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Reclamation at the Ranger Uranium Mine, Australia

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Uranium mines are subject to the same kinds of remediation challenges as other mines, except for one difference—they generate radioactive waste. One of the biggest concerns is how to dispose of the radioactive tailings that are produced as a result of the mining process. Returning the landscape to pre-mine conditions is an enormous task given the size of the disturbance. The Ranger Uranium Mine in Australia covers an area of about 500 hectares, of which 420 hectares have been significantly disturbed by mining activities (ERA, 1997). Operations at Ranger are stringently monitored and must comply to some 53 laws (Parliament of the Commonwealth of Australia, 1997) that consider environmental protection, Aboriginal interests, public health and the surrounding communities.

Ranger is located within the boundaries of Kakadu National Park, a park that is nationally and internationally recognized for its natural and cultural heritage. The 1,980,400 hectare park (ANCA, 1996) is located in northern Australia, and is well known for its spectacular wilderness areas, nature conservation values, and natural and cultural heritage. In 1975 under The National Parks and Wildlife Conservation Act, just over 515,000 hectares of the park was zoned as a wilderness area. In 1981 UNESCO listed 1.3 million hectares of the park as a World Heritage Area (Hall, 1992) because it is truly a unique example of complex ecosystems and landscapes including savannah grasslands, coastal rainforests, extensive mangroves and tidal flats, and wetlands.

The wetlands of Kakadu were given official recognition by the Ramsar Convention on Wetlands of International Importance because of their importance in a biogeographical context, the outstanding diversity of their plant communities, and their role in conserving the large numbers of waterfowl that congregate during the dry season (Finlayson and Woodroffe, 1996). As many as 2 million waterfowl use the wetland areas. The principal wetlands of the park are in the floodplains, samphires, mangroves, and paperbark swamps (Environment Australia Biodiversity Group, 1998).

The park provides habitat for a wide variety of rare, threatened and endemic plant and animal communities. More than 1,600 plant species have been recorded from the park, of which 58 are considered to be of major conservation significance. Additionally, 3 percent of mammal species, 10 percent of birds, 9 percent of reptiles and 4 percent of amphibians occurring in the park have a restricted range, high habitat specificity and low population density, and are considered generally rare. Furthermore, 21 notable species have since been identified on the basis of the species rarity, restricted range, taxonomic interest, uncertain or declining range or substantial range extension (UNESCO, 1998).

The climate of the region is classified as tropical monsoonal with marked wet and dry seasons. Rainfall intensities in the Kakadu region are among the highest in Australia. More than 90 percent of the annual rainfall occurs during the wet season. An average of 1540 millimeters of rain falls during the wet season (Uranium Information Center, 1999), which occurs from

November-March and is characterized by hot and humid conditions. During this time, creeks and rivers carry large amounts of water from the escarpment complex and lowlands, and flood the extensive lowland plain. April-October marks the dry season with mild to warm conditions. Freshwater flow into the rivers ceases and the creeks and lowland plains dry out (Finlayson and von Oertzen, 1996).

The minesite is surrounded by a complex creek system. These ephemeral creeks flow into the East and South Alligator Rivers, which ultimately flow north into the Van Diemen Gulf along the northern coast (McQuade et al, 1996). Ranger is located on the Koolpinyah surface, a series of gently undulating lowland floodplains that stretch from Darwin to the spectacular Arnhem Land Plateau just east of the mine. The Arnhem Land Plateau and escarpment complex has an overall height of about 300 meters with rolling hills rising to 570 meters. The region is estimated to be over 2,000 million years old. As a result of its age and weathering processes, lowland soils are acidic, highly leached and extremely deficient in organic matter. These soils are typically well drained and are highly permeable (East, 1996).

The Kakadu region has been inhabited continuously for more than 23,000 years. Historically, the Aboriginal people were hunters and gatherers, as evident by their extensive rock art paintings, and archaeological sites present (ANCA, 1996). Today, there are about 500 Aboriginals living in Kakadu National Park. The minesite land is owned by and leased from the Mirrar- Gundjehmi Clan of Aborignal people. The mining company rents the land for an annual price of A$200,000 plus an additional royalty payment of 4.25 percent of gross sales revenue. However, the landowners will not receive all of this money because it is distributed by various fiscal agents who either pass it on or retain it for administration costs. Currently, total payments have exceeded A$145 million (ERA, 1999).

The mine itself is owned and operated by Energy Resources of Australia (ERA), Ltd., and is ranked third among the top ten uranium mines in the Western world. In terms of world uranium production, Canada provides 35 percent, followed by Africa at 22 percent, and Australia at 15 percent. In 1997, Australia produced 6.5 thousand tonnes of Uranium. Of this, Ranger produced 4.2 thousand tonnes (ERA, 1998), which equates to nearly 65 percent of Australia’s uranium production. The uranium produced at Ranger is transported to countries around the world that use the uranium to fuel nuclear power plants. For example, the United States leads the world in nuclear power facilities. In 1997, the 105 plants in the US required 20,481 tonnes (equivalent to over 45 million pounds) of uranium. It would take Ranger over four years to produce what is consumed in just one year by the United States alone.

Open-pit mining operations began in 1980. The site consists of several processing plants, orebody pits, a tailings dam, and several retention ponds (Figure 1). Two pits exist at Ranger, orebody #1 and orebody #3. Due to its proximity to Aborignal sacred sites, orebody #2 will never be mined. Orebody #1 contained approximately 59,000 tonnes of uranium and was completely mined out in 1994. When fully excavated, the pit measures approximately 180 meters deep and 750 meters wide. Orebody #3 is currently being mined and is estimated to contain

53,000 tonnes of uranium (Supervising Scientist Group, 1998A). Mining is expected to continue at orebody #3 until 2004 (ERA, 1998).

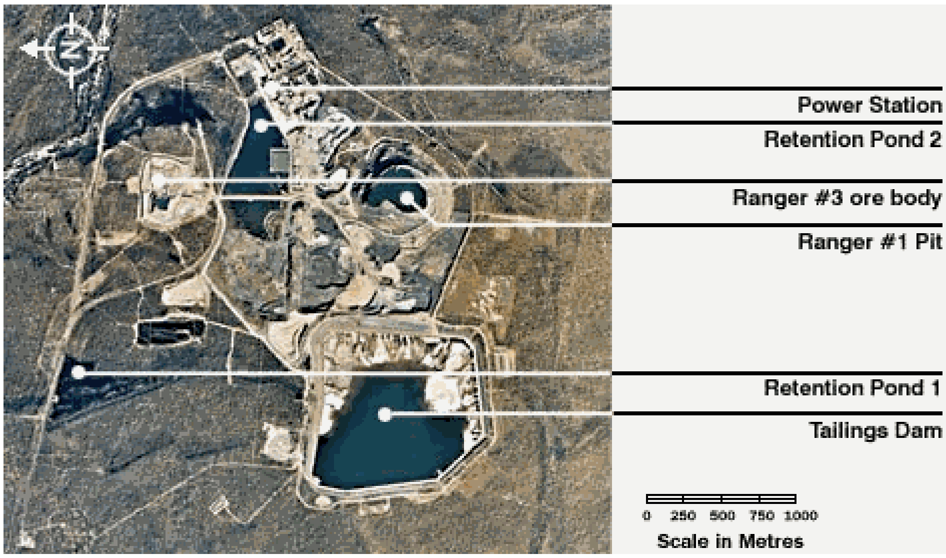

Figure 1. Ranger Uranium Mine

Processing uranium begins with crushing and grinding the ore to sand or silt sized particles to release uranium minerals. The released uranium minerals are then separated from other solid materials by using sulphuric acid to leach out the uranium (Frost, 1998), resulting in a clarified uranium solution. Then the clarified solution is further separated and concentrated by an ion exchange or solvent extraction method. Next the uranium is precipitated from solution that results in a bright yellow substance commonly referred to as 'yellow cake'. The final step is to heat the yellow cake. The end product is a dark green powder that is more than 98 percent pure uranium oxide (ERA, 1996). All uranium oxide produced at Ranger is exported to countries like the USA, Japan, Sweden, France, and Germany to fuel nuclear power plants (Uranium Information Center, 1999).

In the most simplistic model, mining operations begin with extraction and end with waste. The waste generated from uranium mining includes waste rock, tailings (leftovers from processing the ore), and waste water. Waste rock is the material removed from the pit in order to get to the ore. The waste rock can potentially be problematic because when exposed, the rock can generate acid and metals may leach out from weathering (Frost, 1998).

Tailings are a by-product of uranium processing. They are the impurities that have been separated from the uranium and left as a solution of acid, which is neutralized with lime and blended with the ground rock to form the tailings. Tailings are thus a mixture of fine solids in water that includes sulphuric acid, hydrogen peroxide, water, and particulate matter. They also include radionuclides and heavy metals (Supervising Scientist Group, 1998B). From 1980 to

1996, tailings at Ranger were deposited into a 100 hectare tailings dam. The dam is nearly full and the tailings are being placed in the mined out orebody #1. The goal is to have as much of the water evaporate during the dry season thereby reducing the volume.

Waste waters from processing uranium are laden with a slurry of ingredients including radium, arsenic, nickel, and acids. Waste water management at Ranger can be classified into three categories or zones (Supervising Scientist Group, 1998A):

1. Non-Restricted Release Zone. The water here has not been contaminated by the mining process, it meets drinking water requirements, and is discharged into nearby streams during the wet season. The run-off water has had no contact with ore stockpiles, the processing plant, or disturbed ground.

2. Restricted Release Zone. This water is a result of rainwater run-off from stockpiled ore and the processing plant. It contains low levels of dissolved uranium and other contaminants. This water is disposed of by evaporation, watering lawns, and dust control. The researchers are looking into the possibility of using constructed wetlands to filter this water before releasing it to the environment.

3. Process Circuit. A closed system that includes run-off water from the tailings dam, the uranium processing plant, sulphur stockpiles, mine workshops and vehicle wash-down areas. This water is recycled in the processing plant and will never be released into the environment, except by evaporation from the tailings dam.

Four retention ponds, also referred to as RP1- RP4, are located within these zones. RP1 collects runoff from the surrounding vegetation and from the waste rock stockpiles. This pond is used primarily for sediment control. RP2 collects the rain that falls on the ore stockpiles, orebody #1 and other areas around the processing plant. Pond 3 contains the most severely contaminated water. Water runoff is collected from the vehicle washdown areas, the power station, the acid plant and stockpile areas. RP3 is a dam and is part of the Process Circuit zone, which includes the tailings dam and the processing plant. During the wet season, this pond becomes inundated with rainfall. When this occurs, the excess water is stored in orebody #3. Pond 3 is part of the closed water system where the water is continually recycled until it evaporates. Pond 4 collects runoff from the non-mineralized ore stockpiles. The water in RP4 is relatively uncontaminated, therefore, it is released directly into nearby Magela Creek when approved by the governing authorities (ERA, 1999).

According to the Supervising Scientist Group (1998A), these retention ponds are intended to "...contain and dispose of large volumes of contaminated water in a manner which does not adversely effect the surrounding environment". Potential problems can arise when the retention ponds are at or near capacity. During the wet season the ponds may not be able to hold the excess water and spillage may occur. One such incident occurred in 1995 due to above normal rainfall in the area. About 3 million megaliters of water accumulated in the Restricted Release Zone. ERA intended to release the excess water under controlled conditions to Magela Creek until concerns were raised by Aboriginals in the area. As a result, a $500,000 wetland filter system was proposed and developed. The water that passes through the filter is effectively decontaminated before release (Kay, 1997). The minesite has several artificial wetlands that they use to filter contaminated water runoff from disturbed areas.

Rehabilitation efforts at Ranger are an ongoing process because the mine is still active. Rehabilitation efforts are based on three plans: 1) Annual Plan, 2) Five Year Plan, and 3) Long Term Plan. Each plan addresses specific aspects of the rehabilitation process. The Annual Plan sets short term rehabilitation priorities such as stabilizing disturbed areas prior to the next wet season. Stabilization work involves drainage work, tyning of barren areas, and replacing topsoil and seeding with grass and tree seedlings. The Five Year Plan is supposed to address the amount of waste materials being produced and where they will be placed to minimize ground disturbance. However, according to Needham (1999) the Five Year Plan is no longer of any consequence because the mine is within about 7 years of its extractive life. Therefore, emphasis is on the continually evolving Long Term Plan that addresses the rehabilitation goals of defining the horizontal and vertical landform design. These plans are not highly developed because they prefer the planning to remain flexible to take into account any new research findings (Needham, 1999). Additionally, the Company created a Plan of Rehabilitation that is amended at regular intervals to incorporate the continual changes occurring at Ranger. These planning methods will enable them to refine their approach over time while attempting to understand ecosystem functions and processes.

Rehabilitated areas must meet detailed conditions set down by Ranger’s supervising authorities and those of the Aboriginal owners. Numerous research programs have been implemented to ensure these conditions are satisfied. Examples of research efforts include disposal and capping strategies for the tailings, measuring and modeling the behavior of groundwater in relation to interactions with contaminants, and validation of wetland filtration methods to immobilize contaminants (ERA, 1998). Rehabilitation efforts must use the Best Practicable Technology as defined in the Uranium Mining Act of 1979 (ERA, 1997).

Reclaiming the minesite and incorporating it into the existing landscape encompasses rehabilitating the mined out pits, tailings disposal, water and waste rock management, and ecosystem reconstruction. Returning the land to its original form involves filling and covering the disturbed areas. The main concern here is to blend the minesite into the surrounding landscape while minimizing environmental impacts. According to ERA (1997), the minesite landscape will appear as a low hill rising 24 meters above the present tailings dam. The final landform will have a design life of 200 years and structural life of 1000 years. They are also planning on sloping the land in such a way that water will runoff into the artificial wetlands before entering the nearby creek complex. The slopes and disturbed areas are stabilized with native vegetation and matting to minimize erosion. The newly established vegetation will be irrigated and hydromulched to speed recovery. Hydromulch is an organic mulch made of seed, fertilizer, pulped cardboard boxes and water. Weeds are controlled by applying a non-residue herbicide and the feral animals (pigs, buffalo, wild horse) are physically removed. The mining company also conducts prescribed burns to promote native species.

Water management is probably the most difficult aspect of the minesite rehabilitation efforts. Water from rainfall and the ponds must be properly treated before release, and tailings must be safely contained. The water that is allowed to run off of the site is directed into artificial and natural wetlands. The wetlands serve to filter out contaminants and sediments. The resulting ‘purified’ water is used to irrigate the revegetated areas. ERA (1998) states that more than 90 percent of uranium and all nitrate and manganese were removed by these wetlands. Typically, the nitrates will be removed by plant uptake, leaching into the groundwater, or they will volatilize and be lost into the atmosphere as nitrogen gas. Conversely, heavy metals like uranium and manganese will persist because they adsorb to clay particles in the sediment where they accumulate without degradation (Sturm, 1997). This lack of degradation is due to the structure and lengthy decay stages of uranium. The inorganic atoms of uranium are unstable and thus undergo several stages of radioactive decay. Uranium itself has a half-life of 4.47 billion years, and will eventually decay into elements such as radium, radon, and lead. (Hall, 1998). The resulting lead atom will persist in the environment harming both aquatic and terrestrial species. Hence, wetland sediment will become saturated with heavy metals over time, and eventually need to be removed from the environment.

In 1998, Retention Pond 4 was emptied by releasing the water into Magela Creek over a three month period during above average rainfall in the region. The tailings are being dredged from the dam and placed into orebody #1 and will eventually go into orebody #3. Once orebody #1 is full, the pit will be capped using a geotextile liner, covered with clay material and a few meters of waste rock and then revegetated using native species. The surface will be sculptured to minimize erosion and to resemble the surrounding landscape (Supervising Scientist Group, 1998A). Mention has been made of creating an underground leak-proof containment structure that can retain the highly contaminated tailings for several hundreds even thousands of years. However, plans to bury the tailings in mined orebody #1 have already commenced. Recently the Supervising Scientist Group and ERA have begun researching ways to optimize a landscape design that will minimize the risk of exposure to the radioactive mine tailings. Their target is 10,000 years using a predictive landscape evolution model called ‘SIBERIA’. They are going to use the results of this model to assist with rehabilitation design (Needham, 1999). SIBERIA models both runoff and erosion and predicts the long-term evolution of channels and hillslopes in a drainage basin (Evans et al. 1998).

An environmental performance review for Ranger was conducted in 1997. The report briefly addresses matters concerning the current status of the tailings pond, waste rocks, and the wetland filter systems. The report concludes that there have been no significant issues related to environmental protection at Ranger (Supervising Scientist Group, 1998C). Despite Rangers’ relatively superior environmental track record, concerns still exist. There is no guarantee that the tailings would not leak from an underground containment unit or the orebodies. If leakage does occur, say in 100 or 500 years, assigning responsibility may be problematic. Additional research is needed to develop technology for decontaminating tailings to reduce reliance on burial methods. According to ERA (1991), the Commonwealth Scientific and Industrial Research Organization (CSIRO) has researched and studied the properties of tailings so they can eventually be rehabilitated. To date, results of this research have yielded no new technologies capable of decontaminating the tailings, and thus tailings will continue to be placed in the orebody pits.

Another concern is water quality monitoring. Because Ranger is located near a complex creek system, it has potential to pollute beyond its boundaries. Monitoring the water for contaminants nearby the mine does not account for the contaminants that have dispersed downstream, especially during the wet season, a time when the company releases pond water into the nearby creek system. Additional monitoring is needed along various segments of the creeks and rivers that extend beyond the immediate minesite area. Finally, there is the issue of waterfowl using the constructed ponds. As previously mentioned, some 2 million waterfowl use the wetlands in the Kakadu region (Environment Australia Biodiversity Group, 1998). The artificial ponds at Ranger offer a year round supply of water, which is important during the dry season. However, the water in these ponds is not suitable habitat. Not only can the fowl ingest contaminants but they can also carry contaminated dust particles on their feathers. Furthermore, the Aboriginal diet includes species of waterfowl such as ducks and geese (ERA, N.D).

Uranium mining at Ranger has far reaching consequences. It transcends national, political, and environmental boundaries. The potential for damage exists whenever humans alter the natural state of the environment. The extent to which it can be repaired depends on the activity. Mining operations at Ranger will leave a legacy that will be apparent for many centuries, if not millenia. The landscape has been permanently changed and will always differ from pre-mine conditions. Reclamation efforts have been, and will continue to be an enormous scientific and engineering endeavor as well as a cultural endeavor. To their credit, the mining company has spent millions of dollars rehabilitating the mine and is providing revenue for the Aborignal land owners.

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