and regulations, and the growing level of public participation in both green and brown environmental issues. Finally, there must also be consideration of the increasing level of public expectation in relation to environmental protection.

This meeting will hear from a wide range of presenters about the most recent developments in tailings management throughout the Asia-Pacific region. The intention in this paper is to discuss what is best practice in modern tailings management, with a strong emphasis on the environmental advantages. It will then go on to describe briefly some examples of best practice tailings management and provide some guidelines for determination of best practice. Later speakers will be giving us detailed examples of current and future operations and I do not wish to be stealing their thunder. So really I shall be setting the scene, to suggest what we mean by "Doing it right!"

BEST PRACTICE IN ENVIRONMENTAL MANAGEMENT

In order to understand the thrust of this paper it is necessary to agree on what is meant by "Best Practice". In simple terms it may be considered as just the best way of doing something (Carbon, 1995). But "*best*" is a subjective term and what may be best for the financial department may not be best in the opinion of other stakeholders such as the community or the mine manager or the environmental superintendent. Equally it may not be best for another operation. So first we need to consider that Best Practice is a concept that needs to be applied in a site specific context. Thus, what we are seeking to establish is not perhaps 'Best Practice' but 'Best *Practicable* Practice'. That is to say the most suitable practice at a site for dealing with an issue in a manner that not only achieves the outcome desired by stakeholders, but in a manner that they are all, hopefully, happy to accept and work with. This is in essence what is applied in Australia at the Northern Territory uranium mines where it is known as 'Best Practicable Technology"(BPT). The concept was developed with the assistance of the Supervising Scientist at the time of the creation of the legislation to regulate the Ranger and Nabarlek mines (OSS, 1979). There are a number of elements to be taken into account in arriving at a BPT solution.

The practice proposed must produce the minimum levels of environmental pollution and degradation that can reasonably be achieved having regard to:

- the level of effluent control and minimisation of adverse environmental impact anywhere in the world in a comparable operation;
- the cost effectiveness for the level of environmental protection achieved,

- the location of the project (eg terrain, climate, receiving environment, etc.),
- the facilities and plant available on site (eg type of mine operation, type of processing systems etc), and
- social factors, including possible adverse effects of introducing new technology.

Again it is emphasised that all these factors need to be considered in a site specific context. The outcome is arguably what we may really mean by "Best Practice".

This concept is embraced in the Best Practice Environmental Management (BPEM) booklets produced by Environment Australia (Environment Australia, 1995). These have been distributed throughout the Australian mining industry and are well known in many other parts of the world, including Europe, America and India. In particular they have been widely distributed throughout the South East Asian region with the first 9 booklets in the series already translated into Bahasa Indonesia, Mandarin and Spanish.

WHAT IS BEST PRACTICE TAILINGS MANAGEMENT?

The important issues in tailings management may be considered under three major headings:

- Long term containment
- Prevention of pollution
- Minimal intervention after mine closure

In order for Best Practice to be achieved each of these issues must be addressed satisfactorily.

The physical containment of the waste solids is an issue that demands a great deal of attention from managers, engineers and environmental staff in the mining industry. In the past there have been examples of tailings dams or similar containments that have collapsed with subsequent loss of life and damage to property. A review of tailings dam failures carried out by UNEP was published in 1996. The report only covered incidents which had resulted in fatalities or significant injuries and found that there had been about 25 incidents in the period 1980 to 1996 (UNEP, 1996).

The prime objective in long term tailings containment should be to ensure that the containment is going to retain its integrity for as long as possible and that the maximum amount of waste is fitted into that containment. In some jurisdictions there are standards set down for the minimum design and structural life of an above ground containment. If the containment structure is below ground the major issues will be seepage of leachates, groundwater ingress and geological stability.

In order to achieve as efficient containment as possible the settled density of deposited materials must be maximised. Not only does increased density allow a greater mass to be stored but it also offers greater geotechnical stability, increased resistance to erosion by wind and water and reduced risk of liquefaction. The use of sub-aerial deposition methods is to be encouraged unless the tailings are to remain below water for all time. However, this should not rule out the introduction of new technologies such as thickened discharge, paste technology or belt presses. All of these methods aim to make the tailings more "solid" and competent to manage and thus more stable in the long term.

The nature of the containment is significant too. Placing tailings in mined out pits is an environmentally elegant solution if the circumstances are right:

- The tailings must be suited to such a system of storage by not being chemically or physically reactive. This may be as a consequence of their natural state or following suitable treatment after processing.

- The pit must be suitable with respect to stability, possible interactions with aquifers, location in relation to process plant, possible interaction with underground workings and availability for use as a storage.
- There must be sufficient volume to accommodate the tailings mass safely.

The same criteria would apply if operators wish to consider tailings disposal through backfilling underground stopes or other workings. Returning wastes to their place of origin, if it can be achieved in a manner acceptable to all stakeholders, is often a very suitable solution. The major problem in using tailings as backfill has been the tendency to use only the coarse fraction. This still leaves fines and slimes at the surface requiring some other disposal method. The concern is that these fine portions are usually the most difficult to manage, are the slowest to dry out, and often contain the highest levels of contaminants and potential pollutants.

The application of co-disposal, as is now common place in the coal industry, goes a long way to provide a solution for this issue. In co-disposal the fines are deposited simultaneously with coarser waste such as solid waste and rock. Under controlled conditions this produces a final waste that is more cohesive and homogeneous which renders it easier to manage and improves structural stability for the long term. All of these factors improve long term environmental security and reduce pollution risk.

The concept of Best Practice requires that new technologies should be evaluated, especially for inclusion in a new project. Increased slurry density in the tailings disposal circuit has been introduced in many locations as an improved management practice. Thicker slurries mean less excess water at the disposal point and a reduction in water management concerns. Central thickened discharge is a management method for tailings that was first proposed by Robinsky (1979) and has been taken up by some projects with great success, eg at the Peak gold mine, New South Wales (Bourke, 1997) and Mount Keith nickel mine, Western Australia (Robinson, 1997). The advantages are that greater settled densities are achieved, and the tailings mass is less prone to layering and fractionation or fines separation, and so long term structural stability is improved. The system may require relatively large areas of flat land but if rehabilitation and revegetation are well managed the end result should be satisfactory. This method can also be used on downslope discharges where it may be applied to tailings used as a valley fill.

The application of paste thickener technology and belt presses to reduce the moisture content of tailings before deposition have also grown in importance in recent times. Again the long term structural security of the waste is improved in both cases and the aim is to reduce the stored volume of waste as well as improve structural stability.

If a tailings dam is to be built either as a free standing structure or a valley in-fill then the decision has to be made if the design will be to water retaining standards or as a conventional tailings dam. Will the construction be by upstream or downstream methods? There are modern practices associated with all these options, and many of them may be best practice in context. The International Congress on Large Dams (ICOLD) has published seven reports relating to tailings dams between 1989 and 1996 (Phillips, 1997). This series covers all aspects of tailings dam operation and construction, effects of seismic activity and environmental and monitoring issues. These reports deal mainly with large dams which for ICOLD means structures over about 15 metres in height, but the principles detailed in the documents may be applied to all sizes of structures.

Then there is the issue of depositing tailings under water, into the sea or a deep lake. Such options may be problematical for some stakeholders; for example, in Australia the concept of submarine tailings disposal is opposed by many non-government organisations and community groups. However, in some parts of the world there are locations where these methods can be argued as being best practice (Ellis, 1996). Again the issue of site specificity has to be brought into the equation when determining best practice.

If we accept that best practice has an element of site specificity built in, then risk assessment plays an important part in the decision making process at this point. The nature of the environment, both natural and built, that requires protection from the possible impacts of any failure or shortcoming in the containment is of great significance in the decision making process. The level of risk, both potential and acceptable, must be assessed and a suitable action plan devised that can be presented to stakeholders for assessment and ultimate acceptance.

Cost is also an element. The direct costs of operating a tailings disposal system are relatively simple to calculate; what is more difficult is quantifying indirect costs. These can be considerable where there has been a failure of a tailings dam, for example at Omai in Guyana (Vick, 1996). In such cases the cost of repairing the damaged structure and immediate compensation can often be overshadowed by the costs of "repairing" or establishing public perceptions of the operators as environmentally responsible people (Jewell, 1997).

PLANNING CRITERIA

When planning for a new mine begins the issues of waste management and final rehabilitation must be included from the very earliest time. Before mining begins the major rehabilitation objective for the tailings must be determined alongside the other elements of the overall rehabilitation plan. This will certainly involve a significant period of stakeholder consultation. The local community must share in the ownership of long term management decisions, including final land use and waste management.

Tailings management is a significant waste management problem in every mine. The ease of finding a widely acceptable solution to the problem is what varies from site to site. The selection of a location and methodology which will allow the disposal and containment of tailings in an environmentally safe and acceptable manner is vital. The location of the tailings disposal site must take into account many factors before a final selection can be made.

Regulatory regime

First and foremost, local regulations must be taken into account relating to tailings disposal and management. Such regulations may specify whether below ground storage is a regulatory requirement, whether containments must be built to the same standards as water retaining structures and so on. Also what do the community think about a tailings dam being placed in their area? These, and many other issues, will have to be addressed and considered in a best practice evaluation, and that should itself include a hazard identification and risk assessment as integral elements of the process (Hallman, 1998). In the following sections examples are given of the items that need to be included in assessments when selecting sites and methods for tailings disposal.

Site significance to all community groups

It must be established if any parts of the area proposed for tailings disposal have special significance.

- Are there any cultural, sacred or religious sites in the vicinity such as ancient monuments or burial grounds?
- Are there sites of social, scientific or archaeological significance that might be affected by the proposed tailings storage development?
- Do any settlements or infrastructure developments need to be taken into account, both existing and planned?

Meteorology

Building or mine operating regulations may impose standards that require tailings dams to be designed to withstand floods or rainfall events of a specific return period. For example, at Ranger uranium mine in the wet/dry tropics of Australia's Northern Territory, the tailings dam has a wet season maximum operating level imposed by the regulating authority which ensures that there will always be sufficient freeboard to accommodate a specified return period of rainstorm as well as coping with wave action. The design of a tailings dam should take into account the severity of rainstorms in the area. Some authorities may require a dam to withstand the flood associated with a probable maximum precipitation event. This is in fact an option being considered by the Australian National Committee on Large Dams as a mandatory design requirement for all future dams in a high risk category, including environmental risk (R.Fell, *pers comm*).

Topography

The topography of a tailings repository site is very important. Often a valley in-fill site is preferred as it offers a minimum cost solution to tailings disposal But valley sites also increase risk, to downstream communities or adjacent wetlands for example. Such sites may be valuable farming sites for communities in mountainous terrain, particularly in third world countries. The site should be set out in such a way that drainage does not run across or accumulate on the site of the tailings. Also, the path of any possible flow following a failure needs to be examined. The camp at the Argyle diamond mine in Western Australia was relocated after it was realised that it lay in the flow path from the tailings dam should there be a failure.

Surface water

Tailings dams are generally not designed as water retaining structures but most do carry decant ponds at the surface. The major concern is to ensure that these waters do not overflow the structure which would present the dual hazards of dispersing contaminants, both solid and liquid. Overtopping threatens the integrity of the structure with the associated risk of complete failure. Tailings dams are rarely threatened by surface water unless they have been located in a stream course, on a floodplain or in a valley fill site. The major concern is that they may release contaminants to surface waters. Steps should be taken to minimise upstream catchment areas as much as possible to reduce runoff inflow to any tailings impoundment.

Groundwater

The commonest concern with tailings in relation to ground water is the risk of contaminants leaching from tailings and passing into the ground water system by a seepage path. This can be minimised or even prevented by a number of techniques. These may include clay based and/or compacted earth layers in the floor and walls of the dam, the grouting of embankments, or a combination of these techniques. The installation of an artificial liner or waterproof membrane at the base of the tailings storage is an effective, albeit usually expensive and perhaps relatively short lived, option. Current best practice in the USA at sites of concern is for tailings repositories to be treated as contaminated waste sites and to have two liners with a seepage detection system operating between the layers. Experience from the USA suggests that such systems are very difficult to manage unless installation and materials are subject to the most stringent quality control procedures. Some facilities have seepage collector systems which vary from open ditches and shallow drains to catch near-surface seepage, through agricultural drains to the sophisticated pumped well schemes and reverse osmosis water treatment plants found in some uranium tailings sites of the USA (UMTRA, 1996).

A further option may be to create a permeable surround to an in-pit tailings repository. In this case a filter layer is built around the outside of the tailings mass as it fills the pit. When the pit is decommissioned, this layer should offer a preferred seepage and flow path around the tailings mass for groundwater flow. This in turn should reduce significantly the amount of leaching occurring in the tailings and, consequently, the level of potential contamination escaping from the pit. Such a system has been implemented at a mine in Rabbit Lake, Canada (Clark, 1989).

It is a matter for debate if seepage collection is best practice after mine closure as it invariably requires very long term intervention and management at a site and arguably best practice means being able to stand back from a completed project. Seepage prevention and retention may be best practice with seepage collection and treatment as an additional precaution. Introduction of modern geotechnical techniques such as membranes, cut-off walls and slurry trenches are seen by some as a way to reduce the risks of groundwater pollution (Cross, 1997).

Foundation suitability

ost tailings containments rely on some form of construction as the retaining device. The foundations of such structures are commonly on the local soils and rocks, particularly in the initial stages of the project development. Later, the tailings impoundment may be built by such methods as upstream construction where the foundation is on previously deposited tailings. In the first instance there needs to be an accurate and detailed assessment of the foundation conditions by specialist geotechnical staff. Such an assessment must include an examination of the seismic risk.

The conditions of the foundations for tailings dams are a vital consideration in ensuring that containment will be safe and secure for as long as possible, ideally indefinitely. Factors to be considered include ground conditions, geology, seismic activity and climate. High rainfall areas often have greater susceptibility to land slips and similar movements (Murray et al, 1996).

Seismic Risk

Some areas have a seismic history which will require a very thorough assessment of the suitability of the site for a tailings dam. In such areas, there is not only the risk of collapse of structures but also liquefaction of the tailings mass which would enable it to flow off site with possibly disastrous consequences for the community as well as the environment.

Geochemical issues

Tailings may be leached (by rainwater, groundwater or expressed pore waters) to release contaminants which may flow to the wider environment. Some tailings are required to be neutralised before deposition in order to reduce the risk of leaching, eg at Ranger uranium mine in Australia. At some locations acid tailings may be discharged to the containment but the natural alkalinity of the host rock is used as a means of neutralising acid leachate passing to the wider environment, eg at Rössing in Namibia where acid tailings are deposited in an area of limestone karst country. Some mines have also tried using the neutralising capacity of gangue minerals in tailings to counteract acidity in tailings liquor or other mine wastes. At the Mount Lyell copper mine in Tasmania the neutralising capacity of the alkaline tailings is used to reduce the acidity of the mine drainage water and improve the quality of the tailings dam discharge water.

Properties of tailings

The physical and chemical characteristics of the tailings must be examined to see if they present any special problems which will require particular management strategies to be employed. For example, are the tailings reactive, that is do they contain chemicals which will continue to react and so provide a risk to the environment? The classic example would be sulfide rich tailings and the associated risks of acid rock drainage developing with all the attendant problems of acidity and heavy metal contamination. There may also be specific chemicals released from the ore during treatment but not recovered in processing, or processing residues which remain mobile after tailings deposition. Many of these issues and management options are explained in the BPEM Booklet "*Managing Sulphidic Mine Wastes and Acid Drainage*" (Environment Australia, 1997).

In Tasmania the Renison Bell mine has been undertaking studies designed at reducing the risk of reactive sulfide rich tailings releasing seepage contaminated with acid and heavy metals. The significant conclusion is that the cover for the tailings consists of another form of tailings from the same process plant, and water; thus providing a neat disposal method as well as addressing the environmental concern. If the method is as successful as tests indicate, this would have to be considered an element in any future best practice assessment when disposing of reactive tailings (CSIRO, 1997).

In the case of uranium mill tailings, there are the issues of gamma radiation and radon gas emissions to be considered. Are any emanations of sufficient magnitude that intervention or special management may be required?

The physical characteristics of the tailings must also be studied. Can the material achieve a satisfactory value of settled density when deposited? Is the material free draining or relatively impermeable? Are there large quantities of fine textured materials or slimes present, does the material dry out? Does the grain size distribution of the tailings make them particularly susceptible to liquefaction or slippage during possible seismic events? All these characteristics should be examined to see if there is any significant increase in risk to the environment.

Re-use of tailings

Finally, there may be a need to consider re-processing of tailings. Whilst we have referred to tailings as waste so far, there have been many instances where the mineral content of tailings has been such that it has been economically attractive to re-process them. Examples include the recovery of gold from old gold tailings in Kalgoorlie (Normandy Mining, 1997), uranium from gold tailings in the Witwatersrand area of South Africa, and gold, copper and cobalt from the tailings at the abandoned Peko workings at Tennant Creek in Australia.

Whilst there is no denying that it is best *economic* practice to maximise returns from all mineral deposits including tailings this should not be used as justification for not employing best *environmental* practice at any stage of a tailings management program. All tailings should be managed in accordance with best environmental practice and this need not render it impossible to re-work them at a later date. Often cleaner production can be more efficient and profitable production.

Once the site selection criteria and engineering issues have been addressed, the social and community matters need to be treated with equal care and diligence.

OVERCOMING ENVIRONMENTAL CONCERNS AND OPERATIONAL CHALLENGES

A major concern to be dealt with will be the feelings of the community and affected stakeholders. Ultimately, as Jerry Ellis of BHP said recently (Ellis, 1997), mining companies have to earn their "licenses to operate" from the communities in which they work. Community consultation is an essential part of best practice. All best practice programs and assessments must include a structured and continuing program of community consultation to ensure that stakeholders are informed and have adequate opportunities to exchange information and provide feedback to the mining company (Needham & Waggitt, 1998). Environmental risks must be minimised to the greatest extent practicable. These issues must be addressed in an open manner, that is what constitutes best practice. Openness in consultation and transparency in information exchange, are the keys to successful "defusing" of community concerns about tailings disposal. Also, it is important to set up the communications network between the stakeholders at the earliest opportunity, especially since waste management planning must be incorporated into mine planning from the beginning of the project.

As the operational challenges of best practice tailings management are site specific they cannot be listed completely here. Meetings such as this one provide information on the solutions used by others to achieve best practice, and the opportunity to canvas and discuss with professional peers plans and options for individual mines and proposed mines.

CONCLUSIONS

World tailings production is of the order of 3500 million tonnes annually. The materials involved are not necessarily benign and must be managed in a responsible manner which reduces hazards and minimises all risks to the community and the environment as much as possible. It is necessary to apply the principles of best practice environmental management at every opportunity. Solutions to tailings management and disposal need to be site specific. Also a comprehensive study and consultation process must be undertaken to take into account risk assessment and mitigation procedures as well as the opinions of stakeholders. The outcomes must be taken into account in the final decision making process.

Throughout the remainder of this summit conference we can expect to hear about the latest technologies and developments in tailings management as well as case histories which will show how best practice can, and is being applied. At the end of the day our purpose is to be confident that we are in a position to say to our stakeholders

"Yes - We are doing it right!"

REFERENCES

Australian Bureau of Statistics 1998. Australia at a Glance. *Pamphlet 1309.0.* Commonwealth of Australia, Canberra.

Bourke S 1997. Conditioning tailings for optimum disposal performance at Cobar, New South Wales. in Proceedings " *Innovation, operations, maintenance and rehabilitation for successful tailings management" Sydney, Australia October 1997*, International Management Resources, Sydney.

Carbon B 1995. Foreword in *Overview of Best Practice Environmental Management* part of the series *Best Practice Environmental Management in Mining* Environment Protection Agency, Canberra.

Clark GW 1989. Rabbit Lake Project - Mining and development. *Canadian Institute of Mining Bulletin*, 82, No 932. December 1989.

Cross M 1997. The application of geotechnical engineering techniques for the prevention and control of pollution. *Land Degradation & Development* Vol 8, 159-177.

CSIRO 1997. Decommissioning sulfide tailings. Interface No 19 July 1997, *CSIRO Coal and Energy Technology Newsletter*, North Ryde, NSW, Australia.

Ellis DV 1996. Regulations controlling submarine tailings disposal in the USA and Canada. in *Building International Partnerships in Environmental Management for the Minerals Industry, Proceedings of the 21st Annual Environmental Workshop, Newcastle 14-18 October 1996*, Minerals Council of Australia, Canberra.

Ellis J 1997. Meeting the Challenges. *Groundwork* No 1 Vol 1 Australian Minerals & Energy Environment Foundation, Melbourne.

Environment Australia 1995. *Tailings Containment* part of the series *Best Practice Environmental Management in Mining*, Environment Australia, Department of the Environment, Canberra.

Environment Australia 1997. *Managing Sulphidic Mine Wastes and Acid Drainage*, part of the series *Best Practice Environmental Management in Mining*, Environment Australia, Canberra.

Hallman M 1998. Risk assessment of tailings containment. *Mining Environmental Management*, Vol.6, No1, January 1998.

IAEA 1992. Current practices for the management and confinement of uranium mill tailings. *Tech Report No 335*. Vienna.

Jewell, R 1997. Seminar looks at the real cost of tailings disposal. *Landline* Minerals Council of Australia, Canberra.

Murray L, Davies M, Chin B & McLeod H 1996. Design considerations for tailings disposal in tropical high rainfall, seismically active environments, in *Proceedings of the 3rd International and 21st Annual Minerals Council of Australia Environmental Workshop, Newcastle NSW October 1996*, Minerals Council of Australia, Canberra.

Needham RS & Waggitt PW 1998. Creating transparency: Stakeholder involvement in environmental management of the Northern Territory uranium mines. in *Proceedings of the 2nd Australian Uranium Summit, Adelaide 11-12 February, 1998*. AIC Conferences, Sydney.

Normandy Mining 1997. Kaltails - Fact Sheet, August 1997. Normandy Mining, Adelaide.

OSS 1979. Supervising Scientist Annual Report 1978-79. Australian Government Printing Service , Canberra.

Phillips J 1997. International Dam Standards, in "*Proceedings of the International Workshop on Managing the Risks of Tailings Disposal, Stockholm, Sweden, 22-23 May 1997*". UNEP, Paris.

Robinsky EI 1979. Tailing disposal by the thickened discharge method for improved economy and environmental control in *Tailing Disposal Today* ed GO Argall Jr. *Proceedings of the Second International Tailing Symposium, Denver CO May 1978*. Miller Freeman San Francisco

Robinson J 1997. Assessment of central thickened discharge operations at Mount Keith. in Proceedings "*Innovation, Operations, maintenance and rehabilitation for successful tailings management*" *Sydney, Australia. October 1997*, International Management Resources, Sydney

UMTRA 1996. Uranium Mill Tailings Remedial Action Project - *Fiscal Year 1996 Annual Report to Stakeholders*. US Department of Energy, Washington DC.

UNEP 1996. Environmental and Safety Incidents concerning Tailings dams at Mines; Report for United Nations Environment Program, Paris.

Vick SG 1996. Failure of the Omai tailings dam. *Geotechnical News*, September 1996.

Waggitt PW 1994. A review of worldwide practices for disposal of uranium mill tailings. *Technical Memorandum 48, Supervising Scientist for the Alligator Rivers Region*, AGPS, Canberra.

A Case Study of Mine Development in the Kakadu Region

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A case study of mine development in the Kakadu region

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ABSTRACT: Uranium mining is usually accompanied by controversy. Even more controversy surrounds uranium mining in Australia, where the country's most important uranium province lies in a region recognised internationally through World Heritage Listing - the Kakadu National Park. Special measures have been put in place which have allowed profitable uranium mining to co-exist without significantly compromising the region's outstanding natural values. The special measures involve two layers of government involvement - one (at the state level) to implement regulation and ensure compliance with health and environmental standards; and the other (at the federal level) to oversee the regulatory system, promote best practice in environmental management and continual improvement, facilitate full disclosure of information, and report to parliament and the public. This paper describes the main issues which have arisen in the region, and presents a case study describing regulatory requirements, organisational arrangements, and outcomes.

INTRODUCTION

Governments in democratic societies such as Australia have the often difficult task of setting policies which are technically sound, and which take account of the potentially diametrically opposed views of sections of their constituencies. Differences in the value systems of stakeholders can render consensus an almost unachievable goal by setting a multi-dimensional negotiating table upon which lie a plethora of different bargaining chips. This is particularly relevant where the two competing ideals are economic development and environmental and cultural protection. Add the controversy associated with uranium mining in a unique pristine wilderness environment, and the issue of land rights for indigenous people to the equation, and a satisfactory result becomes more difficult to achieve.

This is the position in which the Australian government found itself in the late 1970s when the Ranger uranium mine proposal was considered. The mine opponents forecast contamination and degradation of the natural environment, and severe health and cultural consequences for the local Aboriginal people. The mine proponents promised extensive environmental protection systems, large economic returns for the nation, and employment opportunities and infrastructure benefits for the indigenous population. In response, the Australian Government initiated the Ranger Uranium Environmental Inquiry (RUEI), to gather information from all stakeholders, assess the likely environmental and social consequences of uranium mining in the Alligator Rivers Region, and make recommendations to the government. The system now in place in the Alligator Rivers Region has evolved over the last 17 years following the adoption of the bulk of the recommendations of the RUEI. Today, the Ranger uranium mine, on a lease surrounded by the World Heritage Listed Kakadu National Park, produces about 4000 tonnes of U_3O_8 annually.

THE ENVIRONMENTAL REVIEW SYSTEM

The system involves two main steps: environmental performance audits, and stakeholder consultation. These operate on a six month cycle, reflecting the dynamics of the activity, and the extreme pressures that the wet-dry tropical climate can impose upon environmental management at the mine (in particular, water management and disposal of excess water). These processes, which are lead by the Australian federal Government (the "Commonwealth"), complement the day to day regulation of mine activities undertaken by the Northern Territory government.

The key features of the system are shown in Figure 1. Important underlying principles are:

- there are no surprises or no secrets

- the focus is on outcomes rather than process
- continual improvement is encouraged by a shared problem-solving approach which is kept apart from regulatory, compliance-focused processes
- as far as possible, all relevant data are in the public domain
- the process is independently chaired
- key stakeholders are always consulted on major issues
- detailed scrutiny is expected from the broad stakeholder group
- the processes are transparent, predetermined, and frequent.

AUDIT AND CONSULTATION

The audit process

Audits of the mine are undertaken every six months. Termed "environmental performance reviews" they focus on measuring outcomes rather than process, and are not designed to operate as a regulatory compliance tool. Areas of performance which do not meet the reasonable expectations of the broad stakeholder group are examined to determine possible methods of achieving improved performance, and are commonly referred to working groups to evaluate options in terms of effectiveness, cost, and acceptability. Non-compliance issues may be exposed and are reported upon, but disciplinary action is pursued through the normal regulatory framework which provides a "safety net" of minimum acceptable performance to the environmental performance review process.

A five-year forward plan of audit focal issues is developed and available for adjustment by the broad stakeholder group. The audit protocol is in the form of a questionnaire which is provided to the company at least two weeks before the scheduled audit week. After two years of undergoing this audit process, Energy Resources of Australia (the operators of the Ranger uranium mine), began to prepare fully documented responses to the questionnaire which have considerably assisted in the detail and efficiency of the process.

Each item in the questionnaire is assessed as acceptable, unacceptable, or requiring further work. A scoring system, of for example a mark out of ten, is avoided, because this always implies that for any score of less than 10/10, there is a significant degree of under-performance and hence impact on or risk to the environment. Following the audit interview, a site inspection is made to examine areas of particular interest, including those where poor performance has been indicated.

A summary report of the review is prepared and signed by the principals of organisations participating in the review team. The outcomes are therefore agreed before the results of the review process are presented to the stakeholder consultative group.

The consultative process

The stakeholder group, the Alligator Rivers Region Advisory Committee (ARRAC), meets in the same week of the environmental performance review, and is presented with copies of the audit assessment, and the summary report. ARRAC is made up of representatives of Aboriginal groups, environmental groups, unions, local government, and federal and territory departments and agencies of resources, health and environment. The stakeholder groups are approved by the Minister for the Environment, and the groups are free to select their representatives.

Evaluation

The performance review approach to environmental audit has engendered a more harmonious working relationship with the company. This has resulted from a mutual understanding that the intent is to identify areas where improvement is warranted to meet government and community expectations which exceed regulatory requirements, and that the response is one of shared commitment to problem solving rather than apportioning blame. The success of the procedure relies heavily on trust between the parties.

The scope of the audit goes well beyond regulatory considerations, and so regulatory sanctions generally cannot be called upon in the case of this trust-based relationship breaking down. However, the sensitivity of the mining companies to negative perceptions in the community and government over uranium mining/national parks/Aboriginal issues, and the effectiveness of the stakeholder group as a conduit to expose controversial issues to community groups and government agencies, have to date guaranteed positive mining company participation in the performance review process.

ORGANISATION, ADMINISTRATION AND LEGISLATION

Australia consists of states and territories federated under the Australian Commonwealth Government. Each state and territory has independently enacted legislation to regulate the mining industry, and has established government agencies or departments to administer and enforce that legislation. The environmental oversight role assumed by the Australian Commonwealth Government in the Alligator Rivers Region represents a much greater level of involvement at this level than exists in other areas.

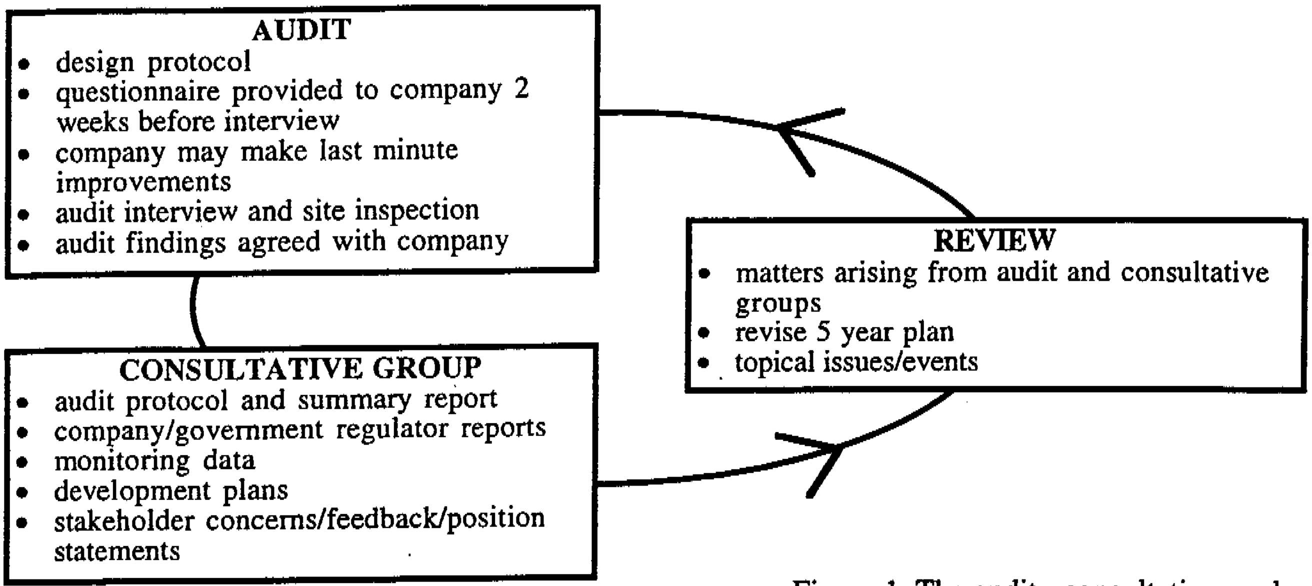

Figure 1. The audit - consultation cycle

Inter-government interaction

The Commonwealth Supervising Scientist supervises the implementation of requirements under applicable law, which includes the laws of the Northern Territory. To reduce duplication of effort, and maximise the level of environmental protection afforded by government scrutiny, formal Working Arrangements stipulate how the governments interact in discharging their obligations, and clearly delineate the responsibility for particular tasks. Cooperation and communication between governments underpin the Working Arrangements. For example, the Northern Territory Government agrees to consult with and have regard to the views of the Supervising Scientist prior to granting licences, permits or other legal instruments related to uranium mining in the Alligator Rivers Region. The partitioning of responsibility for particular functions is based on the Supervising Scientist's emphasis on environmental outcomes rather than routine regulation. The Working Arrangements have facilitated a more efficient regulatory regime and a good working relationship between the Northern Territory regulators, the Supervising Scientist and the mine operators.

Legislative framework

The operations at the Ranger uranium mine are subject to Commonwealth and Northern Territory legislation. Established in this legislation are the Commonwealth Environmental Requirements (ERs), a set of 45 conditions with which the operator of the mine must comply. Defined within the ERs is the concept of Best Practicable Technology (BPT), the method which is the most protective of the environment, taking account of environmental protection levels achieved at other uranium mines, the age and effectiveness of existing plant and equipment, and the cost of implementing new methods or installing new equipment. It may be likened to a cost-benefit analysis.

Whereas the ERs represent conditions imposed on the operator by the Commonwealth, the Northern Territory Government administers a comprehensive set of operational criteria called the Ranger General Authorisation (RGA). The RGA covers all aspects of mine operation at a level of detail appropriate to regulation, and is consistent with the more general Commonwealth Environmental Requirements.

The administrative framework

Apart from the Alligator Rivers Region Advisory Committee, there is also the Alligator Rivers Region Technical Committee, which reviews and makes recommendations in regard to the environmental research programs of the Supervising Scientist; and the Ranger Minesite Technical Committee, which is made up of technical experts representing key stakeholder groups, and develops solutions to topical environmental problems which arise from time to time or which are identified through the audit process. Figure 2 describes the administrative and legislative framework within which environmental protection measures in the Alligator Rivers Region operate.

ENVIRONMENTAL ISSUES

The operation of a uranium mine and mill in a region which is World Heritage Listed, subject to the seasonal extremes in rainfall typical of monsoonal climates, and which represents forty thousand years of habitation by the Aboriginal people, provides many environmental challenges. The public perception of the radiological hazards associated uranium mines, although much exaggerated, has ensured continuous high levels of public interest in this mining operation.

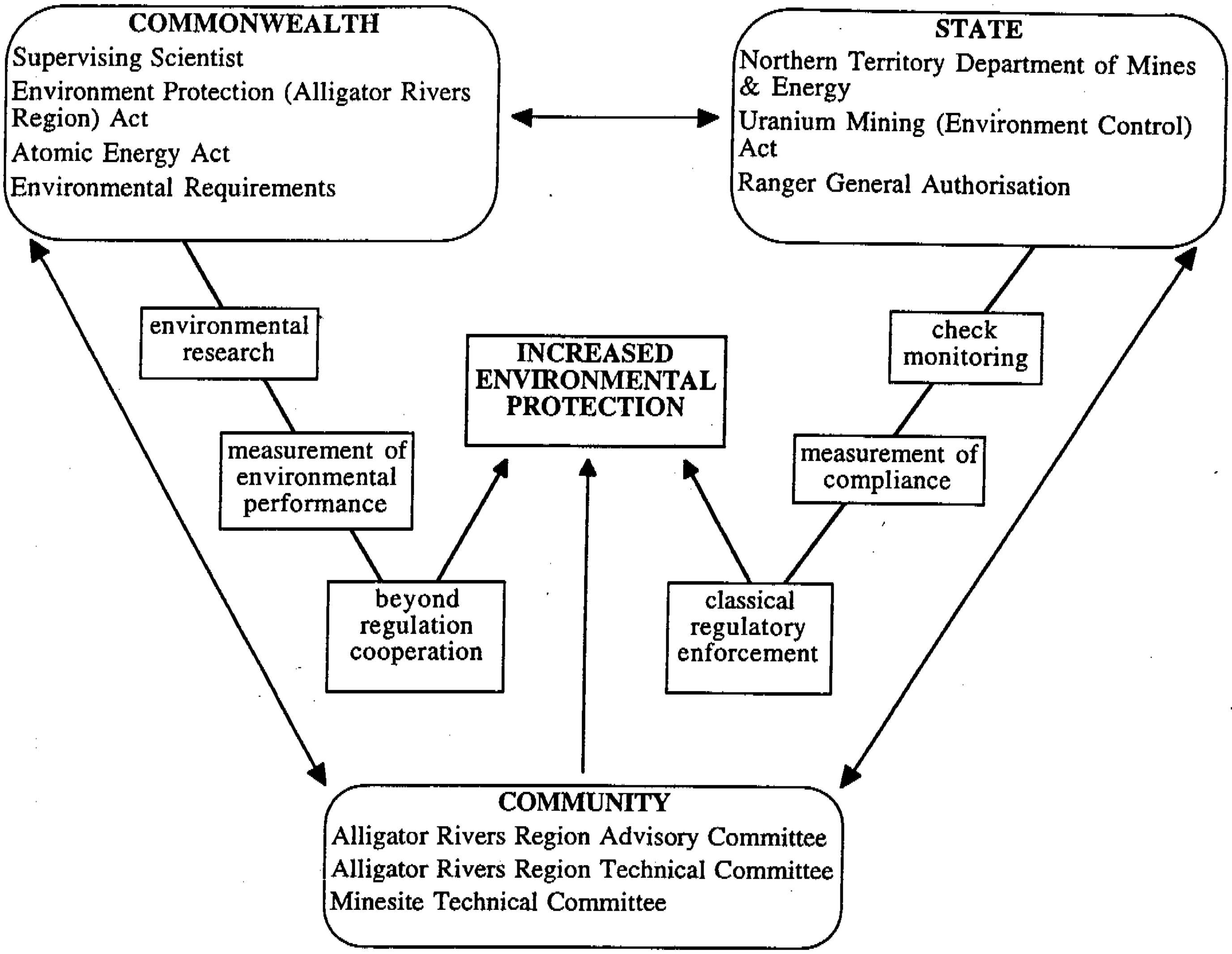

Figure 2. The administrative and legislative structure

Water management

The water management system in place at Ranger is probably the most critical component of the environmental protection regime. Unlike mines in arid regions where the primary concern is water conservation, the water management issue at the Ranger uranium mine is the collection, containment and disposal of large volumes of contaminated water in a manner which does not adversely effect the surrounding environment.

Water collected on the site is classified into three categories depending on the area it is collected from and the materials it has contacted. Thus the three categories reflect different water qualities. "Non-Restricted Release Zone" water includes rainwater run-off from areas where there are no stockpiles or uranium processing plant and no disturbed ground. This includes about 250 hectares of native bush, and regions which have been disturbed for the construction of roads and the like, but in which there are no mining or processing activities. This water is not contaminated, meets drinking water standards, and is discharged into local waterways during the wet season.

Rainfall run-off from ore stockpiles and the process plant contains very low concentrations of dissolved uranium and other contaminants is termed "Restricted Release Zone" water (RRZ). This water is collected and disposed of using a number of methods including evaporation, watering of lawns, and dust control. Research is continuing on the use of wetland filters to reduce contaminants in the RRZ water so that it may be disposed of by flood or spray irrigation without causing significant environmental impact. Whilst RRZ water may, under law, be released to the creek system subject to strict environmental criteria related to contaminant concentrations and creek flow rates, this disposal option has never been used owing to the concern of the Aboriginal people living downstream.

The third part of the system is a closed circuit comprising water in the tailings dam, uranium processing plant, and run-off from the sulphur stockpiles, mine workshops and vehicle wash-down areas. This water is recycled through the processing plant and lost through evaporation from the tailings dam in the Dry season.

Tailings disposal

For the first 16 years at Ranger, tailings were deposited into a one square kilometre tailings dam. The dam, which is built to standards applicable to water storage structures, is now effectively full. Mining of the first of two orebodies to be extracted was by then complete, and the tailings are now being deposited into the mined out pit. The Environmental Requirements state that all tailings must be returned to mine pits unless the Supervising Scientist is convinced that another disposal option will be at least as protective of the environment. Hence, the operator will be required to relocate all the tailings currently stored in the tailings dam to the pit at the end of the mine's life, unless research on the in-situ rehabilitation (ie capping) of the tailings in the tailings dam clearly demonstrates that this option is as protective of the environment as below grade disposal.

Once full and sufficiently de-watered, the pit will be capped using a geotextile and a few metres of waste rock, and will be revegetated with native species. Radon emanation will be reduced to levels where the post rehabilitation critical group receives radiation doses much less than one milli Sievert above the pre-mining radiation background dose. The topography of the repository will be sculptured to minimise erosion and to resemble the surrounding landforms.

Mine rehabilitation

The goals for minesite rehabilitation applicable to the Ranger mine are based on the anticipated post-mining use of the area. The lease will be incorporated into the Kakadu National Park, requiring that it be restored to a state consistent with the surrounding environment, suitable for occasional occupancy by the traditional owners, and amenable to recreational use by park visitors. In this respect, it differs from American uranium mines or mills which place overriding emphasis on the reduction of radon emanation due to the permanently occupied communities which typically surround the sites.

The operator is required to undertake progressive rehabilitation of areas of the minesite wherever possible. This has involved revegetation and contouring but operational constraints have allowed for little ongoing rehabilitation work.

Social impacts

There can be no doubt that the mining operation has had indirect deleterious social impacts on the local Aboriginal population. Aboriginal people commonly have difficulty integrating their own values and social system with encroaching European equivalents. The development of the mining town of Jabiru in the region, with a population of 1400, has brought with it all of the problems encountered elsewhere in Australia where Aboriginal and western cultures collide. One of the manifestations of many of these problems is the abuse of alcohol, which prior to the town's development, was not so readily available in such remote areas.

An Aboriginal association has received mining royalty payments from Ranger since mine commissioning, however the membership of the association has been a constant source of dispute (KRSIS, 1997). Monies received have been used for social infrastructure development, services, financial investment (eg in tourist ventures), and for individual income distribution. However, anecdotal evidence suggests that the benefits provided by these royalties, which are indisputable, have been offset somewhat by lower levels of government Aboriginal funding for the region. In competing for government support, other regions without significant resource-development income, have been allocated a larger slice of the cake (KRSIS, 1997).

Whereas the consultative mechanisms emplaced by the Supervising Scientist provide a conduit for the transmission of Aboriginal views and the consideration of Aboriginal concerns, the scope of this process does not encompass the broad spectrum of social issues on which the mining operation has impact. In July of 1997, the Kakadu Region Social Impact Study, with the task of identifying and recommending solutions to the social impacts of development in the region, including mining, delivered its reports. Its recommendations are comprehensive and beyond the scope of this paper; however, the process employed warrants discussion. Two parallel and interacting committees were established, each delivering its own report. The Aboriginal Project Committee (APC), comprising senior representatives of the Aboriginal communities of Kakadu, determined the issues and expectations of the Aboriginal people. The Study Advisory Group, comprising senior representatives of government and non-government organisations influential in decision making, interacted with the APC to transform these issues and expectations into proposed actions (KRSIS, 1997).

The Commonwealth government has broadly adopted the study's recommendations, but detailed action plans are yet to be finalised This study was the first of its type since mine development commenced almost twenty years ago, reflecting the historical emphasis of government on ecosystem rather than cultural protection. The momentum built up by the study will almost definitely result in a more strategic and substantive approach to social impact amelioration.

Ecosystem health and radiological impacts

The program of research and monitoring of the ecosystem surrounding the Ranger mine over the past seventeen years has provided an extremely large pool of information which is used to identify impacts and determine methods for increasing environmental protection. This dataset has facilitated the development of environmental measurement protocols based directly on ecosystem health, rather than the more conventional chemical parameters, which may act as a surrogate. Indicator species have been identified which are sensitive to the contaminants which may be released and/or other stressors which may arise from the mining operation, and which are relatively easy to breed and maintain in laboratory conditions. The behaviour, breeding cycle and population size and health of these indicator species in ecosystems immediately downstream of the mine may then be compared with those upstream, or mine water may be added to laboratory populations to determine the level of impact which may be ascribed to the mine. The wide natural variability in these parameters endemic to the region, related mainly to the extreme contrast in seasonal rainfall, and other natural factors, necessitates careful interpretation of variations in measured parameters. Nonetheless, this direct biological monitoring has failed to reveal any significant impacts on the health of ecosystems surrounding the mine. Since mine commissioning, the Supervising Scientist has only reported one instance of unacceptable impact, where a diesel spill resulted in the death of several birds in one of the water retention ponds.

The only appreciable source of radiation dose arising from the Ranger uranium mine to inhabitants of the nearby town of Jabiru is due to the inhalation of radon progeny originating from the tailings and ore stockpiles. This dose has been estimated at approximately four percent of the applicable dose limit recommended by the International Commission on Radiological Protection. Although radiation doses to non-human biota in the surrounding region has not been the subject of continuous research, the biological monitoring program has not indicated that there is any cause for concern. In any case, effects on biota due to the toxic characteristics of mine origin contaminants would be observed well before any radiological effects.

CONCLUSION

The dual government regime of environmental regulation and oversight applied at the Ranger uranium mine has been successful in ensuring that the environmental performance of the operation meets the highest standards. During the seventeen years of the mine's operation in a region subject to the extreme meteorological conditions associated with monsoonal climates, and despite a continuous and comprehensive environmental research and monitoring program, no significant impact on the surrounding World Heritage listed Kakadu National Park has been identified. The system, which is fully transparent and in the public domain, has as its cornerstone community consultation and participation in the decision making process. This determines that the concept of continuous improvement is inherent in the regulatory regime, as community expectation, which is dynamic, sets the benchmarks rather than static legislation.

There remain many challenges in regards to the Ranger mine; maintaining parity with stakeholder expectations, which are continuously increasing the burden on environmental managers, immediately comes to mind. The ultimate fate of the tailings in the tailings dam is yet to be decided. The operators may propose that they be rehabilitated in situ rather than be relocated to mine pits. If such a proposal is brought before government for consideration, there will be many technical issues which require careful scrutiny, in addition to accounting for community perceptions and values. The shift in priority in regard to social and cultural issues may spawn a completely new component of the environmental protection program. Rehabilitation issues will come further to the fore as the mine approaches the end of its life. The system has performed well so far, and may need to evolve further to cope with issues yet to emerge. Whatever problems lie ahead, the level of community consultation will ensure that complacency is not one of them.

REFERENCES

Kakadu Region Social Impact Study 1997. *Community Action Plan - Report of the Study Advisory Group*. Canberra: Supervising Scientist.

Kakadu Region Social Impact Study 1997. *Report of the Aboriginal Project Committee*. Canberra: Supervising Scientist

Needham, R.S. 1996. A system of environmental performance assessment and reporting which serves the needs and expectations of operators, regulators and the concerned public. *Proceedings of the Academy of Science Fenner Conference on the Environment.* University of New South Wales.

Office of the Supervising Scientist 1995. *Supervising Scientist Annual Report.* Canberra: Australian Government Publishing Service.

Introduction of Modern Environmental Management and Regulation at Christmas Island Phosphates, Australia

Peter Waggitt

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Introduction of modern environmental management and regulation at Christmas Island Phosphates, Australia

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ABSTRACT: Christmas Island is the peak of a submarine mountain in the Indian Ocean, 1400 km west of Australia and 1300 km south of Singapore. An Australian external territory, the island has been mined for its natural phosphate deposits since the mid 1890's. After a succession of operators, mining closed down in 1987 but operations restarted in 1990 by a company which is owned by most of its own workforce.

Although there had been some environmental considerations in the 1960-70 period, in relation to endangered bird species, environmental management of operations was not consistent with best practice. In 1995 the Supervising Scientist Group was asked to assume the role of the environmental regulator for the Territory, and specifically progress the upgrade of environmental management performance of the mining operation. Through a process of environmental auditing, performance reviews and best practice awareness training the mine has made substantial progress in the areas of dust control and environmental management planning and has reduced the environmental impact of operations. This paper describes the process of improvement and the increase in quality control in environmental management from the initial preliminary inspections and audits, through reviews and ongoing public consultation to the present improved situation. Details of the specific improvements achieved are given and discussed in detail.

INTRODUCTION

In the past mining has been an industry with a poor public image. Scenes from around the world of adverse environmental impact from mining are frequently brought to mind, the moonscape of Queenstown in Tasmania, the abandoned lands of the Pennsylvania coalfields and oceanic islands dug up for their phosphate deposits leaving stark landscapes of limestone pinnacles behind. Internationally the modern mining industry is working hard to improve its image and to show the community that it is capable of operating more in harmony with the environment than in the past (Hore-Lacey, 1992; EPA, 1995). It has been suggested by some people that today mining companies effectively have to earn the right to operate from the communities in which they are situated (Ellis, 1997).

This paper describes how a mining operation on Christmas Island, an Australian Territory in the Indian Ocean, that had a long history of limited environmental management has been resurrected and a modern regime of environmental regulation and management introduced to ensure that the operations are in accord with contemporary standards.

BACKGROUND

Christmas Island is the tip of a submarine mountain rising approximately 5000 metres from the sea bed and 340 metres above sea level. An Australian territory, the island is approximately 1400 km west of the Australian Coast and 365 km south of Jakarta (Figure 1).

The island has an area of about 135 sq km of which about two thirds is a National Park A 50 metre wide Marine Park extends from the low water mark around most of the island's coast (Gray, 1981). There a few beaches and no true port on the island. The coastline is mainly limestone cliffs between 15 and 25 metres tall (Woodmore, 1996). The land rises in a series of three terraces to a central plateau at an elevation of between 150 and 360 metres. Managing a mining operation within "windows" surrounded by a national park presents some unique management issues (Needham et al, 1996). The Park is primarily a rainforest habitat and home to some unusual fauna and flora. Most notable are the famous migratory red land crabs and several endemic bird species including the threatened Abbot's Booby.

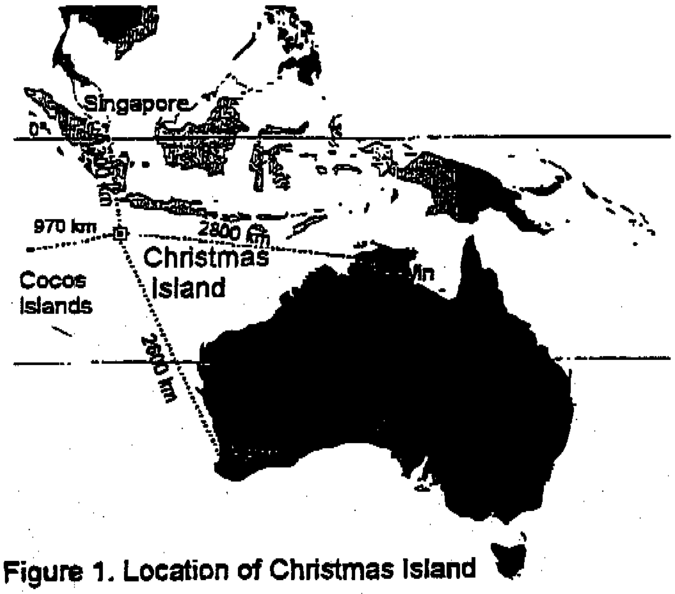

Figure 1. Location of Christmas Island
adapted from Auslig Map 94/068

MINING HISTORY

The phosphate deposits on the island are thought to be a marine sediment (Woodmore, 1996). They were first explored in 1887 with commercial shipments beginning in 1895. The mine operated almost continuously until 1987. Ownership of the company was private until 1948 when it was sold to the Governments of Australia and New Zealand. In these operations, topsoil and low grade phosphate materials were moved into stockpiles to allow mining of the very high grade deposits at depth, between the limestone pinnacles. Processing consisted of simple drying and screening before shipping out in bulk.

In 1987 the mining operation was shut down when the Australian Government decided to place the Phosphate Mining Company of Christmas Island into liquidation. The local community, through the Union of Christmas Island Workers, was concerned that the island's major industry was ending and fought for the operation to be re-opened. This was achieved in 1990 when the employee-owned company now known as Phosphate Resources Limited (PRL) began trading, using the name Christmas Island Phosphates (CIP).

PRL has about 20 sq km of lease area scattered across most parts of the island and mostly on excisions from the National Park. The primary operation is recovery of second grade material from the old stockpiles. In addition, there is a small amount of in-situ mining for high grade phosphate. PRL also recover dust from the product stream at the dryers and sell this as a bagged product into South East Asian markets. Although the initial PRL operation was for a 10 year period, a new lease was signed in 1997 which will allow operations to continue until at least 2014 (CIP, 1996). Production has increased from less than 64 000 tonnes in 1990-91 (56 480t of rock and 7 129t of bagged dust) to a total of 421 906 tonnes which were shipped in 1994-95 (Phosphate Resources NL, 1995).

INTRODUCTION OF REGULATION

When mining recommenced in 1990 there was no effective legislation to control any aspect of the operations. The same was true for many aspects of everyday life on the island and so the Commonwealth Government decided to adopt all the existing Western Australian legislation and enact it as Commonwealth law. This was achieved through the introduction of the Christmas Island Act of 1992.

The Commonwealth had only a limited administrative capacity on the Island and so application and enforcement of laws was a progressive, rather than instant process. Of particular interest to the mining operation were the Mining Act and the Environmental Protection Act. It was decided that carriage of the occupational health and safety issues, from the Mining Act, would be contracted out to the Western Australian Department of Minerals and Energy (WADME) under a service delivery agreement. PRL was given a grace period of two years to bring the operation up to the required standard in respect of those parts of the Mining Act administered by WADME. Protection of the environment was covered by legislation but there was no agent to enforce the Environmental Protection Act. Much of the mine's equipment dated from an era when attitudes towards protecting the environment were very different to the situation we have today. As the new operation increased production so did the potential for adverse environmental impact.

As time went on, there were other business developments on the Island, especially an increase in tourism. At the beginning of 1995 the expanding community on the island began to notice that increasing mining activity was associated with various impacts and complaints started to arrive in the office of the Commonwealth Minister for the Environment. With much of the mine's infrastructure old and worn out and having little real understanding of modern environmental management, PRL tried to devise a plan to reduce environmental impacts, especially dust related impacts. As a first step to resolving these issues the management, waste management, energy conservation, and heritage. Other issues such as the protection of native flora and fauna, including rehabilitation of new and old minefields are also under review.

A comprehensive upgrading of the fuel infrastructure is underway with the installation new pipelines, refurbishment of fuel storage tanks, and the implementation of improved delivery arrangements for both diesel and fuel oils. All fuel is off-loaded via a floating pipeline and the land terminal is included in the upgrade program. A complete series of oil handling policies and operational manuals have been drawn up by a specialist consultant.

REHABILITATION

A further part of the environmental improvement program relates to the rehabilitation of old mine workings. Parks Australia have managed the Christmas Island Rainforest Rehabilitation Program (CIRRP) in conjunction with PRL since 1989 (ANCA, 1996). The program concentrates on rehabilitating areas which are nesting grounds for the endangered bird species, Abbot's Booby.

PRL pays a rehabilitation levy of $1.50 per tonne of bulk rock phosphate shipped from the Island. Parks Australia is currently rehabilitating approximately 10-15 hectares per year with PRL as the earthmoving contractor. Parks Australia operates a nursery which produces the necessary seedlings of native tree species for use in the replanting program. In the present system of rehabilitation of old minefields, extensive earthworks are required in order to prepare the sites prior to planting. 'C' grade material, a sub-commercial grade of phosphate containing between 5-18% P_2O_5, is recovered from stockpiles and is used for the earthworks.

Limestone pinnacles are leveled by bulldozer as much as possible and then "C" grade is dumped to a depth of approximately 1 metre. The surface is left as a series of swales and dales to reduce erosion and runoff and aid rainwater infiltration. Alternate rows are planted with an introduced species of cover tree, the Japanese Cherry (*Mungia spp*) which provides shade for the intervening rows of seedlings of native rainforest species. Macaranga is also being used as an alternate shade species. The rainforest plants eventually grow through the shade cover and out compete the shade-intolerant supporting species. In the interim the Japanese Cherry provides a valuable food source for fruit eating native fauna until the native species have begun to fruit (P. Bridgewater, pers.com.).

With the introduction of the Western Australian mining legislation, there will now be a requirement for PRL to rehabilitate the areas in which it is currently mining. As a result, the present program is being reviewed in order to provide for a more integrated approach to rehabilitation in both old and presently mined areas and to improve rehabilitation success. The EO will probably become involved in the assessment of the rehabilitation works under the proposed new administration process.

CONCLUSIONS

Modern environmental management practices have been successfully introduced on Christmas Island. Progress already made by the phosphate mining company has substantially reduced dust emissions at the ship loading facility and measures and plans are in place which will reduce dust emissions across the entire operation including the wharf storage areas, the conveyors and the dryers. Implementation of the new EMP has been the reason for many of the other environmental improvements seen in the mine's operations. The prognosis is good. Within two years the objective to have a modern mining operation with high environmental standards should be well on the way to being fulfilled. The story so far shows how regulators and mine operators can work together to achieve improved environmental management in a non-adversarial way.

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REFERENCES

Australian Nature Conservation Agency (1996) Annual Report 1995-96, Australian Government Printing Service, Canberra.

Australian Nature Conservation Agency (1994 a) Christmas Island National Park-Plan of Management, Colemans Printing, Darwin.

Australian Nature Conservation Agency (1994 b) Corporate Plan 1994-96, Goanna Print Pty Ltd, Canberra.

Brown G (1995) Preliminary Environmental Audit of the Indian Ocean Territories. Report to the Territories Office, Department of Environment Sport and Territories. Canberra. (unpublished).

Christmas Island Phosphates (1996) Dust Removal Project: Project Presentation Folder, (unpublished).

Environment Protection Agency (1995) *Overview of Best Environmental Management in Mining*, module in the series *Best Practice Environmental Management in Mining*, Commonwealth of Australia, Canberra.

Gray HS (1981) *Christmas Island Naturally*, Scott Four Colour Print.

Hore-Lacey I (1992) *Mining and the Environment*, Newstyle Printing, Adelaide.

Needham R S (1995) Best Practice Environmental Management in Mining in *Proceedings of the 20th Environmental Workshop, Darwin NT, 2-6 October 1995.* Minerals Council of Australia, Canberra.

Needham RS, Nicoletti-Lewins C, Waggitt PW & McBride TP (1996a) Mining and National Parks. in proceedings *Mining and the Environment Workshop*, Jakarta, 9-10 June 1996. (unpublished), Jakarta.

Needham RS (1996b) A system of environmental performance assessment and reporting which serves the needs and expectations of operators, regulators and the concerned public, in proceedings *Academy of Science, Fenner Conference on the Environment*. University of New South Wales.

OSS (1995) Supervising Scientist Annual Report. Australian Government Printing Service, Canberra.

OSS (1996,1997) Environmental Performance Reviews of Phosphate Resources Limited #1,#2 and #3. OSS Darwin, Christmas Island and Canberra. (unpublished).

Phosphate Resources NL (1995) Annual Report 1994-1995. (unpublished).

PRL (1996a) Christmas Island Phosphates Environmental Management Plan. Company Report. (unpublished).

PRL (1996b) Christmas Island Phosphates Dust Removal Plan. Company Report. (Unpublished).

Woodmore FP (1996) *Christmas Island Explorer's Guide*. Lone Island Publications, Christmas Island, Australia.

The Decommissioning and Rehabilitation of the Nabarlek Uranium Mine, Northern Australia

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The decommissioning and rehabilitation of the Nabarlek uranium mine, northern Australia

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ABSTRACT: The Nabarlek uranium mine is located in the aboriginal area of West Arnhem Land[1] in monsoonal Northern Australia and operated from 1979 until 1989. Decommissioning was carried out in 1994-95. Several features of the Nabarlek story are considered unique and offer interesting approaches for consideration in other mine rehabilitation programs.

The Nabarlek ore body was mined in a single campaign during the dry season of 1979. Ore was stockpiled on a specially prepared site while the mill was built. Milling took approximately ten years.

The final decommissioning and rehabilitation program was developed from the outset of operations as a series of specific component plans. Throughout the life of the mine these components were reviewed at intervals and updated to take account of changes in mine development as well as incorporating the results of site specific research and new technology. The final domed cover over the pit was shaped on the basis of geomorphological research.

The rehabilitation objective, as agreed with the aboriginal Traditional Owners and the supervising authorities, was to establish a landscape that matched as closely as possible the surrounding areas and would permit traditional hunting and gathering activities to be pursued.

The rehabilitation of the site is progressing well and on-going monitoring is in train to establish when the site can be returned to the custody of the aboriginal Traditional Owners.

INTRODUCTION AND BACKGROUND

Nabarlek uranium mine is located in the Aboriginal lands of West Arnhem Land in Northern Australia, about 300 km east of the city of Darwin (Figure 1). The climate of the area is wet-dry tropics with an average annual rainfall of about 1450 mm, which falls between October and April. Storm intensities can be extreme and temperatures are high all year round. Annual pan evaporation averages about 2500 mm.

The natural vegetation is a dry sclerophyll forest dominated by *Eucalyptus* and *Acacia* species with *Pandanus* and *Melaleuca* in low lying or poorly drained areas.

The mill operated from 1979 until 1989 when it was "mothballed" in anticipation of the discovery of a further orebody in the vicinity which would allow the mill to re-open. This was in response to the "three mines uranium policy" of the Commonwealth Government of the day which forbade the opening of any new uranium mines.

Decommissioning was undertaken through the wet season of 1994-95. Rehabilitation and earth works were carried out in the 1995 dry season with seeding taking place just before the onset of the 1995-96 wet season. Several features of the Nabarlek story are unique, offering interesting approaches for consideration in other mine rehabilitation programs.

HISTORY OF OPERATIONS

The Nabarlek ore body was discovered in May 1970 by Queensland Mines Limited (QML), a small uranium exploration company. The deposit was identified as a small, high grade pod, and was excavated by QML between April and October

[1] Arnhem Land is an area where indigenous Australians are able to live a traditional life style with some degree of autonomy. They are referred to as the Traditional Owners of the land and control development through Land Councils

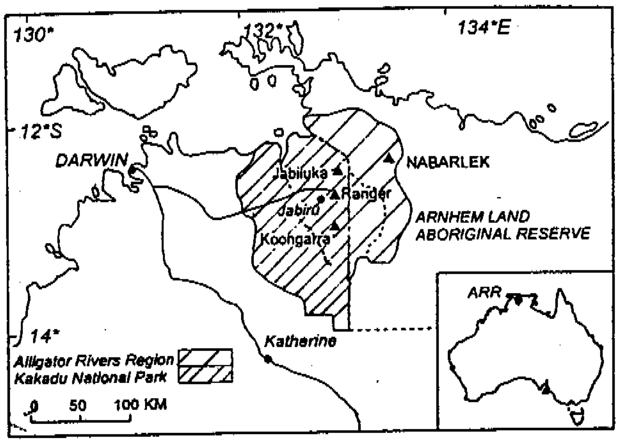

Figure 1 Location Map

1979, within the one dry season (UIC, 1996). Ore reserves were estimated to be 606700 tonnes containing approximately 12 000 tonnes of U_3O_8 at an average grade of about 2%. Waste rock totalled about 2.3 million tonnes. The ore was stockpiled on a custom-built pad with a 400 mm thick ferricrete and gunnite (sprayed-on sand-cement mortar) cover (OSS, 1981). The cover was to reduce radon emanation and prevent erosion by wind and leaching losses through percolating water. The runoff from the whole pad area was retained in a pond and then evaporated during the dry season.

The processing plant was built following mining; trial commissioning began in May 1980 with commercial production being licensed on 22 August 1980. The initial process used pyrolusite as the oxidising agent in the leach circuit, but by late 1980 the plant had been modified to use Caro's Acid (a mixture of hydrogen peroxide and sulphuric acid), which obviated the need for manganese in the operation with positive environmental benefits. By the time the mill ceased full time operations in June 1988, total production totalled 10857.6 tonnes of U_3O_8 (OSS, 1988).

A significant feature of the operation was the return of tailings directly to the mined-out pit. It is still believed to be a unique occurrence in uranium mining in the world. This was in accordance with the Environmental Requirements (ER) of the Federal Government of the Commonwealth of Australia, a set of conditions which were put in place to ensure that the operation afforded the environment the highest possible level of protection. The ER were drawn up by the Governments of the Commonwealth and the Northern Territory and the Northern Land Council, acting on behalf of the Aboriginal Traditional Owners of the land.

The ER covered all manner of environmental issues, especially water management, tailings disposal, staff training and environmental impact minimisation. The Commonwealth Government's Office of the Supervising Scientist (OSS) provided environmental oversight of the operation, and the Northern Territory Government's Department of Mines and Energy (DME) regulated the operation. OSS promoted adoption of Best Practice Environmental Management and with DME contributed to technical discussions to determine solutions to environmental management issues. In particular, the disposal of excess water from the mine site during the decommissioning was achieved using management techniques recommended by OSS and DME staff.

OPERATIONS

The planning of the decommissioning and rehabilitation began with the operation of the mine. From a very early stage there was a decommissioning engineer on the staff who had responsibility for not only developing the necessary plans but also updating them to take account of changes in operations and technology. The documentation for the decommissioning was essentially a three tier system. In the first tier the general principles were set out in the deeds and agreements with the mining company, the Aboriginal traditional landowners and the Commonwealth and Northern Territory governments. In the second tier was a set of broad based plans which determined the general pattern of works and specifications for a variety of activities, including earth moving, water management, revegetation and erosion control works. The third tier was detailed specifications and contract documents to be used for each stage of the works program. The overall program was costed from the second tier documentation for the purposes of setting the rehabilitation bond.

SITE DECOMMISSIONING AND REHABILITATION

Site cleanup

The first operations in site decommissioning were the running down of the mill and cleaning out of pipes etc as a mothballing operation. This work was carried out by the mine staff and was intended to leave the mill ready to be reactivated should a further deposit become available. This work was completed by the end of 1989.

The mining company attempted to sell the mill facility on an "as is where is" basis. The effort was unsuccessful and the company was obliged to decommission the site itself.

The main task of decommissioning the site began early in December 1994, at the end of the dry season. The successful contractor took possession of the site before the area became cut off by road for the wet season.

Once equipment was on site dismantling began. Items were thoroughly checked by a radiation safety officer at all stages of the works program. A code of practice for radiological safety had been set up by the supervising authorities and all items were checked against the appropriate criteria. As much as possible was to be salvaged for sale. Some items could not be reclaimed due to high levels of contamination or the practical problems and costs of decontamination when compared to possible re-sale value. Non-salvageable items were placed in the pit to be buried below the base of the final cover. The site work continued throughout the wet season with the workforce operating on a fly in-fly out basis.

Work was completed in the early dry season of 1995. Once the road had opened at the beginning of the dry season, the dismantled mill was transported off-site after further de-contamination checks. The mill was sold to an equipment broker for disposal.

The mine village was handed back to the Traditional Owners of the land who chose to sell the buildings to a number of contractors in 1996. The final clearance of the village site is expected to be complete by December 1997.

Tailings

Tailings deposition at Nabarlek had initially been sub-aqueous, to reduce the perceived risk of radon emanation from the tailings surface. In 1985 the company was permitted to change to a sub-aerial deposition system which allowed the beached tailings to settle at greater average densities. However, the previous system left lenses of slimes and fine materials throughout the tailings mass which were susceptible to differential settlement.

In September 1988 the tailings rehabilitation program began with the insertion of vertical "wicks" to drain the mass and aid consolidation. The first stage was to place a double thickness geotextile cover across the tailings surface once it had become dry enough for workers to walk safely across the site. A layer of graded waste rock and sand was then placed over the cover to provide a working platform. This layer was designed to be 1 metre thick but due to differential settlement in places this varied up to 3 metres. The material was dumped at the edge of the pit and pushed out over the cover by a small bulldozer. A "wave" of displaced material advanced in front of the operation and eventually became a raised area near the centre of the pit. This was also finally covered with waste rock. Once the working platform had been established the insertion of the wicks began.

A modified piling rig was used to push the wick material down into the tailings on a grid approximately 3 m by 3 m. A specially made mandrel fitted to the shaft of the rig held the wick material which was pushed to a maximum depth of 33 m. In most cases water was expressed from the wick almost immediately, indicating relief of pore water pressure at depth in the tailings. Water coming from the wicks was allowed to run to a low lying portion of the surface. This water was then pumped to an evaporation pond via the pit water clarifier. The pumping was carried out only in the dry season (Waggitt, 1989).

Water continued to run from the wicks at intervals over the following years right up to the time when the pit was being filled at the final stages of decommissioning. Each time material was deposited in the pit area the wicks were re-activated by the increased surcharge. Excess water was managed by an enhanced evaporation system which irrigated water around the edges and inside walls of the pit. This water was recirculated and no runoff was permitted to leave the pit area.

Water management

The minesite had been designed as a "no-release" operation with substantial evaporation ponds constructed to ensure that all accumulated waters could be evaporated on site with no need to discharge to the off-site environment. However, it had been calculated that the pond system might have to be operated for 2 or 3 years after the end of operations in order to clear all excess water from the site (OSS, 1986).

A trial of land application of evaporation pond water was carried out in 1984 to see if this could be used to speed up the rate of water loss from the site. The option of controlled discharge directly to the adjacent creek system was not considered to be viable at the time.

The trial involved sprinkler application of water to about 1.6 ha adjacent to the airstrip. The only change detected was slight elevation of levels of sulphate and nitrate in the ground water. As a result, in 1985 the operation was extended to an area of 10 ha. In 1986 this area was further extended to include an additional 10 ha of natural forest land. Although the initial trial had been considered successful, the extension into the forest produced adverse impacts.

By 1987 some tree deaths had been observed in the forest area and the levels of sulphate and nitrate in the ground water had increased noticeably. Investigations were put in place and it became apparent by 1988 that significant numbers of trees were either dying or showing symptoms of stress which would result in death. Attempts to ameliorate the area by applications of borewater were only moderately successful and tree deaths continued. Irrigation of evaporation pond water was discontinued.

By 1990 the area's vegetation was markedly different to surrounding areas, with many dead trees. The decision was taken to clear all dead trees to reduce the fuel load as seasonal forest fires, common in the area, were likely to be extremely hot and so have a very severe impact on the re-emerging vegetation. The area was re-seeded after the clearing and allowed to recover naturally.

By 1997 the area was showing considerable re-growth by a wide range of species, and the long term prognosis for recovery is good.

Pond management

The evaporation ponds contained waters whose quality varied considerably with the seasons. As a first step in decommissioning of the ponds the sediments were cleaned out in 1990. Clay and silt were removed from the base of all three evaporation ponds and placed in the pit for disposal. This action removed both evaporites and radionuclides and the associated risk of their washing out to the environment. Once completed this enabled the controlled release of water from the ponds in subsequent wet seasons. Ponds were allowed to overflow through channels cut in their walls. The overflow levels of the spillways ensured that any salts present were well diluted before discharge occurred. Thus the risk of damage to the environment through salt contamination was reduced to an acceptable level.

In the final stages of decommissioning the ponds were allowed to evaporate to dryness during the dry season of 1995. As the area became accessible, so earth-moving plant was able to collapse the walls into the base of the ponds; thus not only burying the materials which had been exposed to the impounded water, but also restoring the land form to an approximation of its pre-mining contour. The ponds had been built above ground but with excavated floors in some parts, hence the need for infilling. The final cover over the pond area was waste rock and soil from the stockpiles created during mine development.

SITE LAND FORMING AND REVEGETATION

Pit cover

Conventional wisdom for cover design over uranium mill tailings containments often calls for complex multi-layer designs incorporating radon barriers, erosion control layers etc. The original design at Nabarlek included a radon barrier made from clay materials. During the final design phase it was realised that the tailings would all be below the ground water table at the end of the operation, which would greatly reduce the potential for any significant radon emanations at the surface. After a series of technical discussions and modelling sessions, the supervising authorities accepted the revised design. The design had no separate radon barrier, but relied on the tailings being below ground water and approximately 13 metres below ground surface as a means of reducing radon emissions.

Land form

The final landform was designed to look like the pre-mining situation as far as was practicable. This included a low area in the vicinity of the ponds and a small hill over the pit site. The pit cover was left raised to take account of subsidence over time as the tailings consolidated, as well as to shed water. The presence of the wicks in the tailings enabled settlement to proceed very quickly in the initial stages.

The final pit land form was originally designed as shown in Figure 2: a low ridge to the south, with the majority of the cover forming a single slope to the north (Weatherhead & Dyke, 1987) Research carried out at the Environmental Research Institute of the Supervising Scientist (***eriss***) showed that erosion risks for the site could be considerably reduced by re-modelling the cover to include a small ridge running SE-NW along the centre line of the old pit area (Riley, 1994, 1995). This feature reduced slope lengths to less than 150 metres and gradients to less than 8%, values which research had shown were unlikely to lead to gully formation on areas similar to the Nabarlek site (Riley & Williams, 1991). The resultant land form is shown in Figure 3. Later modelling using the universal soil loss equation indicated that the cap would remain viable at the site for at least 10 000 years, and erosion studies for the surrounding land forms estimated the tailings would stay contained for at least 100 000 years (Riley, 1994).

The overall land surface was left covered with run-of-mine waste rock. The material was mainly schistose materials which had been observed to weather rapidly on the waste rock dump. The dump

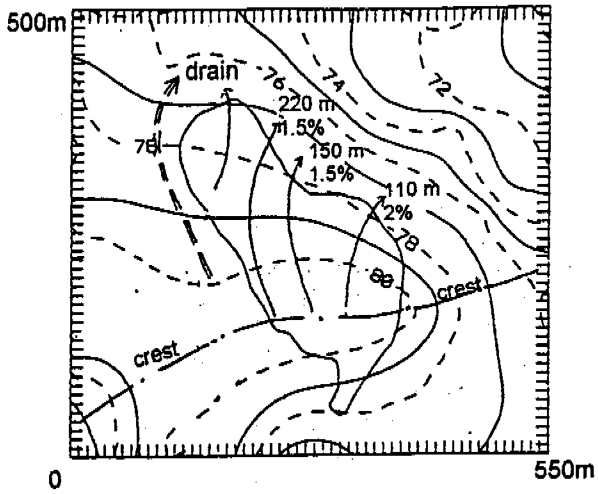

Figure 2. Nabarlek: As designed (after Riley, 1994)

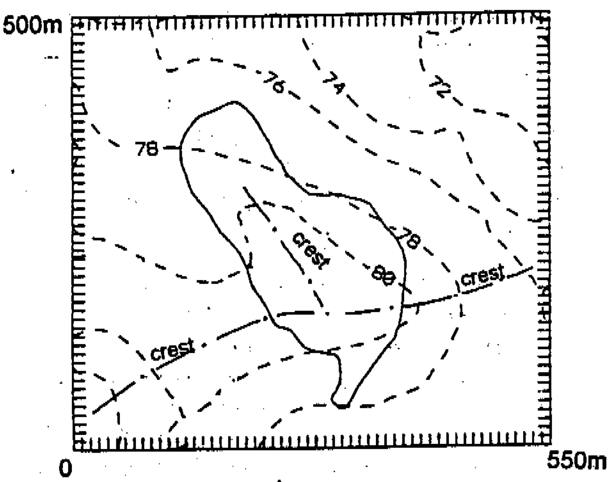

Figure 3. Nabarlek: As constructed (after Riley, 1994)

had become extensively colonised by plants during the mine life. A survey of vegetation found 124 plant species on the waste rock dump, including 40 tree species and 84 herbaceous species (Brennan & Bach, 1994). This was despite no seeding, planting or spreading of topsoil having taken place.

At the final stages a deep ripper with a single winged tine attached to a large bulldozer was used to break up any surface compaction due to construction activity over the pond areas. The ripping also assisted rainwater infiltration, and hence germination and plant establishment. Some large rocks were pulled to the surface by the ripping operation and these were piled up to provide habitats for small mammals and reptiles which would hopefully re-colonise the site (P. Bailey, pers.com).

Revegetation

As the rock had shown itself to be a good medium for plant growth it was decided to leave it as the final surface, the stockpiled soil having already been found to be of little value as a growth medium (Klessa et al, 1995). The overall intention was to leave slopes on the reconstructed surface of less than 1:25, which would aid the rapid establishment of a vegetative cover that would resist surface erosion.

During the life of the mine, research was undertaken into suitable revegetation strategies for the local conditions (Hinz, 1989). Trials with locally collected seed showed that direct seeding would be more successful than using tube stock (Queensland Mines Limited, 1990). Also, studies showed that several local seed species could not be stored and would need to be collected in the season immediately before revegetation work was to begin (Hinz, 1990).

POST CLOSURE MONITORING

Throughout the operation of the mine and mill the company was obliged to carry out a comprehensive program of environmental monitoring. This included quality of ground, pond and surface waters, radiological measurements, stack emissions, weather recording and some subjective vegetation assessments. A modified version of the program remained in place during the time the site was "mothballed". Throughout the life of the site the Northern Territory Department of Mines and Energy, the regulator of the mine, also ran a parallel check monitoring program.

Once decommissioning works began, many of the sampling sites were destroyed by earth moving etc. As a result the monitoring program was reduced in both scope and frequency of sampling. A vegetation monitoring program using fixed photographic recording points was set up. An independent ecological consultant was appointed to commence an evaluation of the success of the rehabilitation program. The opinion of the expert will be the basis for the decision that the site is reaching the objectives required by the Traditional Owners and the supervising authorities.

The Nabarlek site offers a number of unique opportunities for research and a range of studies are being carried out on the rehabilitated areas. Radon levels are being monitored by the Supervising Scientist Group for a complete year to establish what seasonal variations occur. The Northern Territory authorities are studying ground water changes in the vicinity of the pit, and some work on erosion rates around the site has been planned for the future.

FUTURE AND HANDOVER

Revegetation at the Nabarlek site appears to be proceeding well, and it is anticipated that the self-sustainability of the system will be demonstrated within ten years. Once that stage has been reached the site will be certified by the supervising authorities as meeting revegetation requirements and handed back to the Traditional Owners. The issue of very long term environmental monitoring has yet to be resolved.

CONCLUSION

The Nabarlek uranium mine and mill operated for nearly ten years with no significant adverse environmental impact to the off site environment. The tailings were returned directly to the pit in what is regarded as a unique operation. Decommissioning was planned from the first day of operations and updated frequently throughout the entire mine life, taking into account the local situation and incorporating research results as well as technology developments.

Decommissioning of the operation appears to have been successful, and revegetation is apparently proceeding well. The probability of the site returning to a condition similar topologically and ecologically to the pre-mining natural state, and allowing traditional hunter/gatherer activities by the Traditional Owners, appears high. In such circumstances mining can be seen as a temporary user of land and in tune with ideas of ecologically sustainable development.

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REFERENCES

Brennan K & Bach C 1994. A vegetation survey of the Nabarlek waste rock dump. Internal report 165, Supervising Scientist for the Alligator Rivers Region, Canberra. (unpublished).

Hinz R 1989. Revegetation and tailings disposal at Nabarlek in Richards et al (eds) *Environmental Planning in Multiple Land Use Areas, Proceedings of the 11 North Australian Mine Rehabilitation Workshop,* Darwin 11-15 June 1989.

Hinz R 1990. Seed Technology for the Northern Territory's Top End in *Proceedings of the Australian Mineral Council Environmental Workshop,* Wollongong, October 1990. AMIC, Canberra

Klessa DA, Hunt C, Brennan KG, Templeton S & leGras CAA 1995. The effects of soil storage on soil properties and the soil seed bank and its implications for the rehabilitation of Nabarlek Mine Site: Final Report September 1995. Internal report 193, Supervising Scientist for the Alligator Rivers Region, Canberra. (unpublished).

OSS 1981. *Supervising Scientist for the Alligator Rivers Region: Annual Report 1980-81.* AGPS, Canberra.

OSS 1986. *Supervising Scientist for the Alligator Rivers Region: Annual Report 1985-86.* AGPS, Canberra.

OSS 1988. *Supervising Scientist for the Alligator Rivers Region: Annual Report 1987-88.* AGPS, Canberra.

Queensland Mines Limited 1990. *Surface Preparation and Revegetation Techniques Project.* (unpublished).

Riley SJ 1994. Approaches to estimating the erosional stability of the Nabarlek tailings pit cover. in *Proceedings of the AusIMM Annual Conference 5-9 August 1994, Darwin.* AusIMM, Melbourne

Riley SJ 1995. Geomorphic estimates of the stability of a uranium mill tailings containment cover: Nabarlek, Northern Territory, Australia. *Land Degradation and Rehabilitation*, **6** 1-16

Riley SJ & Williams D 1991. Some geomorphic thresholds related to gullying, Tin Camp Creek, Arnhem Land, Northern Territory, Australia. *Malaysian J of Tropical Geography* 22(2): 133-143.

UIC 1996. *Environmental Management and Rehabilitation of the Nabarlek Uranium Mine,* Mines Paper #5, Uranium Information Centre, Melbourne.

Waggitt PW 1989. Tailings Management at Nabarlek. *Australian Science Mag* **2,** 27.

Weatherhead J & Dyke J 1987. *Surface Preparation and Revegetation Techniques for Nabarlek Project Site.* Queensland Mines Limited (unpublished).