WASTE MANAGEMENT PROPOSALS FOR NEW AUSTRALIAN URANIUM MINES AND MILLS

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INTRODUCTION

In the first phase of uranium mining and milling in Australia in 1954-1971, about 7800 tonnes (t) of uranium were produced at five locations[1]. Most of the production came from the mines at Rum Jungle in the Northern Territory and Mary Kathleen in Queensland. These early operations were typical of overseas practice at the time. At some of the sites environmental pollution occurred which would not be acceptable by today's standards.

A new exploration phase, which commenced in 1966, led to discoveries of significant uranium resources and there is potential for further discoveries. As a consequence Australia's reserves (i.e. reasonably assured resources recoverable at a cost below US$80/kg U) increased from 6200 t in 1967 to 292 000 t by June 1979[2], at which date it was estimated that 17.6 per cent of the western world's uranium reserves were located in Australia[2].

The recent discoveries of significant uranium resources, the potential for further finds, and the fact that nuclear power generation is unlikely in Australia before the 1990s suggested that Australia could become a major exporter of uranium. This was affirmed when the Commonwealth Government announced in the Parliament on 25 August 1977 its decision to proceed with the further development of Australia's uranium resources on a carefully regulated and controlled basis and with full regard to the protection of the environment and the welfare of the Aboriginal people[3]. This decision was made after detailed consideration of the principal findings and recommendations in the reports[4,5] of the Ranger Uranium Environmental Inquiry (RUEI) which was held from 1975-1977.

So far, approval has been given to mine and mill three of the recently discovered deposits - the Ranger and Nabarlek deposits in the Alligator Rivers region of the Northern Territory, and the Yeelirrie deposit in Western Australia.

Waste management at Australian mines and mills has been reviewed in detail[6,7,8] in recent years. The present paper draws upon these reviews and updates the status of development and waste management proposals with particular reference to the above three projects.

AUSTRALIAN URANIUM RESOURCES AND THEIR DEVELOPMENT STATUS

The major Australian uranium deposits for which development plans are available and the status of their development are listed in Table I[9-14]. The geology of Australian uranium deposits was described recently[9,15] and will not be discussed in this paper.

Mining

It has been proposed that the deposits listed in Table I, except for Jabiluka, will be mined by the conventional open-cut technique. The draft Environmental Impact Statement (EIS) for the Jabiluka project proposed an open-cut over 300 m deep but the final EIS[10] came out in favor of underground mining which combines open stoping, vertical crater retreat stoping and cut-and-fill stoping.

There are two Ranger ore bodies with approximately equal reserves. The company will initially mine the No. 1 ore body, to a pit diameter of 680 m and a final depth of 175 m, over a period of 10 to 14 years.

Queensland Mines completed mining of the Nabarlek ore body at the end of 1979. The resultant pit measured 335 m major axis, 185 m minor axis and was 72 m deep. The ore has been stockpiled for treatment in the mill over a period of eight to 10 years[11].

The uranium mineralization at Yeelirrie occurs at a much shallower depth than in the deposits in the Northern Territory. The ore body occurs in a horizontal zone 7 m thick about 5 m below the surface[9]. For the first 10 years, only prime ore (> 0.20 per cent U) will be mined. Intermediate ore (0.08 per cent U) will be mined for a further 12 years. Blasting will not be

TABLE I. MAJOR AUSTRALIAN URANIUM DEPOSITS

Deposit and Company	Resources* (tonnes U) and Ore Grade (% U)	Planned Initial Production (tonnes U per year)	Status at 1 February 1980
Jabiluka, NT Pancontinental Mining Ltd	176 000 0.33%	2 500+	Final EIS submitted
Ranger, NT Ranger Uranium Mines Pty Ltd	85 000 0.20%	2 500#	Construction started June 1979. Mill startup planned for Oct. 1982
Yeelirrie, WA Western Mining Corporation	40 000 0.12%	2 200	Pilot plant under construction. Production mill startup by late 1984
Koongarra, NT Noranda Aust Ltd	11 000	900	Draft EIS submitted
Nabarlek, NT Queensland Mines Ltd	8 000	900	Construction started May 1979. Yellowcake production by mid-1980
Mary Kathleen, Q Mary Kathleen Uranium Ltd	5 000	600	Mill recommissioned in 1975;only operating mill in Australia at present

* *In situ* resources based on company announcements

\+ Expansion to 7 600 tonnes per year planned after five years

\# Expansion to 5 000 tonnes per year envisaged

NT = Northern Territory; WA = Western Australia; Q = Queensland

required as the ore body occurs in soft sediments.

Milling

All the uranium mills in the Alligator Rivers region will use the acid-leach route[10,11,13,16]. Typically, the ore will be crushed in several stages and then wet ground to 50 wt.% less than 75 μm. Leaching for 16-36 h at pH 1.5-2.0 is then carried out at about 55 wt.% solids. Pyrolusite is added to provide an oxidant. Uranium extraction efficiencies are expected to be 90-96 per cent for sulphuric acid requirements of 35-60 kg t^{-1}. Mixer-settlers will be used for solvent extraction. The uranium will be stripped from the organic phase with ammonium sulphate and the raffinate recycled to wash the tailings in a countercurrent decantation (CCD) circuit. Ammonia will be used to precipitate the yellowcake which is dried at high temperatures (500-800°C) to give a product containing over 90 per cent U_3O_8.

The recommissioned Mary Kathleen mill uses essentially the same flowsheet; however, radiometric sorting is used to pre-concentrate the ore, and cyclones have been installed for sand/slime separation in order to improve the capacity of the CCD circuit[14].

Alkaline leaching will be used to extract the uranium from Yeelirrie ore because the high carbonate content of the host rock requires excessive quantities of acid. The ore will be leached at elevated temperature and pressure in sodium carbonate-bicarbonate solution. Processing of the ore is complicated by its high clay content which results in slow settling and low pulp densities in the CCD circuit. Complete flowsheet details for the mill have yet to be finalized. A one-tonne ore per hour pilot plant is being constructed to test various processing options including roasting, leaching at low soda concentrations and alternative washing circuits[12].

Two of the mills plan to recover by-products. A small fraction of the Jabiluka ore contains gold which will be extracted in a cyanide leaching circuit. Yeelirrie ore contains vanadium which will be recovered as redcake (V_2O_5).

ENVIRONMENTAL IMPACT ASSESSMENT AND CONTROL

In recent years, the public and governments have become more concerned about the possible impact on the environment of new industrial developments.

In 1974, the Australian Parliament passed the Environmental Protection (Impact of Proposals) Act which requires that a proponent provide information to the government on any project which has some environmental significance. A decision is then made on whether an EIS is necessary. If an EIS is required, it is made available for public review, and advertisements are placed in the press calling for written comments. In some circumstances, the Government may appoint Commissioners to hold a public inquiry.

One of the first projects to be considered in terms of the Act was the proposal by Ranger Uranium Mines Proprietary Limited[16] to construct a mine and mill at Jabiru in the Alligator Rivers region to produce 2500 t of uranium per year. A full public inquiry before three Commissioners, headed by Mr. Justice Fox, began in July 1975. Two reports were issued by the Commission; the first dealt with generic issues associated with uranium mining and nuclear power[4]. The second report[5] considered specific aspects of the Ranger proposal but also commented on other mining proposals within the Alligator Rivers region.

After examination of the second report, the Government announced in August 1977 its decision to proceed with development, subject to stringent environmental safeguards and agreement with the traditional Aboriginal landowners. The Environment Protection (Nuclear Codes) Act 1978 was subsequently enacted. This Act gives legislative force in the Northern Territory to the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores[17]. The Code establishes standards for the protection of miners, mill workers and the general public, and includes maximum permissible levels of exposure to radiation, radon and its daughters.

Over 80 per cent of Australia's uranium reserves lie within the Alligator Rivers region of the Northern Territory, and the Environment Protection (Alligator Rivers region) Act 1978 provides for the appointment of a Supervising Scientist and the establishment of a Co-ordinating Committee and a Research Institute to co-ordinate and integrate environmental control in the region. Control will be exercised by the Director, Australian National Parks and Wildlife Service and other Government agencies including the Northern Territory Government. The Co-ordinating Committee and the Research Institute, headed by the Supervising Scientist, will assist in the implementation of controls, the development of standards, and the monitoring of the impact of mining operations on the environment.

The detailed environmental conditions for the Ranger Project have been established and are contained in the Authority to Mine the deposits[18]. One of the provisions relating to technology states that "Taken as a whole, and in their component parts, the plant and the mine shall be designed, and the mining, milling and related operations within the Ranger Project Area shall be carried on in accordance with best practicable technology." The Authority to Mine defines in detail the concept of "best practicable technology". The Ranger Project also requires authorizations to be issued under the Uranium Mining (Environmental Control) Act 1979 of the Northern Territory.

The Nabarlek, Jabiluka and Koongarra projects are intended to proceed under leases granted to the companies issued in accordance with the Northern Territory Mining Act (1939). This Act and other relevant Northern Territory legislation will ensure that environmental control is maintained over these operations.

The various State governments also have their own procedures for the environmental assessment of proposed new developments. It is usually possible to satisfy both State and Federal requirements with the same EIS as exemplified by the approvals obtained for the proposal for the Yeelirrie Project in Western Australia[12].

Regional Environmental Factors

The Alligator Rivers region is an area of great natural beauty. The Ranger Inquiry recommended that the area become a major national park and the Commonwealth Government has accepted this recommendation. The average annual rainfall is 1350 mm while evaporation is about 2200 mm. The climate is monsoonal and characterized by short duration, high intensity rain storms in the wet season, which extends from November to April. The heavy rainfall creates problems due to flash flooding and splash erosion. During the wet season, the lowlands are traversed by meandering creeks and streams, and the lowest parts of the plains become vast lakes. The water is naturally acidic, very soft and normally low in suspended solids. As the dry season progresses, water quality progressively deteriorates imposing stresses on aquatic organisms through high temperatures, low oxygen levels and high concentrations of potentially toxic metals. These factors suggest that the biota would be very sensitive to added heavy metals[19].

In other Australian regions where uranium has been found, the climate is drier and the environment less fragile. The annual rainfall at Mary Kathleen is 430 mm. Because of this dry climate, a water balance is readily achieved by evaporation and the environmental effects of the mine and mill have been limited[14].

The Yeelirrie deposit occurs in a semi-arid region with an annual rainfall of 200 mm and surface evaporation of about 2300 mm[12]. Process water for the mill will be obtained from groundwater reserves; these are generally saline with elevated concentrations of radionuclides (e.g. radium-226 concentrations up to 30 Bq L^{-1}). Because of the low rainfall and the natural level of contaminants in groundwater, the environmental impact of mining is likely to be small; the major concern is depletion of groundwater reserves.

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Airborne Releases

The principal airborne releases are: radon and its daughters, ore dusts containing silica and α-emitters, yellow-cake dusts, and oxides of sulphur.

Radon emanates from mine faces, ore stockpiles and the tailings dam and also is liberated, to some extent, by drilling, blasting and crushing operations. The radon emanation characteristics of Australian ores and tailings are similar to those from North America. The average emanation coefficient for crushed ore is about 0.2 but the carnotite ores from Western Australia have a much lower coefficient, typically about 0.07.

Radon released from the mines and mills will have little effect beyond their immediate environs. The total radon release rate from all the mines and mills in the Alligator Rivers region is unlikely to exceed 3 TBq per day. This compares with an estimated 60 TBq per day which emanates naturally from the region. Davy[19] has calculated that, at the regional town about five km from the Ranger mine, the increment in average radon concentration due to the Ranger Project will be only 1 Bq m^{-3}.

The Australian Code of Practice sets a maximum limit of four Working Level Months (WLM) per year for occupational exposure to radon daughters[17]. In open-cut mines, natural ventilation is generally sufficient to ensure adequate dispersion of radon. In underground mines, forced ventilation is required to maintain safe working levels. The ventilation system for the Jabiluka mine is being designed for an average residence time of five minutes which is expected to keep the radon daughter concentration below 0.2 WL[10].

Dust is generated by mining operations such as drilling, blasting, loading, hauling and dumping. All Australian ores contain some silica which, in a finely divided form, can cause the serious lung disease, silicosis. This hazard is aggravated by the presence of α-emitters in the ore. Dust control measures during mining are typified by the Ranger proposal[5,16]. The open-cut will be evacuated before blasting, which will be carried out before the lunch break or at the end of the day under favorable atmospheric conditions. The quantity of broken rock in the open-cut will be limited to two days' supply. The air supply to the cabins of earth-moving equipment will be filtered to prevent ingress of dust and radon daughters.

In the mill, dust is generated by ore crushing operations and yellowcake handling, crushing and packaging. Proposals to collect airborne dust include the use of venturi scrubbers, electrostatic precipitators and bag filters[10,13,16]. All companies propose to maintain a 1-2 m water covering above the tailings during operation in order to suppress radon emanation and eliminate tailings dispersal.

Sulphuric acid will be manufactured from imported sulphur at the Ranger, Jabiluka and Koongarra mills[10,13,16]. The Nabarlek mill will use sulphuric acid trucked to the site[11]. A single catalysis plant was planned originally for the Ranger plant. The Ranger Inquiry considered that sulphur dioxide emissions (about two tonnes per day) were excessive and recommended installation of a stack gas scrubber[5]. More efficient double-contact sulphuric acid plants have been proposed now for Ranger and the other new mills. Dispersion calculations show that ground level concentrations of sulphur dioxide will be well below the USEPA limit of 80 $\mu g\ m^{-3}$ for three-hour peak concentration[5,16].

Water Management

The potential sources of polluted water from uranium mines and mills are: process effluents from the mill circuit, mine water resulting from run-off and groundwater ingress, run-off and seepage from ore stockpiles, run-off and seepage from waste rock dumps, and run-off from haul roads, the mill and other disturbed areas of the site.

Detailed management schemes have been proposed at the Ranger, Jabiluka, Koongarra, Nabarlek and Yeelirrie sites to ensure that the release of contaminants to natural waters is prevented as far as possible.

The water management system to be adopted at Ranger is given in the Authority to Mine[18]. The whole area of operations at Ranger will be designated a "Restricted Release Zone" and water, other than the natural sub-surface flow of groundwater, will be released only with the approval of the relevant supervising authority (i.e. government agency) and in accordance with standards set by that authority. Initially, the water management system will not allow any intentional releases and, before these are allowed, investigations into the flow, mixing and dispersion characteristics of the Magela Creek system, the nearest waterway, are to be undertaken. A series of three ponds will be used to collect water from the plant area, the pit and the waste dump. Water from the plant area and the waste dump will be used as treatment plant process water and any excess will be released later if approved. Mine water will be treated with flocculents and will be used in the treatment plant or pumped to the tailings dam.

At Nabarlek, the water management system incorporates retention and evaporation ponds, and disposal of tailings into the pit from the commencement of ore treatment. Containment of all waters from the plant area, sewage treatment, ore stockpile and waste dumps is planned. A retention pond will act as a buffer storage for excess plant requirements. It is expected to take 10 years for stored waters to evaporate after all treatment operations have ceased. During operation and/or decommissioning, application may be made to the appropriate supervising authority to release water which satisfies water quality standards for the region.

Design of water management systems at Jabiluka and Koongarra is based on the principle of no-release from all potential contaminated catchment areas. Seepage from containment structures will be minimized by the use of impervious clays and other selected materials.

Tailings

Tailings disposal at the various open-cut operations will utilize surface storage dams, storage in the mined-out pits or a combination of both. Details of the proposed dams are given in Table II[8] based on data provided in the EISs.

TABLE II. TAILINGS DAM DESIGN DATA[8]

Deposit	Tailings area (ha)	Final height (m)	Tailings storage (10^6 t)	Seepage (m^3 d^{-1})	
				Gross	Net
Ranger	100	16-30	27	150- 1 000	NA
Jabiluka	180	14-34	37	320- 1 100	100-300
Yeelirrie	300	7	27	400-10 000	400-10 000
Koongarra	70	6-16	5	300	100

NA: Not available

An environmental requirement for the Ranger Project is that tailings be returned to the No. 1 Pit on conclusion of operations in that pit unless otherwise mutually agreed by the Commonwealth Government, the Northern Land Council and the Ranger Joint Venturers[18]. At Nabarlek the pit is available for the direct discharge of tailings during the treatment operations. The Nabarlek pit will be sealed where necessary to reduce the flow of groundwater through the stored tailings. This flow has already been shown to be much lower than originally estimated.

At Jabiluka, Koongarra and Ranger the dam walls have been designed to minimize seepage and to remain stable under all likely climatic and seismic conditions. The dams will be earth-rockfill structures, constructed of selected impervious and semi-pervious materials derived from waste rock and borrow areas. At Koongarra, the borrow area for dam construction material will be within the tailings pond area and will provide essentially sub-surface storage of the consolidated tailings. Collection of seepage through dam walls will be standard practice during operations.

The tailings slurry from the countercurrent decantation circuits will be neutralized with lime slurry, generally to pH of above 8, before disposal to the tailings area at Ranger, Koongarra and Nabarlek[7]. Neutralized tailings from the Nabarlek plant (pH 8.5-10.0) will be further treated with barium chloride solution to facilitate precipitation of radium before disposal of the tailings.

The partially neutralized tailings at Jabiluka will be treated in a flotation circuit to produce a concentrate which will be treated in a 600 t per day cyanide leaching plant for gold recovery. Flotation tailings will be neutralized before pumping to the cemented-fill preparation plant. About 50 per cent of the tailings as sands will be returned to the Jabiluka underground mine as fill. The remainder as slimes will be passed to the tailings disposal area.

Final details of rehabilitation of the tailings disposal areas are not known at this stage, but will depend on agreements to be reached between the parties concerned - for Ranger, as indicated above; and for other projects in the Northern Territory, the Northern Territory Government, the Northern Land Council and the company involved. Below grade disposal of the tailings was a condition for approval of the Yeelirrie project. In Australia, the mining companies generally have proposed covering the tailings surface with a clay blanket, rock fill and topsoil followed by establishment of indigenous vegetation[7,10,13]. The appropriate governments have accepted this as the most practicable of the presently known rehabilitation methods.

CONCLUSIONS

The presently approved new mining and milling projects in Australia at Ranger, Nabarlek and Yeelirrie have an initially planned production totalling 5600 t U per year. They will depend on open-cut mining operations, well-established treatment techniques and best practicable waste management procedures. Several other projects have been proposed, including an underground mine at Jabiluka, but these are awaiting approval.

The proposed developments have been subjected to detailed environmental impact assessments. The overall operations, and particularly the waste management procedures being adopted, should ensure that harmful effects on the workers in the industry, the public, and the environment in general are kept to an acceptably low level.

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