

THE NORTHERN TERRITORY OF AUSTRALIA

# DEPARTMENT OF TRANSPORT AND WORKS



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RUM JUNGLE
REHABILITATION PROJECT

IMPLEMENTATION REPORT

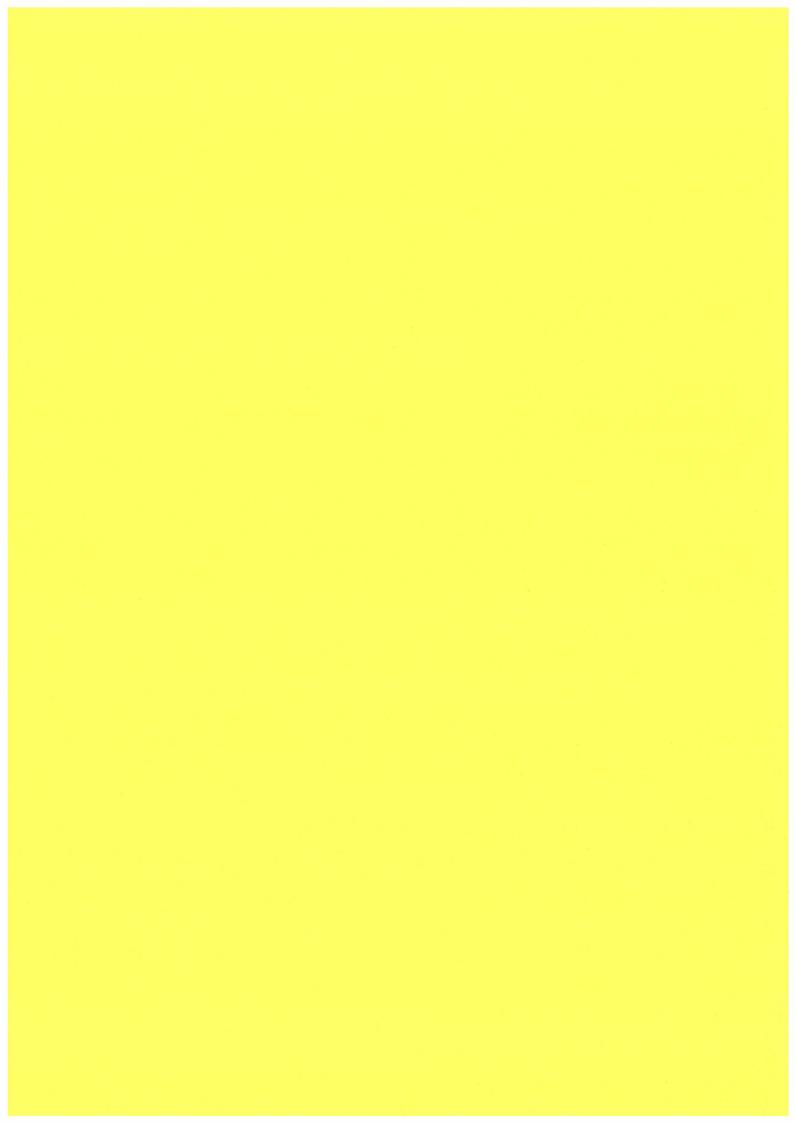
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VOLUME 2 APPENDICES TO REPORT OCTOBER 1981

#### APPENDICES

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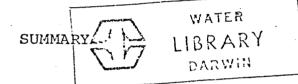
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	Prepared by the Commonwealth	
	Department of Housing and Construction	
	- Canberra region	
	September 1979	2



## CONFIDENTIAL

REHABILITATION AT RUM JUNGLE

Report of the Working Group



Department of the Northern Territory

April, 1978.

COMPIDENTIAL

CLASS NO. ACC. DATE

## REHABILITATION AT RUM JUNGLE

Report of the Working Group

Department of the Northern Territory

April 1978

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#### 1. SUMMARY

No

Alternative works designed to rehabilitate the abandoned Rum Jungle Mine site and to mitigate continuing pollution originating from it have been evaluated and the costs estimated. Recommendation has been made on a preferred scheme.

#### 1.1 Initial Clean-up of the Treatment Plant Area

As a result of action initiated during 1977 by the Deputy Prime Minister and Minister for National Resources, and the Minister for the Northern Territory, an allocation of \$300,000 was made available in the Budget for an immediate clean-up of the treatment plant area at the Rum Jungle Mine site. These works consisted of removal of derelict buildings, rubbish, foundation slabs and miscellaneous plant and landscaping of the treatment plant area using old stockpiled material from the mining, followed by topsoiling and revegetation treatment. This work was completed in December 1977.

#### 1.2 Proposals for Further Rehabilitation

A proposal to study possible rehabilitation of the overall Rum Jungle Mine site was announced in Parliament on August 25, 1977, by the Deputy Prime Minister and Minister for National Resources along with the announcement of decisions concerning the development of Australia's uranium resources. The announcement included a statement which asserted that the Rum Jungle project was carried out with inadequate concern for the environment and would not be permitted by today's standards. The Deputy Prime Minister also announced that:

"The Department of the Northern Territory will coordinate a study of a comprehensive program of rehabilitation of the whole area. The Government will take further decision when that study is completed."

A Working Group of interested parties was convened, by the Department of the Northern Territory to examine alternative rehabilitation measures. These alternatives, their costs and important factors relevant to a further rehabilitation program are summarised below and are discussed in greater detail in the Working Group's report.

## 1.3 Environmental Management of Rum Jungle Mining Operations

Mining, ore treatment and waste disposal operations at Rum Jungle were conducted according to mining regulations and environmental controls which existed at the time. Available evidence suggests that waste disposal practices did not exceed effluent release standards which existed in the Mining Regulations of the Northern Territory Mining Ordinance at the time.

Uranium mining at Rum Jungle was controlled under the Atomic - Energy Act at the time and not under the Mining Ordinance.

However, considerable pollution of the river system was caused by waste disposal practices which resulted in tailings and acidic effluents contaminated with heavy metals entering the East Branch of the Finniss River\*\*.

The operation began to attract criticism on environmental grounds as the public became more environmentally aware. The new approach to environmental management of mining operations was emerging when the operational life of the Rum Jungle project expired.

#### 1.4 Environmental Studies 1969-1975

Between 1969 and the closure of the mine in 1971, a water sampling program was undertaken in order to evaluate past and continuing pollution of the Finniss River system. This led to more detailed environmental studies between 1973 and 1975 which were conducted jointly by the Australian Atomic Energy Commission and the Department of the Northern Territory. These studies identified the sources, the nature and extent of pollution, which has continued by natural processes since closure of the mine, as well as the physical, chemical, biological and seasonal climatic factors governing the continuing release of contamination from the site.

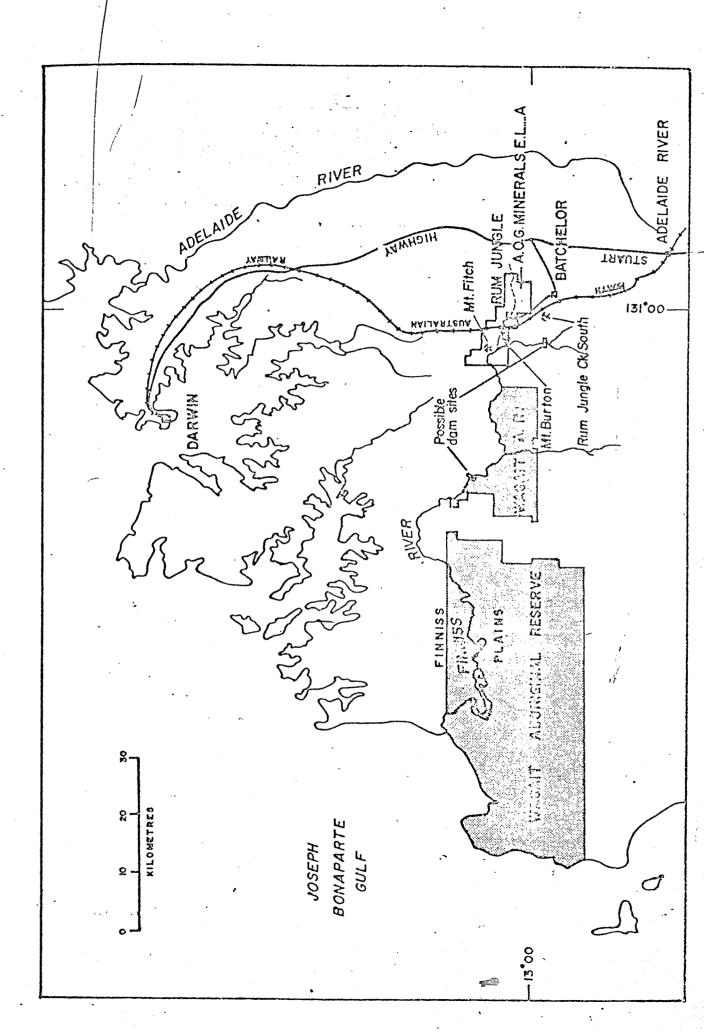
#### 1.5 The Problem

The Rum Jungle Mine site is located 64 kilometres south of Darwin on the East Finniss River (see Figure 1). The site consists of an area of open tropical woodland, typical of the northern part of the Northern Territory, in gently undulating country straddling a creek system. Streamflow mainly occurs in the wet season. The area was significantly affected by mining, ore treatment and waste disposal operations. The present condition of the site (see Figure 2) can be considered to present three broad categories of problems, which are as follows:

### 1.5.1 Despoliation of the natural landscape

Approximately 200 hectares of land in the immediate Rum Jungle mine and treatment plant area was significantly affected by the operation. The composition of the area is approximately as follows:

<sup>\*\*</sup> Throughout the remainder of this report the East Branch of the Finniss River is referred to as the East Finniss River.



TERRA MINE OF T

FIGURE 2. RUM JUNGLE MINE AREA

in gradical turned to	Arriver (1986)	% of
	area, ha	affected area
	-	
Open Cuts	22	11%
Overburden Heaps	51	25%
Areas affected by seepage		, · · · · · · · · · · · · · · · · · · ·
from overburden heaps	27 <b>12</b> 2	68
Old Tailings Dam	31	15%
Plant and Stockpile area	45	22%
Riverbed and banks	43	21%
	204	100%

In addition, the East Finniss River down to the junction with the Finniss River has suffered erosion of its bed and banks as a result of the destruction of vegetation by effluents released during mining operations.

#### 1.5.2 Public health and safety risks

In the area of the Rum Jungle mine and treatment plant, hazards exist which pose some risk to public health and safety.

The three open cuts, and particularly White's open cut which was fenced from public access at the closure of the operations at the site, contain water which is unfit for consumption or recreation.

Some sections of the affected creeks are quite unsafe owing to the quicksand nature of the bed and banks. Liquor ponds adjacent to the heap leach pile are unfenced and contain acidic sludges.

The tailings area remains uncovered and continues to be eroded by water in the wet season and wind in the dry season. No significant radiological health hazard is involved provided access by the public is limited to that of a transitory nature.

#### 1.5.3 Pollution of the Finniss River System

The site continues to be a source of contamination of the Finniss River system. Contamination occurs in runoff and seepage resulting from seasonal rainfall and consists principally of heavy metals and sulphate released by chemical and microbiologically assisted oxidation.

The individual sources of pollution have been identified, and factors governing the continuing release of contaminants are now reasonably well understood. The principal sources of pollution in approximate order of their importance as contributors are:

White's Overburden Heap
Heap Leach Pile
Intermediate Overburden Heap
White's Open Cut
Old Tailings Dam
Acid Dam

Contamination enters the East Finniss River in slugs of fluctuating concentrations from the beginning of the wet season, to early in the dry season. The annual input of contaminants to the East Finniss River varies greatly from year to year depending on rainfall occurring at the site and flow in the East Finniss River. In years of above average rainfall the the East Finniss River increases total pollution load entering the river increases total pollution load entering the rainfall.

The principal contaminants of concern are the heavy metals copper, manganese and zinc, and sulphate, although large quantities of other less toxic contaminants are also present. The present levels of copper and of manganese in forage grasses of the Finniss Plain appears to be on the borderline of stock of the Finniss Plain appears to be on the borderline of injury although no injury has been observed and the levels of injury metals in carcasses are extremely low. Radiological heavy metals in carcasses are extremely low. Radiological contamination of the River system is not significant and the contamination of the River system is not significant and the radium levels in beef, buffalo and fish are well below International standards.

Estimates of the total contaminant load originating from the site have been made (Table 1) and are based on water sampling over five years. Estimates of contaminants originating from individual sources are based on water sampling originating from individual sources are based on water sampling originating from individual sources are expressed season was above average by about 30%. Total releases of season was above average by about 30%. Total releases of contaminant contributions from individual sources are expressed contaminant contributions from individual sources are expressed the site.

The pollution sources and processes are now sufficiently well understood for practical ameliorative measures to be planned and executed.

## 1.6 Environmental Significance of Continuing Pollution from Rum Jungle

Pollution of the East Finniss River during mining operations largely eliminated aquatic life in that river and damaged vegetation. Continuing pollution does not appear to be causing further damage to vegetation downstream in the Finniss River.

TABLE 1

ANNUAL POLLUTION LOAD CARRIED BY THE EAST FINNISS RIVER

infall (mm) 896 1611 1542 1545 2  riod of flow in Dec Nov Nov Dec St Finniss May Aug July July July Ow (10 <sup>6</sup> m <sup>3</sup> ) 7.0 33.2 30.9 26  llution load (tonne) 44 77 51 45 49; 16 110 64 49; 16	Season	1969-70	1970-71	1971-72	1972-73	1973-74	Average	
riod of flow in Dec Nov Nov Dec st Finniss May Aug July July Ow (10 <sup>6</sup> m <sup>3</sup> ) 7.0 33.2 30.9 26  llution load (tonn,e)  the state of the s	Rainfall (mm)	968	1611	1542	1545	2000	1512	
ver       May       Aug       July       July         ow (10 <sup>6</sup> m³)       7.0       33.2       30.9       26         1lution load (tonne)       44       77       51       45         :       46       110       64       49         :       n.a.       24       19       16	Period of flow in	Dec	Nov	Nov	Dec	Nov		
ow (10 <sup>6</sup> m <sup>3</sup> ) 7.0 33.2 30.9 26  llution load (tonne)  thick the second of the second	River	Мау	Aug	July	July	Sept	•	•
llution load (tonne)  t 44 77 51 45  46 110 64 49  n.a. 24 19 16	Flow (10 <sup>6</sup> m <sup>3</sup> )	7.0	33.2	30.9	26	97	39	
. 44 77 51 45 . 46 110 64 49 . n.a. 24 19 16	Pollution load (tonne)						•	-
. n.a. 24 19 16		44	7.7	51	45	130	69	
n.a. 24 19 16	Mn :	46	110.	. 64	24	100	74	
	: uz	n.a.	24	19	16	40	25	
3300	SO <sub>4</sub>	3300	12 000	0099			. 0808	

ESTIMATED ANNUAL CONTRIBUTION OF HEAVY METALS FROM PRINCIPAL SOURCES AT THE RUM JUNGLE MINE SITE FOR THE 1973-74 WET SEASON

Source	, Cu	Annual Release S	Zn	
White's Overburden Heap	32	16	55	
Heap Leach Stockpile	32			,
Intermediate Overburden Heap	18	5	44	
White's Open Cut	8	40	:	
Old Tailing's Dam	5	6		•
Acid Dam		17		
Dyson's Open Cut	1	4		
Dyson's Overburden Heap	0.2	7		
Intermediate Open Cut	3	Ţ		

The only significant observable effects are the absence of fish in the East Finniss River and a decrease in the diversity and number of fish in the Finniss River near the junction with the East Finniss River during the dry season. Fish kills occur at the beginning of each wet season near the confluence of the East Finniss River with the Finniss River. These effects are believed to be due to the contaminant load originating from the Rum Jungle Mine site.

Some 30-40 years from now it is possible that the Finniss River System may need to be developed for an additional water supply for Darwin. If this eventuates the rehabilitation measures proposed later in this report should satisfactorily improve the water quality.

#### 1.7 <u>Unrecovered Mineral Resources</u>

Although some mineralisation remains in the immediate area it is quite uneconomic under present conditions to recover it in the foreseeable future.

Should any further mining operations disturb the area again, the Mines Branch could ensure that any rehabilitation measures implemented at this stage would be reinstated.

#### 1.8 Outlying Uranium Mines

Three other uranium orebodies were discovered in the vicinity of Rum Jungle. These were also developed by open cut methods and two were treated at the Rum Jungle Treatment Plant. None of these three outlying mine sites constitutes an environmental problem nor would they become so in the future. The open cuts and overburden heaps are not sources of pollution that can in any way be regarded as problems and no compelling need or reason exists for implementation of rehabilitation measures at these sites, although a program of tree planting on the overburden at Rum Jungle Creek South is desirable.

#### 1.9 Objectives for an Overall Solution

The principal objectives of alternatives examined in this study are:

- (1) to provide for aesthetic rehabilitation of the area by landscaping and the establishment of permanent vegetation;
- (2) to reduce or eliminate public health and safety risks;
- (3) to reduce continuing pollution originating from the site.

## 1.10 Alternatives for Pollution Control and Rehabilitation

In the following sections various areas within the site are discussed in terms of the specific problems and alternative remedial measures considered for their rehabilitation.

#### 1.10.1 The Heap Leach Pile and Area

The Heap Leach area consists of about 8 hectares. Half of the area is occupied by a low grade ore pile (about 370,000 tonnes) which was heap leached by Australian Mining and Smelting (AM & S)\* for the recovery of copper.

Chemical action and the action of iron and sulphur oxidising bacteria continue naturally within the heap releasing contaminants from the ore. Each wet season, runoff from and seepage through the heap carry a considerable burden of contaminants, the principal one of concern being copper, into the surface and groundwater system.

The heap leach pile is the most localised single source of contamination in the Rum Jungle area and contributes about a third of the copper annually released from the site. (See Table 2.) About three quarters of the contaminant load from the heap enters the East Finniss River via surface flow, the remainder apparently entering the groundwater system.

Since the heap is estimated to still contain some 3500 tonnes of copper, continuing discharge of significant amounts of copper from this site can be expected to occur, (as a result of natural mechanisms), for about a century.

Two practical alternatives were evaluated and costed for the solution of this problem. The first is to seal the heap with a carefully designed clay, gravel or crushed rock, and topsoil layer or a clay and topsoil layer differentially compacted and establish a permanent vegetation cover on this surface. This solution, which includes rehabilitation of the surrounding area, would cost approximately \$0.30 million.

The second alternative would be to remove the heap and dump it into White's open cut. This solution, which includes rehabilitation of the surrounding area would cost approximately \$0.75 million. The effect that the operation would have on water quality in White's open cut would depend upon the effectiveness of the overall solution chosen for White's open cut (see Section 1.10.3). However, it will be necessary to cover the heap leach material in the open cut with barren material and it is suggested that this be Dyson's Overburden.

The then AM & S (Australian Mining and Smelting) company, a subsidiary of The Zinc Corporation Ltd., has no relationship with the company presently bearing the same name.

This is considered along with proposals for Whites Open Cut in Section 1.10.3. This alternative is favoured because it would achieve permanent disposal of the heap.

The heap leach stockpile area is currently held under mining title by CRA Services Ltd.

#### 1.10.2 The Overburden Heaps

Four overburden heaps totalling 43 hectares, or 25% of the total affected site area, are the largest overall contributors to the pollution load. The principal contaminants of concern, the heavy metals, are released from the heaps by chemical and bacterially assisted oxidation and enter the river system in runoff from their surfaces or from seepage resulting from rainwater that percolates through the heap. It is estimated that the heaps contribute about half of the copper, about a third of the manganese and virtually all of the zinc annually entering the Finniss River system (See Tables 1 and 2.)

As the heaps contain significant quantities of pyrite  $(\text{FeS}_2)$ , it is evident that bacterially assisted leaching of heavy metals can be expected to continue for considerable time into the future.

The appearance of the heaps could be substantially improved by the establishment of a permanent vegetation cover by relatively simple and inexpensive techniques. These techniques should reduce soil erosion and contamination of surface runoff water, but could not be expected to satisfactorily reduce leaching of contaminants from the heaps. Rehabilitation of the four overburden heaps using these relatively simple techniques is estimated to cost approximately \$0.44 million.

In order to reduce significantly the amount of contamination released from the heaps a more rigorous solution would be required. The heaps would need to be contoured for better drainage of surface water and be sealed to prevent infiltration and seepage. This alternative would involve increased earthworks, more detailed design and construction procedures and greater expense.

Particular attention would have to be paid to providing a suitable sealing and covering layer that will support a permanent vegetation cover and good surface drainage system, possibly with engineered channels and drop structures where necessary. The design of the covering profile would need to provide for soil moisture storage capability to hold water without allowing it to infiltrate into the heap, to stabilise the surface against erosion and to provide for a permanent vegetation cover. Such a profile may consist of a layer opossibly up to about a metre in depth of first clay and then

topsoil differentially compacted, or alternatively may have a well compacted impervious stable clay sealing layer covered by a gravel or crushed rock layer for drainage capped with topsoil to support vegetation.

Rehabilitation and revegetation of the four overburden heaps using techniques of this type would cost approximately \$1.94 million.

### 1.10.3 The Open Cuts

Three open cuts occupy about 22 hectares or 11% of the affected site area. Two of these, White's and Dyson's Open-Cuts, were mined for uranium on behalf of the Government, copper and lead were also mined from White's open cut. The third, the Intermediate Open Cut was mined for copper by AM & S and is in the lease area held by CRA Services Ltd.

The open cuts also contribute to the annual pollution load entering the river system, contributing about a tenth of the copper, about half of the manganese and less than one hundredth of the zinc. (See Table 2.)

White's open cut is the largest and, of the three, is the main source of pollution contributed by seepage of contaminated water to surface and groundwater systems. It also presents the most difficult and expensive problem of the three open cuts. It contributes about 8% of the total copper and about 40% of the total manganese load. This open cut was used for waste disposal purposes in the later years of the operation of the treatment plant. It is partly filled with tailings, which were not neutralised on disposal, and the remaining volume contains highly contaminated water.

The problems involved in White's open cut are not entirely understood, nor are they ever likely to be, owing to the difficulties involved in identifying sources of pollution in the open cut and the nature and location of seepage exits. It is believed however, that there are two principal sources of contamination in the open cut, firstly, the upward leaching or diffusion of contaminants from the tailings on the bottom, and secondly by the continuous leaching of heavy metals from pyritic rock in the southern perimeter of the open cut as a result of chemical and microbiological oxidation.

Several alternative actions were examined for White's open cut, only one of which can be regarded as a satisfactory practical solution.

This alternative, consists of creating barriers in the open cut above the tailings and the pyritic slates in the southern perimeter and broadly involves at least a partial refilling of the open cut with rock and earth fill. Water displaced by the operation would need to be treated before release to the river system.

Several schemes were considered, each involving the dumping of different amounts of material in the open cut, with costs approximately as follows:-

		Cost \$ Millions
Scheme 1 :	Dump Heap Leach Pile and Dyson's Overburden	5.0
Scheme 2:	Dump Heap Leach Pile, Intermediate Overburden and Dyson's Overburden	7.3
Scheme 3 :	Dump Heap Leach Pile, Intermediate Overburden, Dyson's Overburden, and completely refill with barren material from White's or White's (North) Overburden Heap.	9.0

The Intermediate open cut is a small contributor to the pollution load, contributing by seepage to surface and groundwater systems about 3% of the copper, 4% of the manganese and less than 1% of the zinc. The open cut is full of water but is somewhat less contaminated than water in White's open cut.

The problems arising from this open cut are minimal. It is considered possible to treat the water in the open cut and divert the East Finniss River through it. This proposal would cost about \$0.25 million. Alternatively the open cut could be partially filled with waste rock, following treatment of the water, for about \$1.25 million.

Complete refilling of the open cut, with treatment of displaced water, would cost about \$2.65 million.

A further alternative has been suggested. Owing to the similarity of the Intermediate Open Cut with the future Jabiluka II open cut, in the Alligator Rivers Uranium Region it could usefully serve as a scale model for environmental research. This would be, however, only a short term usage and rehabilitation of the open cut would eventually need to be considered.

Dyson's open cut is a small contributor to the pollution load. It is partly full of tailings and could be rehabilitated relatively simply by removing the water retaining embankment and covering and revegetating the tailings using techniques that are envisaged for the rehabilitation of the Old Tailings Dam. (See Section 1.10.4). This would cost about \$0.15 million.

## 1.10.4 The Old Tailings Dam

Tailings disposal up until 1961 resulted in the creation of a large (31 hectares, 15% of site) unbounded and eroding area of tailings. The tailings material is so inhospitable to vegetation that no natural vegetation at all has encroached on it and it continues to be aesthetically unacceptable.

The area contributes little to the overall heavy metal contamination of the Finniss River system. However, surface erosion by wind and water continues unabated, the latter generating a continuous source of contaminated sediment that can be found along the length of the East Finniss River.

Radiation levels in the tailings area are several times higher than natural background levels. However, radiation exposures which could result from these levels are not a radiological hazard provided that access by members of the public is restricted to that of only a transitory nature.

Two alternatives to mitigate these problems were examined.

The tailings could be dumped into White's open cut and the vacated area revegetated at a cost of about \$1.0 million. Alternatively the tailings could be covered with rock and topsoil and revegetated in situ for a cost of between about \$0.6 million to \$1.0 million. This would satisfactorily reduce \$0.6 million and radiation levels over the tailings area.

## 1.10.5 Acid Dam, Sweetwater Dam, Watercourses and Areas Affected by Seepage.

About 55 hectares (27%) of the affected site was denuded of vegetation, and affected by sheet and gully erosion, as a consequence of waste management practices involving storage or disposal of contaminated process effluents, and by contaminated seepage from waste heaps.

Remedial measures required for the rehabilitation of these areas involve the implementation of three basic types of work. These are:

- return all stream beds to an evenly graded longitudinal profile providing free draining conditions thus preventing the retention of floodwater and allowing affected areas to dry out and revegetate.
- remove all dead trees, stumps and fallen trunks.
- landscape, cultivate and revegetate.

These works would cost approximately \$0.18 million.

Although the course of the East Finniss River from the mine site to its junction with the Finniss River, was significantly affected during mining operations and continues to be a source of pollutants due to tailings material deposited along its bed, it does not constitute a major problem. It is not considered necessary to carry out rehabilitation works as it can be expected that the river course will gradually stabilise and recover, particularly if pollution from the mine site is reduced.

#### 1.10.6 Fencing of the Site

In order to allow establishment of permanent vegetation cover on rehabilitated areas it will be necessary to prevent buffaloes and other large animals from grazing these areas. It is therefore proposed to fence rehabilitated areas. This will cost \$50,000.

#### 1.11 Alternative Rehabilitation Strategies

Alternative remedial measures which have been examined (Section 1.10) may be combined in various ways to produce a number of strategies for overall rehabilitation of the site.

The Working Group considered the advantages and disadvantages of different possible measures and agreed that the following should be essential additions to any program to rehabilitate the site:

- Landscaping, covering and establishing vegetation on the Old Tailings Dam and the tailings in Dyson's Open Cut.
- Clearing, landscaping and revegetation of the acid and sweetwater dams, watercourses and areas affected by seepage.
- Treatment of water in the Intermediate Open Cut and diverting the East Finniss River through the Open Cut.
- Erection of a strong fence around the Site.

The alternative strategies examined were limited to eight. These are based on possible alternative measures for treating the Heap Leach Pile, the Overburden Heaps and the Open Cuts. These strategies are described in Table 3.

Because any rehabilitation program should be expected (Section 1.9) to alleviate the three types of problems contributing to overall environmental degradation at the site (Section 1.5) a methodology was developed to quantify these and the three types of benefits to be gained i.e. pollution: reduction, aesthetic improvement, and elimination of risks? This methodology was used to evaluate and compare the eight strategies from the cost-benefit point of view. The results of this evaluation are also presented in Table 3.

TABLE 3 - ALTERNATITE NEWABILITATION STRATEGIES - BENEFITS AND COSTS

	•							
	Notional	Notional Estimated Benefits	efits	,% Reduc Metal Fo	% Reduction of H Metal Follution f	Heavy from Site	Cost	
Description of Strategy	Pollution Reduction (copper)	Aesthetic Rehabilita- tion etc.	Total Cut of 100	Cu	Mn	Zn	\$ millions	
The following items are common to all strategies except H where the Intermediate open cut is filled:	•	<b>)</b>						
Old Tailings Dam - cover and establish vegetation)  Dyson's Open Cut - cover tailings and establish  vegetation				•	•			•
streams and revegetate	4	50	24	ω	6	LIN	1.63	
Intermediate Open Cut - treat water and divert }  Last Finniss River through open cut  Fence site	,			•				
					, .			
simple techniques , White's Open Cut - no action	Σ Τ	23	17	٠ کو ۲	<del>7</del> 7	O N	2.5(	
B. Heap Leach - cover and establish vegetation Overburden Heaps - landscape, cover and	50	37	57	40	38	. 02	3.87	
on no action	• •				-	•		
C. Heap Leach - dump into White's open cut, cover with Dyson's overburden					-		•	
Overburden Heaps - establish vegetation using	22	40	62	44	46	50	66.9	
			-	•	× *		-	
				-				

TABLE 3 (Cont'd).

			•		i I	g 28 f	
Description of Strateory	Notional	Estimated Benefits	nefits	% Reduction Metal Pollut	of ton	Heavy from Site	Cost
	Pollution Reduction (Copper)	Aesthetic Rehabilita- tion etc.	Total Out of 100	Cu	Mn	Z'n	\$ millions
D. Heap Leach - dump into White's open cut, cover with Dyson's overburden Overburden Heaps - landscape, cover and establish vegetation White's Open Cut - partly refill, treat water - Scheme 1	35	43		70	56	70	8.18
E. Heap Leach - dump'into White's open cut, cover with Intermediate and Dyson's overburden Overburden (White's) - establish vegetation using simple techniques White's Open Cut - treat water, refill - Scheme 2	30	45	75	09.	. 09	746	9.25
very not mat pit	38	47		. 92	89	74	10.23
its benefits would be equal to those of Strategy G. Overburden (White's) landscape, cover and establish vegetation White's Open Cut - treat water, refill - Scheme 2						,	
	·						

- Contide

TABLE 3 (Cont'd)

	su			
	\$ millions	11.83	. 12.63	
Heavy from Site	Zn	74	9/	
of on	Mn	. 76	78	
% Reduction Metal Polluti	Cu	82	78	
enefits	Total Out of	88	98	
Estimated Benefits	Aesthetic Rehabilita- tion etc.	47	47	
Notional	Pollution Reduction (Copper)	41	39	
Description of Strategy		Heap Leach - dump into White's open cut, cover with Intermediate overburden and Dyson's overburden Overburden Overburden (White's) - landscape, cover and establish vegetation White's Open Cut - treat water, completely refill - Scheme 3	As for F (above) but completely refilling the Intermediate open cut	

The Working Group considered that a minimum reduction of copper pollution by two thirds is desirable. Whilst the working Group considered that copper was the most serious contaminant it also considered that substantial reduction (greater than 50%) must be achieved for manganese and zinc.

The Working Group considered that this reduction of contamination would achieve:-

elimination of the fish kills in the Finniss River attributable to effluents from the mine site.

elimination of transient unsuitability of water quality in the Finniss River, due to the same cause, and

contribute to the natural regeneration of vegetation and other aquatic life along the course of the East Finniss River below the mine site.

1.12 Consideration of Alternative Strategies and Adoption of Options

Of the strategies that have been reported in Section 10.4 the Working Group rejected Strategies A, B and C because the degree of pollution reduction which would be achieved is insufficient. It also rejected Strategy E because, as it can be seen in Table 3, it has a higher total cost and would achieve lower total notional benefits than for Strategy D.

Strategy D-is considered to be the minimum satisfactory Strategy for achieving the objectives of aesthetic improvement reduction or elimination of public health and safety risks and reduction of pollution. Table 3 shows that Strategy D for a total cost of \$8.18 million would achieve estimated total notional benefits of 78%, and a 70% reduction of copper, 56% reduction of manganese and 70% reduction of zinc pollution.

Strategy F for a total cost of \$10.23 million is estimated to achieve total notional benefits of 85%, with a 76% reduction of copper, 68% reduction of manganese and 74% reduction of zinc pollution. However, because of the reduction of zinc pollution. However, because of the possibility that Strategy F could result in almost completely refilling White's Open Cut it could achieve benefits which approach those of Strategy G. Hence, Strategy F could achieve total notional benefits of 88%, and 82% reduction of copper 76% reduction of manganese and 74% reduction of zinc pollution.

Strategy H, which is identical with Strategy F other than for refilling the Intermediate Open Cut, would achieve little additional benefit for the additional \$2.4 million involved. It can be disregarded unless it is thought desirable: to refill the Intermediate Open Cut.

The Working Group consider that the estimated benefits from Strategy F would effectively return the site to a condition substantially similar to that prior to commencement condition substantially similar to that prior to commencement of the mining operations. The Working Group therefore considers that the additional benefits of Strategy F over considers that the additional expenditure of \$2.05 million, Strategy D, for the additional expenditure of \$2.05 million, are warranted and therefore recommends that Strategy F benefits adopted as the preferred option.

The Working Group considers that the order of preference should be F, D followed by H but only if it is considered the Intermediate Open Cut should be 'filled.

A significant benefit that has not been quantified and which can be expected to result from the rehabilitation of Rum Jungle is the experience which will accrue in rehabilitating an abandoned mine site. This will be particularly valuable in the abandoned management and rehabilitation of new uranium environmental management and rehabilitation of new uranium mines in the Alligator Rivers Region and will provide useful information relevant to heavy metal mines and treatment plants generally.

## 1.13 Implementation of a Rehabilitation Program

A considerable proportion of work envisaged for an overall rehabilitation program is relatively straightforward and could proceed immediately provided an adequate commitment of funds, labor and equipment is made available.

However, some elements of the program require further study or engineering evaluation before the details of the selected strategy could be specified. The Working Group proposes that a Steering Committee be established to advise or and review the operation. A small Project Group would need to and review the operation. A small Project Group would need to be established to provide and/or coordinate the detailed be engineering feasibility and design services which will be engineering feasibility and design services which will be required. The Working Group considers that one or more full required with appropriate qualifications and experience allocated to the Project Group.

A Submission should be made to Cabinet for an immediate allocation of funds for the establishment of a Project Group finalise an overall rehabilitation strategy.

Much of the work envisaged for an overall rehabilitatic program could be performed in one or two dry seasons. However, should a scheme of substantially backfilling the open cuts, the even only White's open cut, be chosen it is likely that completion of works could take up to 5 years depending on commitment of resources.

At the commencement of the works a monitoring program should be established in order to evaluate the success of the operation. Such a program would provide considerable operation on the effects of various techniques, which would information on the effects of various techniques, which would be useful not only in rehabilitating future uranium mines be useful not only in rehabilitating future uranium mines be useful not only in rehabilitating future uranium mines be useful not only in rehabilitating future uranium mines be useful not only in achieved by various works.

#### 1.14 Conclusions

- 1. The Working Group concludes that satisfactory rehabilitation of the Rum Jungle site can be achieved.
- 2. Various strategies have been investigated. It is considered that the minimum satisfactory strategy for achieving the objectives of aesthetic improvement, reduction or elimination of public health and safety risks and reduction of pollution would cost \$8.2 million. Expenditure of less than this will not achieve the objectives considered to be essential.
- 3. To return the site to substantially the same condition as it was prior to the commencement of mining operations, which includes filling of both White's and the Intermediate Open Cuts, would cost \$12.6 million.
- 4. However, the Working Group considers that it is not necessary to refill the Intermediate Open Cut and concludes that an expenditure of \$10.2 million would effectively return the site to a condition substantially similar to that prior to mining operations, with the exception that the Intermediate Open Cut would remain as a small lake and White's Overburden would remain as a hill.
- 5. The Working Group considers that it is desirable to achieve the objectives of study and concluded that the rehabilitation of the Rum Jungle mine site will provide a valuable demonstration of environmental rehabilitation after mining which will be particularly relevant to new uranium mines in the Alligator Rivers Region. It will also provide useful information for rehabilitation of heavy metal mines and treatment plants generally.

#### 1.15 Recommendations

- 1. The Working Group recommends that a Submission be presented to the Government setting out the alternative options proposed by the the Group, including in it the Group's preference for Strategy F which involves works of the order of \$10.2 million.
- 2. The Working Group further recommends that, when the Government decides what further rehabilitation work is to be undertaken, that a Steering Committee be established to advise on and review the necessary operations and that a small Project Group with one or more full time officer(s) be established to provide and/or co-ordinate the detailed engineering feasibility and design services which will be required.

#### 2. INTRODUCTION

### 2.1 Purpose of this Report

The purpose of this document is to report to the Government on works, and the order of magnitude of their costs, required to rehabilitate the area of the abandoned Rum Jungle Mine site and its environs and to mitigate pollution. The report has been prepared by the Working Group which was convened by the Department of the Northern Territory at the direction of its Minister.

## 2.2 <u>Initial Clean-up Operations</u> (October-December 1977)

An allocation of \$300,000 was made available to the Department of the Northern Territory under its 1977/78 Civil Works Program for works to clear and rehabilitate the treatment plant area. These works consisted of the following:

- (a) The demolition, removal and disposal, by burning, burial or dumping into White's Open Cut, of all unwanted buildings, concrete slabs, foundations and miscellaneous equipment and rubbish.
- (b) White's lead ore stockpile material was removed and used as filling in the treatment plant area and other low lying areas. This was then covered with Dyson's Bogum\* stockpile material which was then covered with topsoil varying in thickness from 15 cm to 45 cm. The area has been contoured to fit into the surrounding environs.
- (c) Other disturbed and bare areas have been covered with topsoil.
- (d) Seed and fertiliser have been applied to topsoiled areas. Furthermore, natural revegetation is also expected to occur from seed present in the imported topsoil, and in fact has already commenced. The topsoil borrow pits have been reworked to enable them to revegetate naturally.
- (e) Unwanted bag ore samples have, with the approval of the Mines Branch (DNT), been dumped into White's Open Cut. Core samples continue to be stored in serviceable buildings.
- (f) Approximately 220 tonnes of a mixture of high grade uranium ore and waste rock has been removed to a safe storage depot off the site.

Bogum - below ore grade uranium mineralisation.

These works were confined specifically to the plant and stockpile area only; it was not intended that they should touch other areas of the mine site affected by mining operations.

In addition to the above works, buildings that are to remain on the site are currently undergoing improvement. Some trial plots are also being attempted on the tailings to establish requirements for the reduction of radiation levels over the tailings and for the establishment of vegetation cover over the area.

#### 2.3 Proposals for Further Rehabilitation

In addition to the above action, the Minister for the Northern Territory arranged for a Working Group, coordinated by the Department of the Northern Territory, to be set up with the purpose of studying further rehabilitation of the Rum Jungle Mine Site as a whole.

A Working Group of Officers of the Department of the Northern Territory and the Australian Atomic Energy Commission was established in September 1977 to analyse the various studies and reports which have been made to date, to make any further investigations which may be necessary and to submit recommendations on the most suitable solutions to the problems. It was agreed that if possible such studies were not to delay rehabilitation measures which, it was understood, the Government was anxious to see undertaken as soon as possible. On receipt of the report the Government would decide what extra funds would be made available for rehabilitation works.

Representatives of Conzinc Riotinto of Australia Ltd. (CRA) were invited to participate in the Working Group after the first meeting because part of the affected area is held under mining title by CRA Services Limited. The Department of Construction, which performed the initial clean-up operation at the site, participated in the Working Group after the second meeting. (The composition of the Working Group is listed in Appendix 1.)

The attitude of the Government in respect of rehabilitation of Rum Jungle was indicated in the announcement in Parliament on 25 August 1977 of decisions on development of Australia's uranium resources. The Deputy Prime Minister and Minister for National Resources made the following statement(1):

"Let me give an illustration of what will not happen in the future. I previously mentioned Rum Jungle. That mining operation was carried out with inadequate concern for the environment. It was an operation which reflected environmental attitudes of 25 years ago which Australians would not tolerate today.

I make it clear that there will be no more projects like Rum Jungle. We will embark on a clean-up operation at Rum Jungle. As a first step \$300,000 has been provided in the 1977-78 Budget estimates of the Department of the Northern Territory for clearance and rehabilitation of the mining area. The Department of the Northern Territory will coordinate a study of a comprehensive program of rehabilitation of a whole area. The Government will take further decisions when that study is completed."

#### 3. THE PROBLEM

#### 3.1 History

Throughout the operating life of the Rum Jungle Mine and treatment plant (1953-1971), six main orebodies were discovered. Three of the orebodies were located in the immediate Rum Jungle Mine area (see Figures 1 & 2). These were white s, which was mined for uranium, copper and lead, Dyson's, which was mined for uranium only, and the Intermediate, which was mined for copper only. The remaining three, Mt. Burton, was mined for copper only. The remaining three, Mt. Burton, Rum Jungle Creek South and Mt. Fitch were Uranium orebodies located some distance from the Rum Jungle Mine site. Five of the orebodies were recovered by open cut mining. The Mt. Fitch uranium deposit, which is rather small and of low grade, was uncovered but not excavated.

Uranium mining and ore treatment operations were carried out by Territory Enterprises Ltd. (TEP) on behalf of the Commonwealth Government. The Intermediate copper orebody was—mined by Australian Mining and Smelting (AM & S)\*. Mill grade ore was treated in the TEP treatment plant and low grade ore was heap leached. The history of the exploration, discovery and development of uranium deposits in the Rum Jungle area is well reported in the literature (see References).

## 3.2 Environmental Management of Rum Jungle Mining Operations

Pollution of the Finniss River system resulting from mining and ore treatment operations at Rum Jungle first became apparent in about  $1960^{(2)}$ , although proper recognition of the significance of the problem did not occur until  $1969^{(3)}$ .

Pollution from the early years of the operation was caused by waste disposal practices which resulted in tailings and contaminated effluents entering the East Finniss River nea the Rum Jungle mine and treatment plant site.

AM & S, a subsidiary of the Zinc Corporation, had no relationship with the company presently bearing the same name.

Departmental and company records show that efforts were made to identify the sources of pollution and to understand and ameliorate the overall problem. Considerable water sampling was undertaken, particularly in the late sixties, by the Water Resources Branch of the Department of the Northern Territory, and by TEP. As a result, waste management practices were altered through later stages of the operations. Tailings were disposed to the open cuts and treatment plant effluents were partially contained. It was not until virtually the end of the life of the operation that treatment plant wastes were contained on a no-release basis.

In addition to the direct contamination of the Finniss River system by the release of treatment plant effluents, additional contamination occurred by natural leaching of heavy metals from the overburden heaps (i.e. waste heaps), and by overflow or seepage of contaminated water from the open cuts. Following closure of the operation these sources have continued unabated as a result of natural processes.

Mining, ore treatment and waste disposal operations were conducted according to accepted mining practice of the time. The Mining Ordinance did not apply to the control of uranium mining because it was controlled under the Atomic Energy Act. The Mining Ordinance did, however, apply to the AM & S Intermediate copper mine.

Mining Regulations (under the Northern Territory Mining Ordinance), which were in force at the time of the operation, relating to water pollution control limited contaminants in solution or suspension to ".... 800 grains per gallon ...." i.e. 11,400mg/l\*. Even though this regulation was not applied to the uranium mining and treatment operation, available evidence suggests that waste disposal practices at Rum Jungle did not exceed this standard.

A comprehensive approach to environmental management did not exist at the time, let alone in Mining Regulations, and the overall operation began to attract criticism on environmental grounds in the mid sixties when environmental awareness became more pronounced.

Very little information has been reported in the literature on the waste management practices and environmental aspects of the mining and treatment operations while the project was actually operating. This reflects the completely different approach at the time from the present philosopy of environmental management of mining operations, which

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Mining Regulations (1966) Sn. 200(2). This standard currently remains unchanged in the Regulations although recent amendments (1977) make it possible to effect much stricter control.

coincidentally was just emerging as standard practice as the operational life of the Rum Jungle project expired. Considerable information relating to mining, ore treatment and waste disposal practices employed during the operation has, however been gleaned from various sources. (See References, particularly (4).)

### 3.3 Environmental Studies 1969-1975

Following an evaluation of the operations at Rum Jungle by officers of the Australian Atomic Energy Commission in 1969<sup>(3)</sup> a more detailed water sampling program was undertaken in order to evaluate past and continuing pollution of the Finniss River system <sup>(6)</sup>.

Following this study, the realisation that knowledge of the precise extent of pollution in the area and that the mechanisms giving rise to the natural release of contaminants following closure of the mine was inadequate, led to the initiation of detailed environmental studies in October 1973. These environmental studies were conducted jointly by the Australian Atomic Energy Commission and the Department of the Northern Territory, and took place over the period October 1973 to September 1975. These studies are reported in considerable detail in Reference (4).

The Study had as its objectives:

- to identify the sources of pollution and their relative importance,
- to determine the extent of pollution and its seasonal variation,
- to obtain an understanding of the basic, physical, chemical and biological mechanisms concerned in the continuing pollution,
- to determine the fate of radium and other heavy metals discharged during the operation, and
- to assess and cost remedial measures.

These objectives were largely met although the proposed assessment and costing of remedial measures was not completed at the time for reasons stated in the Foreword to that Report. The results and conclusions arising from these detailed environmental studies are broadly as follows and are quoted from the Summary Report, (Conclusions p.20)(5);

"The principal heavy metal pollutants have been identified as copper, manganese and zinc. The major sources of these metals within the mine area are White's Open Cut, White's Overburden Heap, the Intermediate Overburden Heap, and the Heap Leach pile. Some uncertainty remains about the relative importance of several sources but these are understood well enough for remedial measures to be planned. There is agreement between the sum of the contributions estimated for individual sources and the total load of chemical pollutants which is observed actually to enter the Finniss River System."

"Chemical and biological evidence of severe pollution is evident at the mine site and along the course of the East Finniss River from the mine site to its junction with the Finniss River. There is evidence that fish are reduced in numbers in the Finniss River between the East Finniss River and Florence Creek junction, but not below the latter point. Local and theoretical studies have given some understanding of the rechanisms which maintain the release of pollutants at present levels. The main factors are bacterial leaching of sulphide containing ores and the highly seasonal rainfall."

Furthermore, among the conclusions, the following points exphasised:

"Since it is probable that bacterial leaching is of rajor importance in causing the continuing dispersion of collutants this must be taken into consideration in planning the disposal of wastes including overburden and waste rock. If an one with a sufficient sulphide content is exposed to air and water it may cause trouble. Disposal of it into an open cut will not necessarily abolve the problem and may make it worse if microbial action is possible."

"The loss of pollutants from uncontrolled sources ra; continue for a long time; in White's Overburden Heap for example, there seems to be sufficient sulphide to fuel the leaching process for up to 100 years."

Since the nature and extent of continuing pollution are description will understood to be able to evaluate remedial measures and to estimate their approximate the Working Group has adopted the approach that this can without delay.

Since the completion of basic environmental studies some search has continued into specific problems relating search array to the release of contaminants from the overburden search will provide significant further understanding of the search, nor is it expected that it will lead in the

foreseeable future to superior solutions than those alternatives which are already available and which have been evaluated in this report. Alternative rehabilitation measures examined and evaluated in this report are works which can be planned in detail and implemented if and when funded.

# 3.4 Evaluation of the Problem

Environmental problems at the Rum Jungle mine site, which continue to attract criticism and adverse publicity, can broadly be considered to be threefold:

- despoliation of the natural landscape an area of approximately 200 hectares of land,
  including river beds and banks, and vegetation has
  been significantly affected by mining operations;
- (b) public health risks various hazards exist which pose some risks to
  public health and safety;
- heavy metal pollution significant heavy metal pollution of natural waters
  results principally from bacterially assisted
  oxidation and leaching from the waste heaps.

The nature and extent of these problems in the Rum Jungle area are briefly discussed below. The three outlying uranium mines, Mount Burton, Rum Jungle Creek South and Mount Fitch are not included in the following discussion. They do not present environmental problems and are excluded from consideration in this study for reasons which are given in background discussion in Section 4.8.

# 3.4.1 Despoliation of the Natural Landscape

During the mining and treatment of ores at Rum Jungle about 200 hectares of undulating country straddling the East Finniss River was directly used and significantly affected by the operations.

The site was largely transformed by the creation of several open cuts (now filled with water), their associated overburden waste heaps, an area of tailings, a low-grade ore leaching pile, and areas significantly affected by various miscellaneous works, including areas of river beds and banks which were affected by storage of acid process waters. Areas in this category also include Old Tailings Creek, which has been significantly affected by acid effluents, deposition of tailings, and erosion of stream bed and banks. The composition of the total affected area by current land use, occupancy or state is summarised in Table 4 (see also Figure 2).

During the operation virtually no consideration appears to have been given to how mining of the open cuts and construction of the overburden heaps might facilitate rehabilitation. Following the actual closure of the mine, works of only a minor nature were undertaken to clean up the plant area, and the Acid and Sweetwater Dams were breached.

#### TABLE 4

# AREAS AFFECTED DURING MINING OPERATIONS

FFECTED AREA	PROXIMATE AREA (HECTARES)
White's Open Cut	11
White's Overburden Heap	26
White's Overburden Heap, (North)	4 9 •
White's; areas affected by seepage from overburden heap	
Dyson's Open Cut	6 10
Dyson's; area affected by seep	
from overburden neap	5
Intermediate Open Cut	7
Intermediate Overburden Heap Heap Leach, Pile and	8
Ponds area	31
Old Tailings Dam Old Tailings Creek	3
Acid Dam (East Finniss River) Upper Dam Lower Dam	
Sweet Water Dam	8 45

Le

The East Finniss River has also been significantly affected between the mine site and its junction with the Finniss River, though particularly more so below the entry of Old Tailings Creek, due to the destruction of stream bed and bank vegetation primarily by acid process waters and tailings material which were released during mining and treatment operations. Tailings material can still be found along the East Finniss River from the mine to its junction with the Finniss River.

# 3.4.2 Public Health and Safety Risks

A number of public health and safety risks exist in the area affected by mining operations.

The three open cuts, White's, Dyson's and the Intermediate, and particularly White's, contain water which is contaminated and unfit for consumption or recreation. White's open cut has been fenced from public access since closure of the mine.

Some sections of the affected creek beds, and particularly the East Finniss River adjacent to the Heap Leach area, are hazardous because bed and bank material are similar in nature to quicksand.

Small liquor retention ponds adjacent to the Heap Leach pile fill with contaminated seepage from the pile each wet season. In the dry season the liquor evaporates exposing acidic sludges.

The tailings area remains uncovered and continues to erode by wind in the dry season and by water in the wet season, allowing continuing dispersal of contaminants contained in the tailings, including heavy metals and radioactive daughter products of the uranium decay chain, including radium and radon. (It should be noted, however, that the concentrations or amounts of these materials are relatively low and are not causing any significant health hazard.)

# 3.4.3 <u>Heavy Metal Pollution of the Finniss</u> River System

Contamination of the Finniss River first observed in about 1960 originated principally from direct disposal to the Finniss River system, via Old Tailings Creek, of tailings and acidic process effluents. Further contamination of the river system by treatment plant effluents continued under various waste management practices until about 1969 when for the first time a policy of complete retention was implemented.

Although the principal impact of the plant and mine area on the eye of the casual observer is the unsightly nature of the mine workings, the sterile tailings area, and the bare overburden heaps, the principal environmental problem is the seasonal contamination, particularly by heavy metal and sulphuric acid, of runoff and seepage entering the East Finniss River.

The sources of pollution have been identified and the nature and extent of chemical and biological mechanisms and seasonal factors governing the continuing release of contaminants are now reasonably well understood (4).

Principal sources of pollution in approximate order of their importance as contributors are:

- White's Overburden Heap
- The Heap Leach Pile
- The Intermediate Overburden Heap
- White's Open Cut
- Old Tailings Dam
  - Acid Dam

Contamination enters the East Finniss River in slugs of fluctuating concentrations from the beginning of the wet season to early in the dry season. The annual input of contaminants to the East Finiss River varies considerably (see Tables 1 and 2) and depends on a complex interrelationship of a number of factors, particularly the rainfall occurring at the site itself, the flow in the East Finiss River past the site, and physio-chemical conditions of the site as a result of the preceding dry and wet seasons. In years of above average rainfall the total pollution load entering the river system increases proportionally more than the rainfall.

Detailed data on the nature and quantity of contaminants contributed from each individual source have only been obtained from studies performed of the 1973-1974 wet season cycle (see Table 5). As this wet season had a rainfall above average by about 30% the input of contaminants during this season can be expected to have been considerably higher than for an average year. In this respect estimates of the total contaminant load coming from the site shown in Table 1 for the 1971-1972 and 1972-1973 wet seasons are more likely to be representative of the average year.

The mechanisms responsible in the pollution cycle are too complex to discuss in detail but a few observations are made to show the irregular and dynamic nature of the cycle.

The first heavy rains which produce runoff and river flow result in an initial flush at the beginning of the wet season of highly contaminated water. The contaminant load arises from the dissolution of precipitates left behind on surfaces and in the river bed by evaporation after the previous wet season and from oxidation or weathering of material since the previous wet season. Hence the first flush may contain considerable contamination resulting from the residue from the previous wet season.

The copper contribution results largely from leaching of the heap leach pile which occurs relatively early in the wet season and also from overburden heaps later in the wet season.

TABLE 5

# ESTIMATED RELEASE OF HEAVY METALS (IN TONNES) FROM PRINCIPAL SOURCES AT THE RUM JUNGLE MINE SITE (1973-74 WET SEASON)

			,
Source	Annual release (tonnes)		
	Cu	Mn	Zn
Dyson's opencut	. 1	3	
Dyson's overburden heap	0.2	5	
White's opencut	8	30	
White's overburden heap	29-53	11-19	17-31
Intermediate opencut	3	3	0.3
Intermediate overburden heap	16-30	2.5-4.5	13-25
Heap leach pile	32-42		٠
Tailings area	5	. 3.5	
Old Acid Dam		. 12	
TOTAL	95-142	70-80	30-56

Note: Rainfall in the 1973-74 wet season was 30% above average. Releases of contaminants would be considerably less in a year of average rainfall.

(See Tables 1 and 2)

The manganese contribution results largely from seepage from White's Open Cut but only occurs late in the wet season when the level of the water in the open cut is raised by wet season inflows.

The variation in pollution load, which can be expected to occur from year to year in the East Finniss River as a function of variations in annual rainfall, is indicated by estimates, which have been derived from water sampling data (1969-1974), and which are given in Table 1. Graphical representation (Figure 3(a)), of data given in Table 1 confirms the rather rapid increase in pollution load carried by the East Finniss River as a function of increases in annual rainfall. Figure 3(b) illustrates the exceedingly large increase in pollution load carried by the East Finniss River which occurs with rather small increases in annual river flow.

Owing to the nature and size of the overburden heaps and the sulphide content in them, the most significant sources of pollutants are expected to continue releasing substantial quantities of heavy metals for the order of about 100 years.

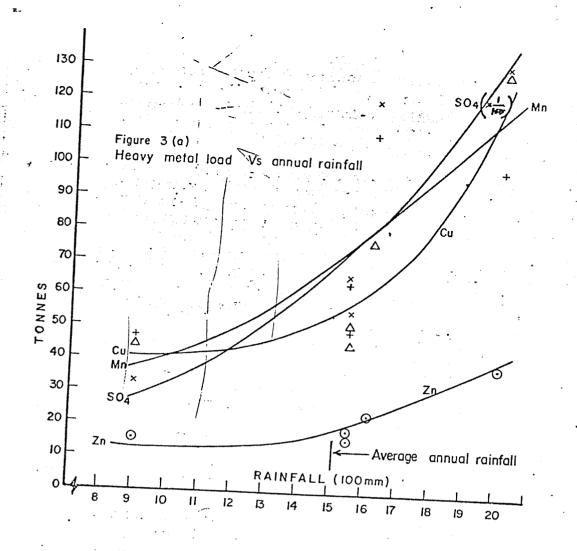
# 3.5 Environmental Significance of Continuing Pollution from Rum Jungle

The state in which the Rum Jungle Mine site was abandoned is unacceptable by present standards and leaves much to be desired in terms of restoring abandoned mining areas to their former condition. The area is not only aesthetically unpleasant, but also has a number of public health and safety hazards.

Furthermore, considerable pollution of the river system is continually occurring, largely as a result of bacterially assisted leaching of heavy metals from the overburden heaps. The total annual contribution of heavy metals from the major sources in the area has been approximately estimated; in 1973-74 (Table 5) this was about 95 to 142 tonnes of copper, about 70 to 80 tonnes of manganese and about 30 to 56 tonnes of zinc, with thousands of tonnes of sulphate and significant quantities of other less toxic contaminants also present.

Having regard to the current climate of concern about the impending development of much larger uranium mines in the Alligator Rivers Region, the area is a rather bad example of abandonment of mine site, not least of all because it was a uranium mine.

In terms of the actual significance or effect of continuing pollution on the local or regional environment there is no observable direct effect, detriment or inconvenience to local or regional human groups or populations on their activities, even though past and continuing effects on aquatic ecology are still observable.



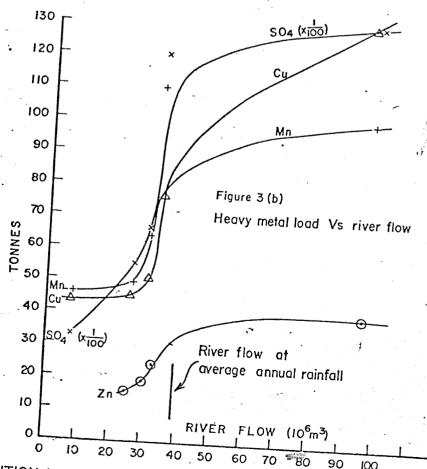


Figure 3 ANNUAL POLLUTION LOAD CARRIED BY THE FINNISS RIVER EAST BRANCH

During the mining and treatment operations, about 100 square kilometres of the Finniss River Flood Plain were affected by contaminants, which are now mainly concentrated in the surface layers of the soil on the flood plains. highest concentrations occur near river banks, particularly at sites where waterholes discharge onto the plains. Most of the total discharge of manganese and zinc and two thirds of the copper can be accounted for if the concentrations recorded in flood plain surface soil apply to a depth of 10 cm.

The significance of the observed heavy metal concentrations is rather uncertain, since copper and molybdenum antagonistic, and there are no data on the molybdenum status of the area. However, the present levels of copper and of manganese in forage grasses appear to be on the borderline of stock injury although this has not been observed.

Samples of flesh and offal of cattle grazing on the Finniss Plains show insignificant quantities of heavy metals and are within International consumption standards. The second second second

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Virtually all of the radium originally present within the ore has been retained within the tailings. Of the small amount of radium lost only a fraction appears to have been retained in the surface soil on the flood plains. was some and

Several routes can be postulated for human exposure to radioactivity in the Finniss Plains area; these include consumption of locally grown fruit and vegetables, local aquatic food including crocodile and mussels, and goose, beef The most critical exposure route would be and buffalo meat. for a hypothetical Aborigine who resided permanently on the plains living on a quite extreme diet of the above foodstuffs; such an exposure route would give a total annual intake of radium about the same as the annual limit derived from the International Commission on Radiological Protection recommendations on dose limits. The maximum permissible body burden of radium-226 would be reached only after 50 years exposure at these limits. At this body burden the equivalent health risk would be similar to that involved in smoking 5 cigarettes per year, or travelling 150 miles by car or 750 miles by air.

It is not possible to say how much of the estimated intake for this exposure route is due to naturally occurring radium. It should be noted that the estimated radium intake arising from natural sources in the Magela Plains of the Alligator Rivers Region is almost identical for a similar group living on a similar hypothetical diet.

Radium levels in beef and buffalo grazing on the Finniss Plains and in fish taken from the Finnis River have been found to be well below International standards.

The only permanent observable effects are the virtual absence of aquatic flora and fauna species in the East Finniss River in the 10 km downstream of the mine, and the depletion of species for a short distance in the Finniss River itself. The high concentrations of heavy metals and the low pH resulted in few aquatic species being able to survive in the East Finniss River between the mine site and its junction with the Finniss River.

Pollution from Rum Jungle during mining virtually eliminated aquatic flora from the East Finniss River downstream to the junction with the Finniss River. Trees and pandanus palms were killed and reeds, water lilies and other rooted aquatic plants were virtually eliminated from the waterway. The loss of vegetation along the stream bed and bank resulted in considerable erosion in the East Finniss River downstream of the mine. Some erosion still occurs but continuing pollution does not appear to be causing further damage to the remaining stream bed and bank vegetation although it may be inhibiting the natural regeneration of aquatic plants.

In the Finniss River the diversity and number of fish to be found in the river during the dry season is lower close to the junction with the East Finniss River than in unpolluted sections. The fish population increases over the next 15 kilometres downstream and is normal 30 kilometres from the junction.

The most significant observable effects which have been observed and which may be a regular occurrence are the fish kills which occur near the confluence of the East Finniss River with the Finniss River. The exact cause of the fish kills is not known, however, it is thought to result from increased levels of contaminants that occur when highly contaminated water from an early flush in the wet season in the East Finniss River coincides with relatively low flow in the Finniss River. These fish kills bear no relation to naturally induced fish kills which commonly occur in billabongs throughout the Northern Territory during the dry season. These result from a combination of changes in environmental factors, i.e., increase in water temperatures; decrease in dissolved oxygen levels and increase in contaminant levels due to reduction in water volume by evaporation.

The fate of contaminants which are being continually carried by the East Finniss River is not entirely known but it appears that the pollution load is flushed into the estuary each year by wet season flood flows; the effects on the estuary are not known but appear to be insignificant. Concentrations of contaminants that remain in isolated pools in the river system, and encrustations which develop on bed and banks as a result of evaporation during the dry season, are washed away by the first flush in the succeeding wet season.

The evidence suggests that continuing pollution emanating from sources at the mine site is not decreasing year by year, although it clearly varies with the annual rainfall. However, owing to the nature and size of the overburden dumps and the sulphide and heavy metal content in them, most sources of pollutants can be expected to continue releasing heavy metals for about a hundred years.

The East Finniss River is not currently relied upon as a water supply for permanent human settlements as it is ephemeral (i.e. non-perennial) and also as a result of chemical pollution from the mine area.

The Finniss River downstream of the East Finniss River is also not relied upon as a water supply for permanent human settlements although it is sometimes used by visiting groups encamped on the Finniss Plains.

The first wet season flow of the East Finniss River into the Finniss River results in a water quality which is unsuitable for human consumption over a distance of some 10 km downstream. However, this occurrence is transient and for most of the year it is chemically suitable for human consumption over its entire length.

Some 30-40 years from now, it is possible that the Finniss River system may need to be developed for an additional water supply for Darwin.

If this eventuates the rehabilitation measures proposed later in this report should satisfactorily improve the water quality.

# 3.6 Objectives for an Overall Solution

Having due regard to the need for a practical cost-effective solution for achieving a high standard of rehabilitation, in which a high level of confidence of success can be expressed, the following specific objectives were formulated by the Working Group:

- (1) That the mine area be landscaped and treated for the establishment of a permanent vegetation cover, especially native plants, in order to merge it back into the local environment.
- (2) That hazards to public health and safety in the area be eliminated.
- (3) That continuing pollution originating from the sources in the mine area be reduced.
- That solutions should be permanent and that, maintenance should be minimal after the initial establishment period (e.g. vegetation establishment), unless follow-up meditoring determines an essential requirement.

- (5) Solutions should be capable of achieving a high standard of rehabilitation and controlling pollution.
- (6) Solutions should be cost-effective having due regard to the above principal objectives.
- (7) Solutions involving the removal or disposal of wastes or waste heaps are not to be adopted on an "out of sight out of mind" philosophy unless it is safe and beneficial to do so in accordance with objectives (2), (3) and (4).
- (8) Having regard to the impending establishment of new-uranium mines in the Alligator Rivers province, which will be subject to stringent environmental standards:
  - that the site be rehabilitated to a degree consistent with the need to demonstrate that a high standard of environmental rehabilitation can be achieved in a monsoonal climate.
- (9) That any works proposed to achieve rehabilitation should:
  - be capable of immediate planning, design and execution, and that subsequent stages of the project should be capable of being followed immediately;
  - not be held up or delayed pending research other than essential, short term immediate investigations; and finally,
  - that essential field trials and pilot scale tests be initiated immediately to avoid delaying implementation of ensuing stages of rehabilitation works.

#### 4. BACKGROUND TO THE PROBLEM

Detailed environmental studies in the period 1969-1975 identified and quantified the principal sources and mechanisms responsible for continuing pollution of the Finniss River system but did not evaluate alternative rehabilitation measures. Owing to the fact that alternative rehabilitation measures were not evaluated a considerable amount of background data had neither been researched, evaluated, nor analysed to a point where it would be useful in consideration of alternative rehabilitation strategies. Throughout this preliminary evaluation essential background information has been reviewed, particularly from the engineering viewpoint, in order to provide sound bases for practical rehabilitation plans.

Relevant data on environmental characteristics of the mine site and its environs, and particular information highly relevant to any proposed rehabilitation program is discussed in the following sections.

#### 4.1 Geography

The Rum Jungle area is a mature peneplain as evidenced by the low relief and drainage pattern. The height above sea level is, in most places, less than 60 metres and relief is generally in the order of 15 metres to 30 metres in the main catchment areas.

Topographically, the area is gently undulating with a developed creek system through and around the site. The principal streams being the East Finniss River and Fitch Creek, which enters the river immediately upstream of White's Open Cut at the upstream end of the diversion channel. This channel was constructed in 1954 to allow mining of White's orebody and its western third was later diverted further south again to allow mining of the Intermediate orebody.

#### 4.2 Vegetation

Vegetation in the area, except for small areas of swamp and the river courses, consists principally of low open eucalypt woodland. Tall annual grasses dominate the understory in undisturbed areas, growing profusely in the wet season and dying off in the dry season. Fires often clear this vegetation in the dry season.

Considerable regrowth of <u>Acacias</u> and <u>Hyptus</u> species has taken place in areas affected by earthworks which disturbed natural soil profiles. However, little vegetation has colonised areas where natural soil profiles do not exist. Some natural vegetation has established in favourable areas on top of White's Overburden Heap and Dyson's Overburden Heap but not on the Heap Leach Pile, the Intermediate Overburden Heap or the tailings. Natural revegetation is, however, occurring quite readily on the Rum Jungle Creek South Overburden Heap. (See Section 4.8.)

A triangular area, immediately south of the point of discharge of effluent from Dyson's copper launders, which was denuded in the mid 1960s, had revegetated naturally by 1973.

The bed and banks of the East Finniss River and Fitch Creek upstream of their confluence, were denuded of vegetation as a result of storing acid process waters in dams, and by seepage from White's and Dyson's overburden heaps. These areas were seriously affected and are only beginning to show signs of recovering now.

#### 4.3 | Climate and Rainfall

The climate is monsoonal with a summer wet season lasting from November to April. Rainfall occurs principally from November to March. The highly seasonal nature of the rainfall is a most significant factor in the seasonal pollution mechanism, as discussed in Section 3.4.3.

Mean annual rainfall is about 1500 mm, though it varies considerably - 900 mm in 1969-1970 and 2000 mm in 1973-1974.

Two characteristics of the rainfall significantly influence the establishment of vegetation and, as a result, would influence the success of vegetative rehabilitation measures. Firstly, storm intensities are high, and as a consequence, erosion forces are severe. Any attempt at large scale rehabilitation involving establishment of plant cover must pay careful attention to management of surface runoff water, otherwise water erosion would rapidly remove topsoil. Secondly, precipitation seldom occurs during the dry season (May to September) and evaporation is high, causing low soil moisture levels. The absence of moisture is a limiting factor for plant growth and establishment of vegetative cover on any area must take account of the lack of precipitation for about half of the year.

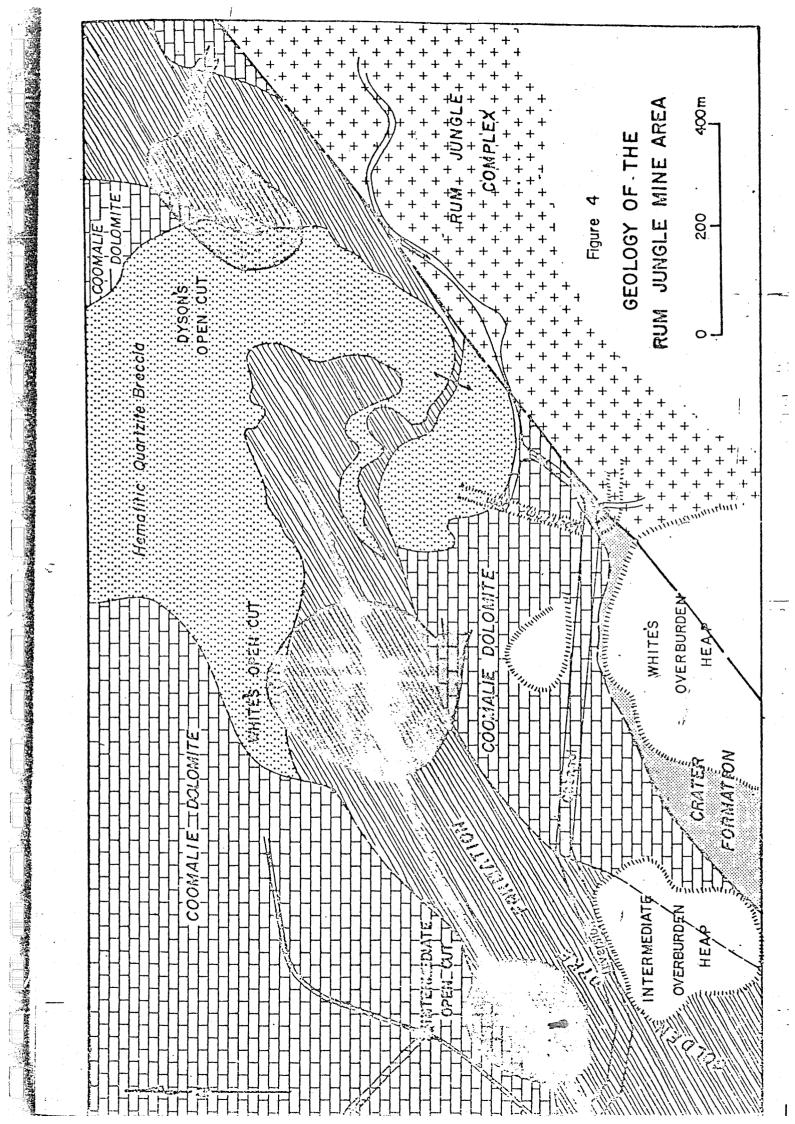
#### 4.4 Land Use in the Area

The Rum Jungle Mine area was abandoned in 1971. Since then serviceable buildings have been used for storage of drill cores and samples, and for the storage of various items of plant and equipment. Serviceable buildings will be retained for storage purposes in the future. (See Section 2.2.)

The area, in its present condition, could be of considerable value for environmental research, an activity which could be continued following any rehabilitation program. Monitoring of the effects of various rehabilitation measures would most likely provide knowledge which could be extremely useful for the rehabilitation not only of future uranium mines in the Alligator Rivers Province but more importantly of heavy metal mines throughout Australia.

Productive land use in the surrounding area is virtually non-existent, though cattle grazing is confined, on a small scale, to a few pastoral leases.

Small groups of Aborigines use the Wagait Aboriginal Reserve, which is well downstream, but are not permanently encamped on the Finniss River plains.



#### .5 Geology

The geology of the Rum Jungle area, and of the orebodies in particular, has been well reported in geological literature. The best accounts are given in publications of geologists involved in exploration and mining at the time. Further geological data exist in voluminous exploration drilling records by TEP and the Bureau of Mineral Resources (BMR). (See References.) In the following discussion of the mine area geology, attention is given principally to those factors pertinent to current problems.

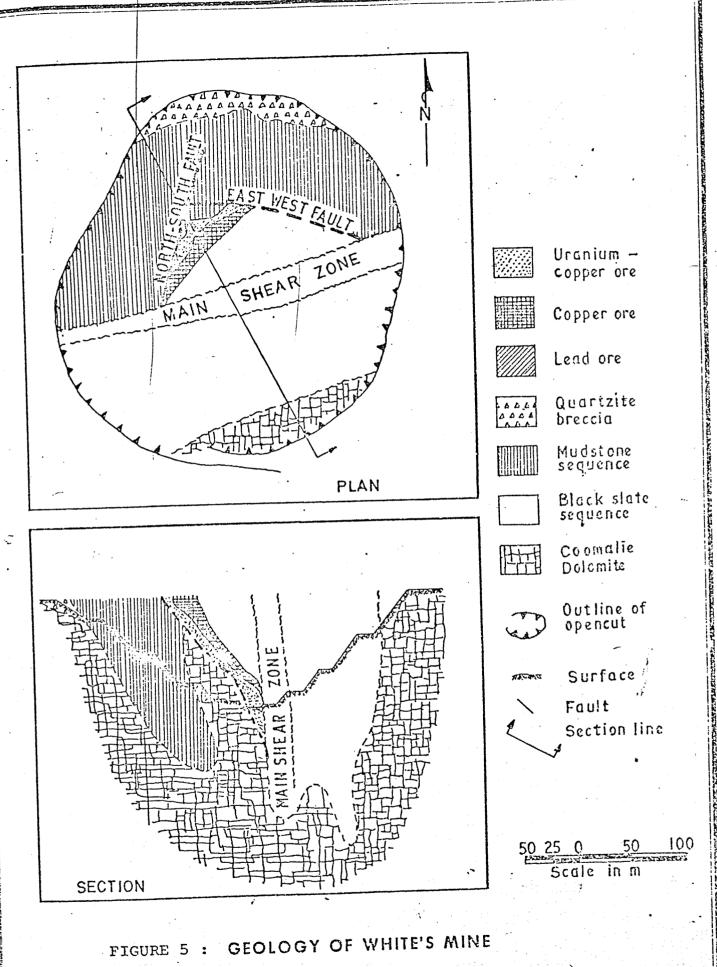
Ground he

White's, Dyson's and the Intermediate orebodies were located on the contact between the Coomalie Dolomite and the Golden Dyke Formation. All three orebodies occurred in or near the carbonaceous pyritic slate member of the Golden Dyke Formation; pyrite is reported as being ubiquitous in the Golden Dyke Formation. (See Figs. 4 to 7.) Of principal importance to the current study is the location of the black pyritic slates and shales of the Golden Dyke Formation. These are to be found in the southern half of the open cuts and are exposed in their southern perimeters. (See Figs. 8, 9 and 10).

An intense main northeast tending shear zone passes approximately east-west through the area and bisects both White's Open Cut and the Intermediate Open cut. Permeability, and hence the likely flow of groundwater, in the Golden Dyke Formation is largely a function of the degree of weathering, and the degree to which the beds have been subjected to shearing (three or four sequences of deformation have taken place). The formation is characterised by a relatively even depth of weathering, which, from geological section plans is about 35 metres. Permeability in the slates and shales is relatively predictable being from moderate to average in unsheared beds but can be expected to be quite high in the shear zones.

The Coomalie Dolomite, which is exposed in both the north and south wall of White's Open Cut, is overlain by haematite-quartzite- breccia in the north. The breccia has a very irregular contact (possibly an erosion surface) with the dolomite and is transitional to siliceous breccia at the surface to dolomitic breccia immediately overlying the dolomite.

The Coomalie Dolomite is characterised by a deep weathered profile which also exhibits large variations in the depth of weathering. Unweathered dolomite is hard and acid resistant but where it is weathered, cracked or fissured, it is prone to solution channelling and acid attack; in these zones the permeability is quite unpredictable and generally very high. Such weathered dolomite is characterised by solution channels, sink holes, cavities and even large caverns. These are known from exploration records to exist to depths of at least 100 m; cavities of 0.5 m to 2 m are reported frequently in the drill logs and intervals of 30 m and higher were recorded.



(From AAEC/E365)

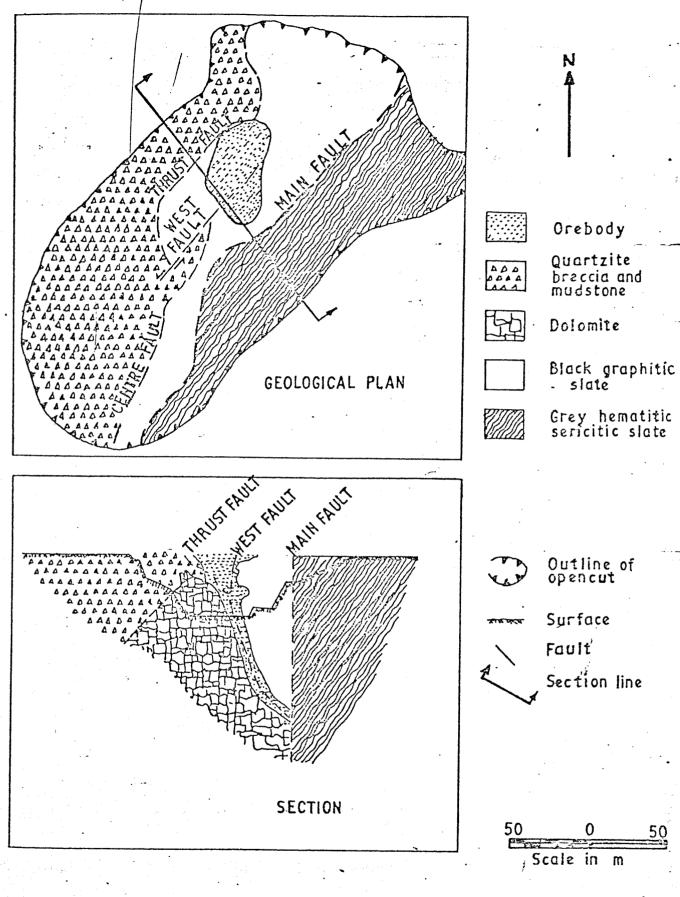


FIGURE 6 : GEOLOGY OF DYSON'S MINE

(From AAEC/E365)

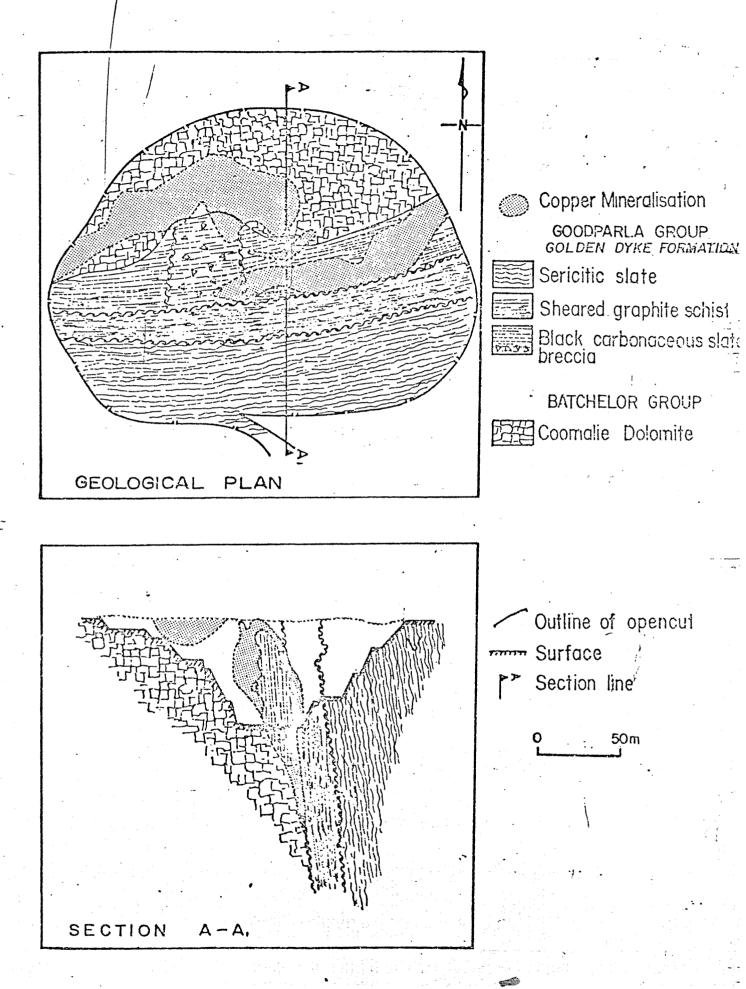
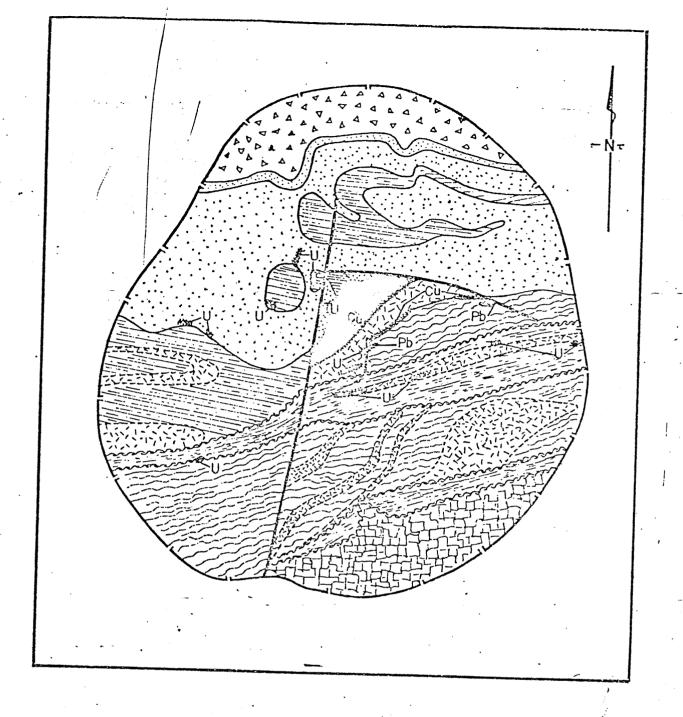


Figure 7 GEOLOGY OF THE INTERMEDIATE MINE

(Compiled from geological data; References 24 - 29)



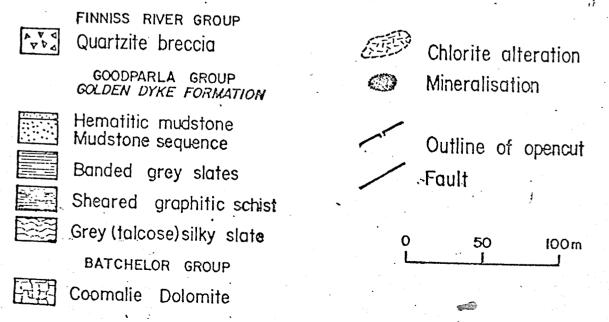
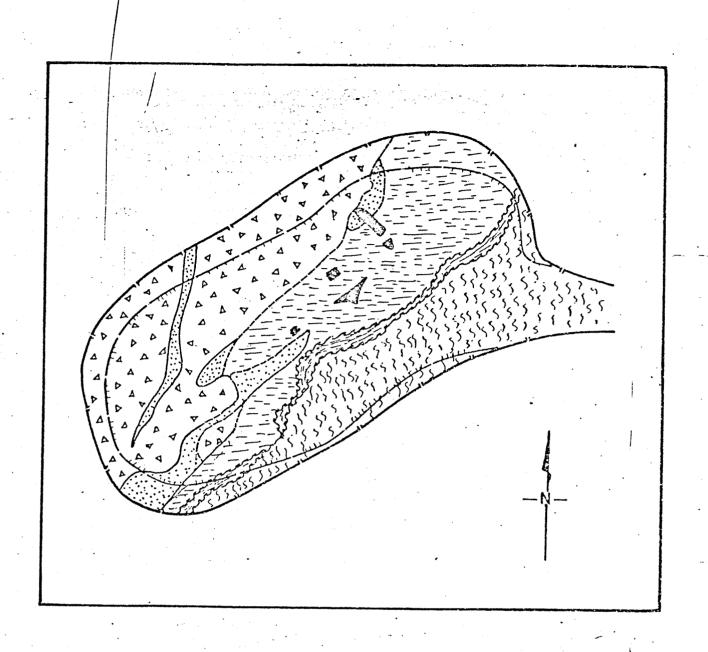


Figure 8 WHITE'S OPEN GUT COMPOSITE PIT GEOLOGY (Compiled from geological data; References 24 - 29)



# PINNISS RIVER GROUP

A V A

Hematite quartzite breccia, mudstone lens

GOODPARLA GROUP (ACACIA GAP TONGUE)



Carbonaceous &/or graphitic slate



Sericitic & graphitic slate

Sheared graphitic schist

Uranium mineralisation

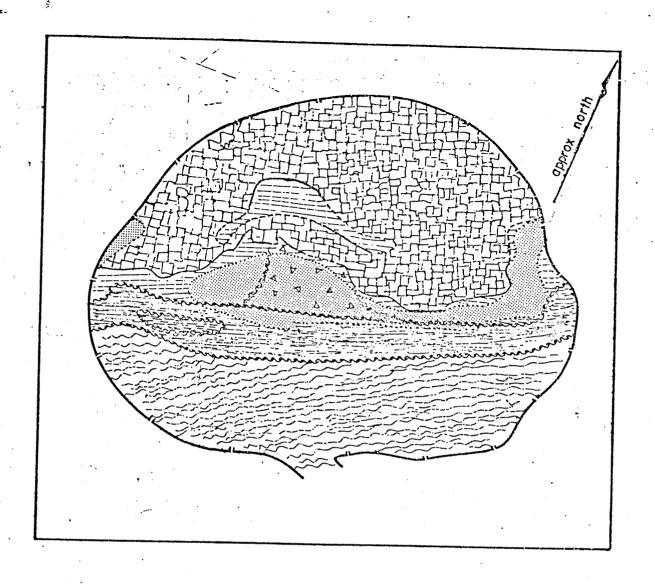
Outline of opencut

Area of opencut filled with tailings

0 50 100m

Figure 9 DYSONS OPEN CUT, COMPOSITE PIT GEOLOGY

(Compiled from geological data; References 24 - 29)



#### GOODPARLA **GROUP** GOLDEN DYKE FORMATION

Sericitic slate

Sheared graphite schist

Biotite chlorite slate

Black carbonaceous slate,

breccia

BATCHELOR GROUP

Coomalie Dolomite

Mineralisation

Outline of opencut

50m

Figure 10

# INTERMEDIATE OPENCUT COMPOSITE PIL GEOLOGY

(Compiled from geological data; References 24 - 29)

Several examples of sink holes in the plant site area have been reported but their exact locations have not been accurately established. In 1961 (or 1962) a sink hole appeared at the surface near the early copper launders, which were located to the south-west of the Old Tailings Dam. It was reported that all effluent for several weeks disappeared into this hole which apparently led to an underground cavern. Sinkholes are also reported to have collapsed beneath a small building in the plant site area just north-east of White's Open Cut, and beneath one of the excavating shovels during the mining of White's Open Cut in 1955.

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Further evidence of the cavernous nature of the dolomite can be found in the bed of the diversion channel, where an outcrop of weathered dolomite appears quite clearly riddled with small caverns formed by solution channelling. This location seeps polluted water even through the dry season; the seepage is suspected to originate from White's Open Cut.

In conclusion it can be expected that the pervious nature of the dolomite, particularly where it is cavernous, will continue to allow seepage of water from White's Open Cut.

#### 4.6 Groundwater

Highly important in any proposal for remedial measures on the open cuts is the nature of the groundwater regime through the area. However, data on the groundwater regime in the area, are virtually non-existent, and very little exists in the mining records (7).

Pumping records (see Table 6) provide aggregate figures for the volumes of water pumped from open cuts during mining but give only brief details of the location or rate of inflow of seepage that entered the open pits. Verbal evidence from persons involved during the mining is neither accurate nor consistent and it has not been possible to draw accurate or even satisfactory conclusions.

Nevertheless, from an examination of the Monthly Mining Reports (7) for the period of the mining of White's Open Cut, a picture of the likely groundwater regime throughout the area can be formed. The following pertinent details emerge:

Underground Mining - April 1954 - water from a solution channel opening in a cross cut nearly flooded No. 4 shaft; estimated flow about 16 m³ per hour; the water was suspected of being corrosive but analysis revealed it "fit for human consumption".

#### TABLE 6

#### WATER PUMPED FROM THE OPEN CUTS DURING MINING

.384

Volume

White's

 $3.6 \times 10^{6} \text{m}^{3}(1)$ , (3)

Dyson's

 $0.045 \times 106 \text{m}^3$ 

Intermediate

no record (2)

#### NOTES

- (1) This includes about  $0.23 \times 10^{6} \text{m}^3$  pumped out when White's open cut partially flooded during the 1955-56 wet season.
- (2) Twin electric pumps (150 mm) 24 hours per day (Roy Miller, Davis Contractors 1964/5 now Theiss Bros. Brisbane)
  - A.M. & S. record (3 x 150 mm) Warman split casing rubber lined pumps

2 x 90 HP ACI electric motors

Whites Normal Water Table reported by Mellor at 3m below surface
Whites Normal Water Table reported by Monthly Mining Reports, at 12 m below surface

Open Cut Mining - August 1955 - a principal aquifer was encountered in the dolomite in the south-eastern corner of the open cut at about 27 m below the surface\*. This aquifer occupied two 600 mm pumps for the remainder of the mining of the Open Cut which ceased in September 1958.

April 1956 - the seepage rate was reported at 123 m<sup>3</sup>/hr; expression of the aquifer shifted westwards as the open cut was deepened.

May 1958 - seepage from the footwall dolmite in the north perimenter of the open cut was collected on a bench 70 m below the surface.

June 1958 - small but significant seepage was encountered from the western end of the main shear zone 76 m below the surface.

Furthermore, it is fairly certain that the main shear zone would have been a significant directional aquifer (over a width of about 35 metres). Seepage entering the Intermediate Open Cut during mining was polluted and it was suspected that this was coming from White's open cut. Also, it has been verbally reported (8) that almost the entire inflow to the Intermediate Open Cut originated from an area in the eastern perimeter wall of the open cut, which would most likely correspond with the location of the Main Shear Zone. A negligibly small seepage inflow was also reported over a broader area in the north-western quadrant of the pit.

#### 4.7 Unrecovered Mineral Resources

Consideration has been given to the possibility of further recovery of metals (including uranium, copper, lead, zinc, gold and cobalt) in the study area.

Changes in metal prices and improvements in ore processing and metal recovery technology sometimes render it economic to reprocess tailings, to process low grade ore not initially processed but stockpiled, and to sometimes even process overburden containing low concentrations of metals. The same factors furthermore, can render it economic to recover extensions of orebodies remaining in the mine workings. Consideration has been given to the possibility of further recovery of orebodies, or their extensions, in White's Open Cut, at Mt. Fitch and in the Intermediate Open Cut. This aspect has been evaluated not only considering recovery of metal per se and the value of resources won, which is marginal to uneconomic at best, but also considering the benefit of rehabilitating the Rum Jungle plant area at the same time.

Final depth of the open cut was 110 m below the surface.

During the life of Rum Jungle operations the area of the plant and mine itself, and the immediate surroundings, were well explored particularly for uranium. Although base metal mineralisation remains in the study area it is quite uneconomic under present conditions to recover it, and recovery is not considered to be viable in the foreseeable future.

The entire surrounding area, with the exception of areas currently held under mining title by CRA Services, and the Mineral Leases applied for by Bennett over two phosphate deposits (See Figure 11), is the subject of an Application for an Exploration Licence by A.O.G. Minerals Ltd. The Mines Branch propose to make it a condition of the Licence, if granted, that the Company co-operate with the Working Group in any measures to rehabilitate the area.

Should any further mining operations take place at some time in the future which might require disturbing the Rum Jungle mine area again, the Mines Branch could ensure, by imposing conditions in the mining tenement, that any rehabilitation measures implemented at this stage would be reinstated.

Current applications for exploration leases, or tenures of mining leases, do not preclude implementation of any alternative rehabilitation measure considered in this report.

#### 4.8 Outlying Uranium Mines

Three uranium orebodies were discovered some distance from the Rum Jungle Mine (See Figure 1), two were extracted and treated at Rum Jungle but the third, Mt. Fitch was not recovered for economic reasons.

Brief consideration is given here to the current state of these abandoned mines and their effect on their own local environment.

#### 4.8.1. Rum Jungle Creek South

The Rum Jungle Creek South mine site is about 6 km south of the Rum Jungle mine. The orebody consisted of about 663,000 tonnes of uranium ore which was extracted in 1960-1962 and was transported to and treated at Rum Jungle through the late sixties.

The open cut is now filled with water of good quality. For some years the site has been and continues to be used as a recreation area and swimming hole and has been declared a Recreation Area. Fish are present and waterbirds can be observed using the lake.

No major stream passes the immediate vicinity of the mine although the western slopes of Castlemaine Hill drain into the open cut. The overburden heap is supporting a variety of grasses, native trees and shrubs and is resignished by natural processes.

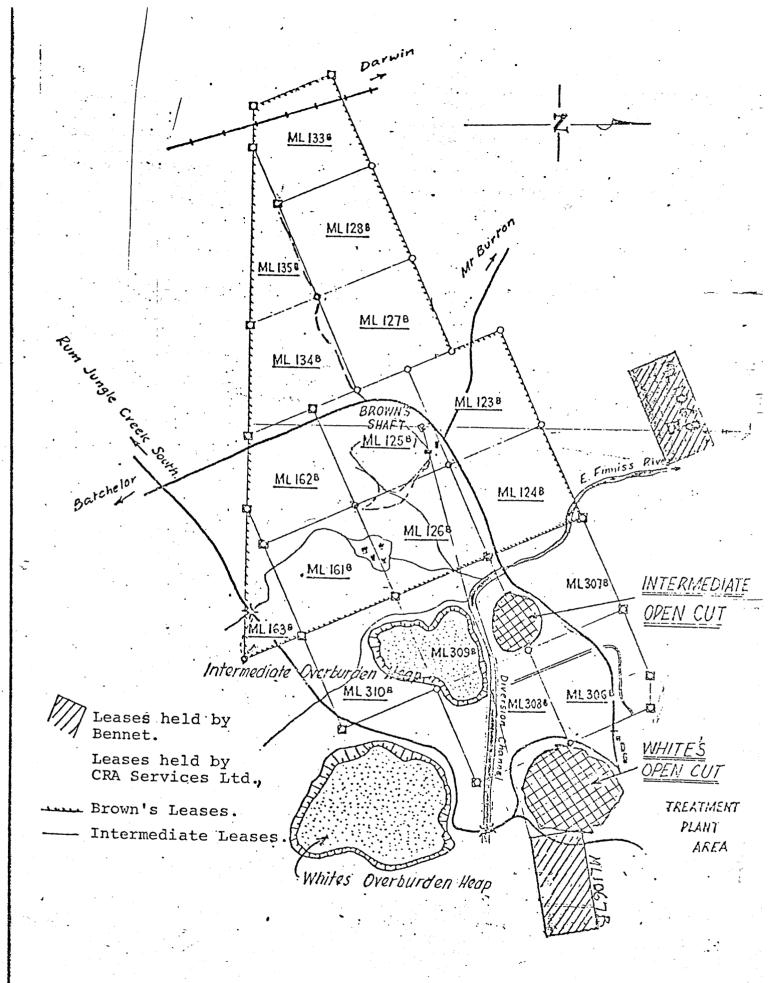


FIGURE 11 - MINING TENEMENTS IN THE RUM JUNGLE AREA

This site was examined during the program of environmental studies reported in Section 3.3. The overburden heap is estimated to contain only about 0.3% sulphur. Evidence indicated that some natural leaching of copper occurs but that no serious environmental pollution problem has arisen. The most that could be suggested in terms of rehabilitation could be to improve the appearance of the overburden heap, with landscaping and drainage control, and to assist it to revegetate, including a positive program of tree planting, of both the heap and around the open cut.

#### 4.8.2 Mt. Burton

The Mt. Burton uranium mine is about 5 km west of Rum Jungle on the north flank of a low ridge. The deposit was discovered in 1954. Open cut mining began in early October 1958 and was completed by mid November. Total excavation was 100,000 m<sup>2</sup>. About 10,000 tonnes of uranium and copper ore were transported to Rum Jungle for treatment.

The overburden heap, a very small dump (around 2 ha) was placed adjacent to the open cut beside a small stream. Seepage flowing from this dump contains some copper and is causing limited pollution of the nearby creek. However, the volume of seepage is small, does not appear to be a significant problem in the creek, and causes only a slight increase in copper levels in the Finniss River at the junction. The overburden dump has not revegated, though it possibly could with a little assistance. Otherwise little reason exists for rehabilitation measures.

The open cut has filled with water and is currently being used as a domestic water supply for an adjacent homstead. Water samples taken regularly for analysis verify that the quality of this water is quite suitable for domestic consumption.

#### 4.8.3. Mt. Fitch Uranium Deposit

The Mt. Fitch uranium deposit is about 8 km northwest of Rum Jungle on a low rise east of the Finniss River. An orebody of about 1.2 x 10<sup>6</sup> tonnes of ore of an average grade of about 0.07%U308 containing about 840 tonnes U308 was identified and uncovered but was not extracted for economic reasons.

The present open cut, which is small compared with those at Rum Jungle, is also partly full of water. No water quality problem has arisen. Fish have been observed in this open cut despite the fact that it is not connected to a stream system.

The overburden, merely a half hectare in area, is piled adjacent to the open cut and has not caused any environmental problems. This site is remote and access is difficult. Little need exists to perform any rehabilitation.



#### 4.8.4. Conclusion

None of the three outlying mine sites currently constitutes an environmental problem nor could they become in the future. The open cuts and overburden heaps are not a source of pollution that can in any way be regarded as a problem.

The overburden heaps from these open cuts were constructed and abandoned in a manner similar to those at Rum Jungle. The Rum Jungle Creek South heap is revegetating naturally and, although it retains the resemblance of a mullock heap, natural revegetation has reduced its visual impact and already disguises the heap as a part of the environment. Overburden heaps at Mt. Burton and Mt. Fitch hardly warrant attention.

In conclusion, there is no compelling need or reason for implementation of rehabilitation measures at these sites.

#### 5. THE HEAP LEACH PILE AND AREA

#### 5.1 Introduction

The copper heap leach pile is located between White's and the Intermediate open cuts (see Figure 2). It was constructed in 1965 by Australian Mining and Smelting, a wholly owned subsidiary of the CRA Group, to recover copper from the low grade ores, which were extracted from the Intermediate copper orebody, by bacterially assisted acid leaching. The pile was constructed on a specially prepared low permeability sealed surface and consists of a 10 m high square heap of sulphide cre (260,000 tonnes, originally 1.7% Cu) attached to a 10 metres high oblong heap of the oxidised ore (110,000 tonnes, originally 2.0% Cu) from the top 10 metres of the orebody. The heap is estimated to currently contain approximately 0.8% copper.

#### 5.2 The Problem

Rainwater falling on the heap percolates through and performs seasonal leaching of the heap in a manner similar to the continuous leaching of the heap while it was in operation. An estimate of the amount of copper, the principal contaminant from this source, leached annually from the heap has been made for 1973-1974. The estimate indicated that about 42 tonnes of copper were leached from the heap, with 32 tonnes of this being discharged down Copper Creek into the Finniss River, and the remaining 10 tonnes percolating into the groundwater. The copper discharged down Copper Creek from this heap contributes a third of the copper, originating from the whole Rum Jungle mine site.

DEPARTMENT OF MINES AND ENERGY G.P.O. BOX 2901, DARWIN, N.T. 0801.

Since the heap is estimated to still contain some 3500 tonnes of copper, continuing discharge of copper at a significant rate from this site can be expected for a period of about a century.

In addition to the heap leach pile itself there are also diversion banks, channels, liquor ponds, concrete copper launder structures adjacent to the pile, and earthworks in the old bed of the East Finniss River which constituted part of the operation. Contaminated seepage from the pile collects in some of the ponds during the wet season, and evaporates during the dry season leaving acidic sludges. The old bed of the East Finniss River has been denuded of vegetation by the operations and is hazardous because of the quicksand nature of the area.

CRA Services continue to hold a Mineral Lease over the area of the Intermediate Open Cut, the Intermediate Overburden Heap and the Copper Heap Leach pile. (See Figure 11.)

#### 5.3 Alternative Solutions

Various solutions have been examined which are discussed below.

#### 5.3.1 Recommissioning

Consideration has been given to recommissioning the leaching operation in order to further recover copper. The heap leaching operation was initially successful but as the leaching rate fell it became uneconomic. Recommissioning would involve re-establishment of plant and works to operate it again. CRA consider that recommissioning would not be a viable proposition, and hence this alternative can be disregarded.

## 5.3.2 Transportation to a copper smelter

The heap currently contains only about 0.8 per cent copper and because of the low grade, among other reasons, it would not be economic to transport it to a smelter, the nearest of which at Tennant Creek is currently closed down.

#### 5.3.3 Sealing with artificial membrane

Being a rather small heap it would be possible to perform a reasonably high integrity sealing of the heap to prevent the infiltration of rainwater, and thus to terminate leaching.

Various methods of sealing the heap in situ were considered. These involve cosmetic surface preparation of the heap followed by application of a bituminous, rubber, or heavy polythene sheeting layer. However, these methods have not provided satisfactory long term solutions elsewhere, and would be unlikely to succeed in the harsh climate encountered at Rum Jungle. Sooner or later the seal would deteriorate and fail, and maintenance would be required. This alternative is unattractive on these grounds.

## 5.3.4 Revegetation in situ

Consideration was given to reshaping the heap to a more convex configuration, in order to promote rapid surface drainage, and then covering with topsoil to establish a vegetation cover. Two basic variations of this scheme could be considered, having particularly in mind the need for eliminating infiltration into, and seepage through the heap.

Following the contouring operation the heap could be covered with a deep layer, about a metre in depth, of clay and topsoil differentially compacted. For success in preventing infiltration and establishing vegetation, the clay and soil cover would need to have soil moisture storage capability to hold soil water without allowing it to infiltrate the heap, to provide for a permanent vegetation cover adequate to stabilise the surface against erosion and to utilise excess moisture from the profile by transpiration.

Alternatively, to prevent infiltration into the heap it could be sealed with a compacted layer of impervious clay. In order to provide satisfactory drainage for a vegetation cover above this layer, the clay layer might need to be covered with a coarse gravel or rock layer for the drainage of infiltrated rainwater. A topsoil cover could then be vegetated. For success the clay layer would have to be a well compacted stable non-swelling impervious clay, and the drainage layer would need to function satisfactorily.

It is not entirely certain at the present time which of these two schemes would prove more satisfactory in reducing infiltration in view of soil formation processes which can be expected to occur in the long term. However, it can be expected that both would reduce infiltration, possibly enough to virtually eliminate leaching and seepage.

Either of the two treatments described above would cost approximately \$0.30 million, which includes revegetation of the surrounding area.

## 5.3.5 Removal to an open cut

The most permanent solution to prevent continuing pollution from the heap entering the river system would be to remove the heap by dumping into one of the adjacent open cuts, provided that this proved to be a satisfactory strategy from the point of view of the open cut.

With the heap removed, and bunds, ponds and launders removed, the leach heap area comprising about 8 ha between the Intermediate and White's Open Cut can be recontoured to a natural profile, topsoiled and revegetated. The total cost for this alternative would be about \$0.75 million.

Consideration would need to be given to the effect that dumping the heap leach material would have on the water in the open cut and on the groundwater regime in the area following the operation. It appears certain that the overall pollution from this area would be reduced but the extent of the reduction cannot be accurately estimated at this stage. This matter is discussed later under consideration of alternative solutions for the open cuts in Section 7.

#### 5.3.6 Burial

Consideration was given to removing the heap and burying it in either a borrow pit or a blind gully. This alternative would incur higher transport costs and would most likely need to consider the problem of a fluctuating water table, regardless of where it was relocated. It is apparent that this alternative is likely to be more costly and less effective than some already considered.

#### 5.4 <u>Conclusion</u>

Two alternatives emerge which can be regarded as satisfactory solutions for the rehabilitation of the heap leach pile and area and for controlling the significant amount of pollution originating from the heap. These are:

- (1) Revegetation of the heap in situ and rehabilitation of the area; approx. \$0.35 million.
- (2) Removal of the heap to an open cut and rehabilitation of the area; approx. \$0.75 million.

The latter solution is regarded as superior because it would achieve permanent disposal of the heap.

## 6. THE OVERBURDEN HEAPS

## 6.1 Introduction

During the open cut mining of orebodies at Rum Jungle, a large volume of overburden (or waste rock) was excavated and dumped adjacent to the open cuts creating the waste rock heaps which remain today.

Two of these waste heaps resulted from mining the two uranium orebodies, White's and Dyson's. The third was a result of mining the Intermediate copper orebody.

A smaller heap of overburden from White's open cut was dumped between White's open cut and the diversion channel in 1954 prior to completion of the bridge giving access across the diversion channel to what became known as Mt. Wimpey but is now known as White's Overburden Heap.

The state of the s

Following closure of the mine in 1971 two small stockpiles remained in the plant area; these were White's lead ore and Dyson's low grade uranium ore. These stockpiles were removed for filling in the treatment plant area in the initial clean-up operation of October-December 1977.

#### 5.2 The Problem

The four overburden heaps together occupy about 47 hectares, or a quarter of the total area significantly affected by the mining operations. (For details of the heaps see Table 7.)

During construction of the heaps no attention was paid to environmental problems which might result in the long term. Following closure of the operation no attempt was made to reshape them for better drainage and no effort was made to vegetate them. The heaps are an intrusion on the landscape yet they inconvenience no-one by their physical presence alone.

However, the heaps together do constitute the most serious pollution source in the mine area. Estimates made for the release of heavy metals from the heaps in the 1973-74 wet season indicate that they contribute about half of the copper, about a third of the manganese and virtually all of the zinc load estimated to annually enter the Finniss River system. (See Tables 2 and 5.) The factors governing pollution mechanisms were the subject of considerable field study in the joint Department of the Northern Territory/Australian Atomic Energy Commission environmental studies. (See Section 3.3.) The basic mechanisms of leaching of heavy metals from overburden heaps are fairly well understood on a broad scale and are reported in the literature (9,10,11,12,13).

Two mechanisms are primarily responsible for the leaching of heavy metals from pyritic waste dumps - biological and The basic biological mechanism is one of bacterially assisted oxidation of pyrite (FeS2) in the presence of oxygen and water to produce ferrous sulphate and sulphuric acid. Ferrous sulphate becomes oxidised through the action of iron oxidising bacteria, Thiobacillus ferro-oxidans, to produce ferric sulphate and ferric hydroxide. Ferric sulphate itself is an aggressive solvent of metal sulphides, thus dissolving. metal sulphides and leading to further oxidation of sulphur and production of sulphuric acid. Furthermore the presence of sulphur oxidising bacteria, Thiobacillus thio-oxidans, which have also been identified in waste heaps at Rum Jungle, may also accelerate the oxidation process. This series of reactions, which only require the presence of water and atmospheric oxygen, are the basic reactions releasing heavy metals from the overburden heaps.

In actual fact each particular leaching situation has its own particular microbial ecology and a variety of species may exist together rendering the overall process quite complex. Only years of painstaking research could thoroughly delineate the actual reactions in detail. The simple picture outlined above summarises the basic mechanism.

TABLE 7

#### THE OVERBURDEN HEAPS - AREAS, VOLUMES AND WEIGHTS

		AREA hectar Top		VOLUME million cubic metres	WEIGHT million tonnes.
White's Overburde (Mt. Wimpey)	en Heap	19.6 75% 26.	6.8 25%	4.0	8.0
White's (North Overburden Heap)	TOTAL	4	• • • •	0.32	0.64
Dyson's Overburde	en	5•9 70%	2.6 30%	1.2	2.3
, <del>, , , , , , , , , , , , , , , , , , </del>	TOTAL	. 8.	.5		: · · · · · · · · · · · · · · · · · · ·
Intermediate Overburden Heap		5 · 70%	2 30%	0.8	1.6
Heen Leach Dile	TATOT	7		0.0	0.37
Heap Leach Pile	TOTAL	3		0.2	0.37

#### NOTES:

#### 1. Density Factors:

- (a) Whites Uranium ore
   Bogum
   Base metal ore

  (b) All open cuts

  (c) All ores

  (c) C(A, 1977)

  (c) Base metal ore

  (c) All ores

  (c) C(A, 1977)

  (c) Base metal ore

  (c) All ores

  (c) C(A, 1977)
- 2. Volume estimates are accurate to  $\pm$  10-20%; a rough check is that broken rock should be about  $\overline{2}$  tonnes/m<sup>3</sup>.

To identify further the nature and activity of microbiological processes in the overburden heaps, microbiological studies were commenced in late 1974 by the School of Microbiological Technology of the University of New South Wales under contract to the AAEC(14,15,16,17). was undertaken in order to assess the nature and extent of microbial associations and to evaluate various procedures for the control and suppression of microbial activity. While this work to date has constituted valuable research, it is apparent that the nature and extent of microbiological activity in the voverburden heaps is, in fact, so complex that no definite -results have emerged that might produce or lead to an easy or simple inexpensive mechanism of controlling microbial biocide. The distinct possibility remains that such a simple inexpensive solution inhibiting microbial action may not be found.

At the present time the only satisfactory way to quarantee terminating or even markedly reducing the leaching process is to either:

- (a) prevent the ingress of water and oxygen into the heap, thus starving the reaction to extinction; this would involve completely sealing the heap with an air and/or water tight cover, or
- remove the entire heaps to locations where oxygen (b) and water cannot enter the waste material, or where leachate solution cannot leave, e.g. by returning the waste underground.

In the latter case the reaction, and possibly leaching would not necessarily be inhibited by returning the waste material to an open cut. If groundwater continues to flow through the buried waste and oxygen is still available, the microbiological action would doubtlessly continue, though probably at a somewhat reduced rate, thereby polluting the If oxygen is not available leaching is still ; groundwater. likely to occur through chemical action. It would therefore be necessary to ensure that groundwater would not flow through waste rock relocated below the water table. Even though details of the precise chemical and bacteriological reactions occurring in the overburden heaps are not known, it is nevertheless possible to draw some conclusions which are relevant to rehabilitation proposals.

It is known that the carbonaceous black slates from the Golden Dyke Formation comprise at least half of the over-burden heaps in the case of White's and the Intermediate, and about a third in the case of Dyson's and that this material contains The overburden dumps have been estimated to contain the following proportions of sulphur, largely as pyriter.

> White's overburden Intermediate overburden 3.1%
>
> Dyson's overburden 3.1%

It is evident, that with these levels of sulphur in White's and the Intermediate Heaps that bacterially assisted leaching of heavy metals will continue for some considerable time into the future and that significant annual releases are most likely to continue for about a century.

# 6.2.1 White's Overburden Heap (Mt. Wimpey)

Between January 1955, on completion of the bridge across the diversion channel, and the completion of White's open cut in November 1958, about  $4 \times 10^6$  m<sup>3</sup> (8 × 106 tennes) of waste rock were dumped south of the diversion channel on an area totalling about 26 hectares.

Little is known of the spatial composition of the heap but it is composed principally of slates and shales of the Golden Dyke Formation, since this constituted the largest fraction of the waste rock. The remaining fractions are mud-stone and dolomite from northern and southern boundaries of the open cut.

The heap as a whole contains the equivalent of about 3% sulphur, most of which is in the form of metal sulphides and is principally pyrites. The heap also contains about 0.09% copper and about 0.003% uranium.

Estimates of the heavy metal load contributed to the Finniss River system by White's Overburden heap in the 1973-1974 wet season were about 30 to 35% of the copper (29-53 tonnes), 15 to 23% of the manganese (11-19 tonnes) about 55% of the zinc (17-31 tonnes) as well as corresponding amounts of other contaminants. This heap is thus the largest single source of contaminants from the mine area.

The top surface of the heap, comprising about 75% of its plan area (walls comprising 25%), is irregular in profile, consisting principally of smooth areas where dumped material has been graded, and large areas where this has not been done. The nature and profile of the surface governs the pattern of water movement in the wet season. Graded areas tend to shed water more readily; ungraded areas trap water forcing it to infiltrate. From a water management point of view the relief of the top surface leaves a lot to be desired, particularly in view of the leaching problem. Any strategy to rehabilitate the heap must give immediate attention to improving runoff and reducing infiltration firstly by smoothing and drainage.

In the 20 years since the construction of the heap, weathering has occurred over the entire dump with some materials weathering more rapidly than others. A soil profile is developing, even though at the present stage it is still quite inhospitable, over most of the heap, to natural regeneration of plant life. On the north-western corner of the heap, where weathered dolomitic and haematite-quartzite-breccia material has been dumped on the surface, vegetation has established naturally and is persisting.

Revegetation trials conducted by the Department of the Northern Territory in 1972 and 1973 on the southern extremity of the overburden heap have proved relatively successful (4). These trials were established by ripping, followed by application of lime, fertiliser and selected seed; topsoil was not applied. It is evident from these trials that a vegetation cover could be established on similar material on surfaces that have weathered since their placement. However, reshaping of the surface of the heap to provide better water management might create surface soil profiles that would require an initial weathering period, or alternatively, significantly different treatment, most likely requiring the application of imported topsoil to enable the immediate establishment of vegetation.

A body of experience exists, both here in Australia and overseas, relating to vegetation of mine waste heaps. There is little doubt that vegetation could be quite effectively established on most of White's overburden with relatively minor works and relatively low costs.

However, in order to reduce the leaching of heavy metals from the heap it will be necessary to significantly reduce the infiltration of rain water into it. This will require earth-moving and drainage works which become increasingly more expensive for a superior result. These solutions are discussed in Section 6.3.

#### 6.2.2 White's (North) Overburden Heap

Prior to the construction of the bridge across the upstream end of the diversion channel, about 0.32 x 10<sup>6</sup> m<sup>3</sup> (0.64 x 10<sup>6</sup> t) of waste was dumped between the diversion channel, the open cut and the old bed of the East Finniss River. This is only a small heap containing dolomite, mudstone and black shales. Only a small amount of leaching is occurring. This seeps into the old bed of the East Finniss River which is connected by a culvert to White's Open Cut. The amount of pollution originating from this source was not assessed during detailed environmental studies, since it is obviously only a very small fraction of the total load from major sources.

However, in any rehabilitation strategy this area would require civil works of a similar nature to that required for the major heaps, but correspondingly reduced in scale. The general area of this heap could be landscaped by pushing material north-eastwards to fill the old bed of the East Finniss River and north-westwards to fill the depression between the dump and the road surrounding White's open cut. The contoured surface could be vegetated with similar . techniques as those employed on the larger heaps. These are discussed in Section 6.3.

#### 6.2.3 Dyson's Overburden Heap

Dyson's overburden heap is estimated to contain about 0.9% sulphur, mainly in the form of pyrite. It is likely that because the concentration of sulphur is low that leaching of heavy metals is not occurring to a greater degree. The contribution of Dyson's overburden heap to the pollution load in the East Finniss River has been estimated at considerably less than 1% of the copper and about 7% of the manganese.

As with White's overburden heap, about half of the top surface of Dyson's heap is smooth where rubble has been levelled. The remainder, being mainly the northern half, is entirely covered with backdumped truckloads that have not been levelled.

Healthy natural vegetation has established over areas where haematite-quartizite-breccia material has been placed. However, over most of the dump, the surface consists of the black pyritic and grey sericitic slates and vegetation has not established at all.

#### 6.2.4 Intermediate Overburden Heap

The Intermediate overburden heap was constructed in 1964/65 and consequently the surface has had so much less time to weather. Furthermore, the profile and drainage pattern of the heap are even more irregular than White's and Dyson's heaps. Owing to the nature of this heap it is expected that it would require considerably more cosmetic earthworks to satisfactorily shape the heap prior to treatment for the establishment of vegetation.

Natural vegetation has not yet encroached on the heap. Some tree seedlings were planted on the heap some years ago but most have died and the remainder are not thriving. Vegetation will not colonise this heap at the present time without a topsoil cover.

#### 6.3 Alternative Solutions

Several alternative methods for rehabilitating the heaps in situ are considered viable options. In some cases removal of the heap has been assessed, but not all of the heaps could be returned to open cuts because of volume expansion which occurs when rock is quarried and broken.

### 6.3.1 Establishment of Vegetation Using Simple Techniques

The minimum effort required to provide a satisfactory improvement in the appearance of the heaps would be to smooth their surfaces, flattening natural angle of respose batters on the top surfaces of the heaps only and cover with 15 cm of imported topsoil. Where areas of the heaps already have a satisfactory soil profile, topsoil is not likely to be needed; this applies to certain areas of White's and Dyson's heaps.

The top surfaces would then be vegetated in a manner similar to trials which have been made on top of White's Overburden Heap. As the Intermediate overburden heap was constructed later the surface has less time to weather and is even more inhospitable to plant life. This dump would certainly require a topsoil cover to support vegetation.

An order of magnitude estimate of costs for treatment involving minor cosmetic earthworks, partial topsoiling and vegetation of the heaps is as follows:

White's Overburden Heap	\$0.25 million
White's North Overburden Heap	\$0.04
Dyson's Overburden Heap	\$0.08
Intermediate Overburden Heap	\$0.07
	\$0.44 million

These works would provide for a visual rehabilitation of the heaps but cannot be considered sufficient to reduce infiltration of rainwater into and leaching of contaminants from the heaps.

# 6.3.2 Seal with Clay, Cover with Rock and Topsoil and Establish Vegetation

To restrict infiltration of rain water into the dumps, in order to limit leaching and seepage, would require that the top surfaces of the heaps be contoured for rapid surface drainage and covered with topsoil for the establishment of a vegetation cover and this could be done according to the techniques suggested in Section 5.3.4 under discussion of vegetation in-situ of the Heap Leach pile. Either technique could be applied to the top surfaces of the heap without major reshaping earthworks. The conflicting criteria of maximising runoff, minimising infiltration, and erosion will require careful attention to design detail. It could be expected that drainage lines will require stabilisation possibly with some types of standard stormwater drainage works.

An estimate of the order of magnitude of the cost to cover with a deep layer of clay and topsoil differentially, compacted or alternatively to seal with clay, cover with rock and topsoil layer, and revegetate is as follows:

White's Overburden Heap	\$1.10 million
White's (North) Overburden Heap	\$0.17
Dyson's Overburden Heap	\$0.39
Intermediate Overburden Heap .	\$0.28
· · · · · · · · · · · · · · · · · · ·	\$1.94 million

#### 6.3.3 Removal of Overburden to Open Cuts

Consideration has also been given to dumping two of the overburden heaps back into an open cut, preferably White's Open Cut. Various complexities arise with this alternative and these are considered in terms of options for treatment of the open cuts (See Section 7).

Following removal of the overburden heaps the vacated areas would have to be rehabilitated most likely by the application of lime, topsoil, fertiliser and seed. The approximate cost of relocating two of the overburden heaps and rehabilitating the areas are as follows:

- Intermediate Overburden Heap

Dyson's Overburden Heap

(relocated to White's Open cut) - \$3.25 million

### 6.3.4 Collection and Evaporation of Seepage from Overburden Heaps

Another possible alternative is to construct a system of banks, channels, culverts and retention or evaporation ponds to collect and evaporate contaminated seepage coming from the overburden heaps. Tentative proposals and estimates considered were principally those proposed and evaluated at their own instigation, by the CRA General Mining Division in February 1976 (37). The advantage of the system is that it would effectively prevent most of the contamination by seepage from Dyson's and White's overburden, and part of that from the Intermediate overburden, from entering the Finiss River System.

The principal disadvantage of the system is that it would require seasonal operating and maintenance effort and attendant costs. Furthermore the appearance of the evaporation ponds would be unattractive. This solution, while possibly reasonably effective for control of most of the contamination by seepage is considered to be a palliative measure and is not favoured with respect to the objectives of seeking a permanent solution.

The capital cost of the proposal, depending on its score and detailed requirements, was estimated to range between \$0.30 million and \$0.70 million; annual operation and maintenance costs would be extra.

#### 6.4 Conclusion

Although simple low-cost techniques can achieve establishment of vegetation on the heaps in most situations, is unlikely that these would significantly reduce pollution.

Works required to prevent infiltration of rainwater and to eliminate leaching involve considerably superior works requiring more effort and higher costs. A final choice on the most appropriate solution could only be made as a result of detailed engineering planning. The range of alternatives and their costs are circumscribed by the schemes discussed in Section 6.3.2.

Rehabilitation of the overburden heaps will require large volumes of topsoil, thus causing some disturbance of the environment of borrow areas. During the October-December 1977 clean-up operations a simple technique was devised for stripping topsoil and rehabilitation of the borrow areas. Hence, the environmental impact of disturbing borrow areas for topsoil can be regarded as temporary and of no significance.

#### 7. THE OPEN CUTS

#### 7.1 Introduction

During mining operations at Rum Jungle three ore bodies were extracted by open cut methods. White's was mined for uranium, copper and lead ores from November 1954 to November 1958; Dyson's was mined for uranium only from November 1957 to November 1958. Both of these open cuts were mined for Territory Enterprises Ltd by George Wimpey Ltd., a Sydney-based earthmoving contractor. The Intermediate open cut was mined for copper ore from June 1964 to October 1965 by Davis Contractors Pty Ltd, a Sydney-based civil engineering contractor, for Australian Mining and Smelting.

Little detail is known of the actual mining of the open cuts, particularly with respect to groundwater, though some is available from the monthly mining reports. (7) Detailed geological level and section data are also available in the archives of the Mines Branch (DNT). (See Figures 5 to 10).

Dyson's and White's open cuts were used for waste disposal purposes during the latter half of the life of mining and ore treatment operations. Dyson's open cut was used for disposal of tailings from early 1961 to 1965 when it was substantially full (to the lowest point on its perimeter) although the level of tailings material is presently some several metres below most of the rim of the pit. About 600,000 tonnes of tailings were deposited in this pit.

White's open cut was subsequently used for tailings disposal from 1965 until the cessation of treatment plant operations in 1971, during the processing of Rum Jungle Creek South ore. This accounts for the present remaining water filled depth of only 36 metres. At no stage of the operations were any tailings neutralised. Table 8 shows the open cut volumes, weights of rock excavated and present unfilled volumes.

#### THE OPEN CUTS: VOLUME, WEIGHT OF ROCK EXCAVATED

#### AND PRESENT UNFILLED VOLUME

Original Volume million cubic metres	l Weight of rock Extracted million tonnes	Present Un- filled Volume million cubic metres
White's open cut 3.5	8.5	2.5
Dyson's open cut 0.92	2.5	0.7
Intermediate 0.97 open cut	2.5	0.95

#### NOTES:

- 1. Rock extracted includes ore and overburden.
- 2. Dyson's open cut was filled with tailings to the lowest point of the perimeter.
- 3. Volume estimates are accurate to ± 20%.

#### 7.2 < The Problems

The open cuts contribute to pollution of the East Finniss River by the release of contaminated water, either by seepage or by overflow. An estimate of the percentage annual contribution from the open cuts to the total contaminant load from the site is given in Table 2. The contributions estimated for 1973-1974 are given in Table 5.

Thus White's open cut is the principal contributor, accounting for about 8% of the total copper load and about 40% of the total manganese load. Data on water quality in White's open cut and the Intermediate open cut are presented in Tables 9(a) and 9(b) respectively.

Dyson's and the Intermediate open cuts are not quantitatively significant contributors to the total pollution load. Alternative rehabilitation proposals for the Intermediate open cut are discussed in Section 7.3.2. The Intermediate open cut may have significant value for use in environmental research; this is also discussed later. Rehabilitation proposals for Dyson's (Section 7.3.3.) would lower the contribution from this source.

#### 7.2.1 White's open cut

The nature and extent of mechanisms responsible for the release of contaminants from White's open cut are quite complex and are far from entirely understood. The following discussion circumscribes the present state of knowledge of the problems involved.

White's open cut was completed in December 1958. Following removal of equipment, the upstream dam was breached in February 1959, allowing the East Finniss River to flood the pit for the purposes of creating a water supply for the treatment plant.

The quality of water in the pit has deteriorated steadily since 1959. At the time of filling the pH was about 6.6. Three months later, when the open cut was considered as a possible water supply source for Darwin, water samples were taken and detailed analyses were made (May 1959); samples of the data are provided in Table 9(a). By this time the pH had dropped to 4.75. It is to be noted that at this stage the open pit had not been used for waste disposal. The inference here is that the process of opening the pit had made water and oxygen readily available for chemical and bacterially assisted oxidation of and leaching of contaminants from pyritic slates in the southern perimeter walls of the pit. Needless to say the possibility of using White's open cut as a potable water supply for Darwin was dismissed.

Tailings material was disposed of at the water surface of the open cut from 1965 to 1971 and raffinate (pH about 1.5) which was excess to the requirements of the heap leach pile, was also disposed to the pit; from some time between 1966 and 1968.

TABLE 9(a)
WATER QUALITY HISTORY OF WHITE'S OPEN CUT

Depth	Date	рН	Cu	Mn .	Fe Cl mg/l	so <sub>4</sub>	u308
Surface	11. 2/59	6.6	0.5		•	·	
Surface	5.59	4.75	3.7	2.7	8.3	179	· · ·
150'	5.59	4.75	4.0	2.8	8.3	201	
300'	5.59	4.55	4.4	4.6	8.5	341	
Surface	14. 7.59	4.9	4.8	3.5	0.1 10	320	0.4
100'	14. 7.59	4.75	5.3	3.0	0.1 10	340	0.4
Surface	6.69	2.7	52	86		4740	
Surface	70	2.8	53	115	·	6000	•
50m	70	2.8	53	115	•	.6000	
Surface	74	2.4	56	150	,	5700	
5·0m	74	2.2	60	220	•	9200	
Surface	14.12.77	2.7	56	108	176	4900	
30m	14.12.77	2.5	55	220	325	7400	•

TABLE 9 (b)

#### WATER QUALITY IN THE INTERMEDIATE OPEN CUT

Depth	Date	рН	Cu	Mn	mg/l	Zn	so <sub>4</sub>	
Surface	1974	3.6	53	58	-	6.5		
Surface	14.12.77	3.2	71	67			3105	
Near Bottom (60m)	14.12.77	3.3	62	63	<b></b>		2800	•

Subsequently the pit was flushed with fresh water from the East Finniss River during the wet season. This practice was discontinued in 1969 when for the first time all treatment plant effluent was contained. Surface water was prevented from entering the open cut and embankments were raised to prevent overflow. This practice continued until shutdown in 1971.

The acidity and the dissolved content in the water of White's open cut can possibly be attributed to two principal sources. Firstly, chemical and bacterially assisted oxidation and leaching of heavy metals from metal sulphides (particularly pyrites) in the carbonaceous black slates of the Golden Dyke Formation in the southern perimeter of the open pit. It is most likely that this would have been responsible for the initial increase in acidity in 1959 when the pit was first flooded. Secondly, further increases in acidity, and marked increases in the levels of dissolved materials would have undoubtedly resulted from the disposal of tailings and raffinate into the pit.

Preliminary theoretical estimates indicate that if the water in White's open cut was neutralised, it could be expected, over a period of time probably between 2 and 4 years, to return to a condition similar to its present contaminated state. While a water body remains in the present open cut, it can always be expected to be polluted, at least for some considerable time in the foreseeable future, could not be a swimming or recreation water hole, or water supply, and must always be fenced from public access.

It can be inferred, therefore, that to control the mechanisms actually contaminating water in White's open cut will require control of the two sources understood to be the cause. The first mechanism is understood to be chemical and bacterially assisted oxidation of metal sulphides, production of sulphuric acid and leaching from the pyrite rich black slates of the Golden Dyke Formation in the southern perimeter of the pit. These mechanisms are believed to be operating on a scale comparable with chemical and bacterially assisted oxidation in White's overburden heap.

To control this process would require an air and water tight barrier to be constructed between the wall of the open pit and the water in the pit in order to prevent the diffusion of oxygen into the slates and to prevent the diffusion or leaching of contaminants out of the slates into the water body.

The second mechanism understood to be contaminating water in White's open cut is by diffusion or upward leaching of contaminants from the tailings in the bottom of the pit. To inhibit or prevent this mechanism in the open cut would require that a low-permeability barrier be placed above the tailings preventing diffusion or upward leaching.

It could be inferred that, with only 700,000 tonnes of tailings material in the pit, this problem would diminish in time if contamination from this source were flushed away regularly. However, with the production of sulphuric acid and the release of heavy metals by bacterially assisted oxidation and leaching from perimeter slates, the pH will continue to be low (i.e. about 4), thus retaining significant heavy metal contamination in solution.

A further consideration is the presence of the main shear zone, a vertical zone of intensely sheared material of the Golden Dyke Formation. This shear zone runs for a considerable distance from east to White's open cut to a distance beyond the Intermediate open cut; it bisects both open cuts and is believed to act as a aquifer between the two open cuts.

Any proposal to ameliorate the problems associated with White's open cut, i.e., to control mechanisms continually contaminating the water within the open cut and to control the release of contaminants from it, is necessarily complex. The problems are not entirely understood, nor are they likely to be. Research into the nature of the problem is significantly more difficult in physical terms, largely because of the difficulties involved in taking samples in and around the open cut, than seeking to understand similar physical, chemical and microbiological processes in an overburden heap, and for this reason it has not been attempted on that scale.

The most significant mechanism of release of contaminated water from White's open cut, i.e. that of seepage through permeable dolomite formations, could remain the focal point for controlling actual releases. (The background to this aspect of the problem was discussed in Sections 4.5 and 4.6) Engineering solutions to curtail seepage, in the event of the open cut remaining otherwise untouched, are possible and are discussed in the following section.

A most interesting, yet unexplained, difference between water quality in White's open cut and the Intermediate open cut is the difference in dissolved oxygen levels. At about 3m depth in White's, dissolved oxygen is virtually depleted, whereas in the Intermediate open cut there is a slight increase to depths between 5 and 10 metres followed by only a gradual depletion for the remaining depth. The simple explanation so far is that it is due to chemical and/or biological oxidation. The nature, extent and effect of this so far unresearched chemical and biological oxidation is open to conjecture. However, it is likely that these factors are highly important in mechanisms governing contamination of water in the open cuts.

#### 7.3 Alternative Solutions

Despite the complexity of the problems and the fact that they are not entirely understood, there nevertheless remain a number of alternative actions which can be taken. These vary from doing very little, to solutions which in fact suggest complete refilling of the open cuts.

Since the principal problem is White's open cut, it is evident from the discussion in the previous section that, should any action be decided upon, the only two alternatives which can seriously be considered as providing a satisfactory degree of rehabilitation would be as follows:

- (a) prevent seepage from leaving the open cut by grouting all aquifers particularly those which lead to surface expression of contaminated seepage;
- (b) construct impervious barriers in the open cut covering the tailings in the bottom and the oxidising pyritic slates in the southern perimeter.

#### 7.3.1 White's Open Cut

#### 7.3.1.1 Grout Aquifers

Engineering solutions for terminating or significantly reducing the flow of contaminated seepage entering the surface and groundwater systems were considered briefly but could not be assessed in any detail. At best an estimate could be made of works which could, with limited assurance, curtail the flow of seepage with surface expression only, by grouting the point of expression at the surface or by grouting the path of the aquifer. Detailed drilling would be required to delineate these flow paths before a proposal could be satisfactorily considered.

More importantly, however, it must be realised that surface expression represents only a small fraction of the estimated total loss by seepage. Furthermore, no estimate is made of groundwater which might traverse the open cut at depth, e.g. entering and leaving via the main shear zone, or by solution channels in the dolomite. The highly unpredictable and permeable nature of weathered dolomite (as discussed in Section 4.6) is considered to be a particular problem. It would be an extremely difficult task first of all to identify and locate the seepage exits from the entire open cut, let alone implement an engineering solution to reduce seepage.

This alternative would require detailed hydrogeological investigation and would doubtlessly incur substantial costs. No cost estimates have even been attempted due to the almost impossible nature of the task and the low level of assurance that could be ascribed to such measures.

The level of water in the open cut(s) could be maintained, by continuous pumping, at a slightly lower level than the surrounding water table to induce flow inward, rather than allowing seepage outwards. Disadvantages of such a scheme are that it would require continuous pumping and water treatment works. This alternative has not been considered further because it would require annual operating and maintenance efforts for an indefinite period into the future.

# 7.3.1.2 Treat water and Re-Open the Open Cut to the East Finniss River

Consideration was given to the relatively simple proposal of treating the water in White's open cut (or even both White's and the Intermediate open cuts) and re-opening the open cut(s) to the East Finniss River. The water treatment method considered appropriate would principally involve the addition of lime in order to precipitate heavy metals. It was conjectured that diversion of the East Finniss River through the open cuts could possibly provide adequate flushing of the open cuts by floodwaters every wet season, thereby maintaining a better water quality in the open cut(s).

This proposal may, in fact, have much merit. Its success, however, is highly dependent on the relative rates of production of contamination and the amount of annual flushing. A severe limitation would be that the ratio of average annual flow in the East Finniss River to the volume of water in White's open cut is only about 10 to 1 and this would be even lower if the Intermediate open cut were included. Mixing processes in the cut(s) would most likely not result in even this level of dilution of contaminants. The effectiveness of this alternative is uncertain and no reasonable assurance can be expressed in it as a viable solution at this stage.

A very tentative cost estimate for this alternative (for White's open cut only) would be approximately as follows:

Water treatment
Diversion earthworks

\$0.51 million
\$ .05

\$0.56 million

In the event that a local lime industry is established to provide lime for the Ranger Uranium Mining Operation, lime may be available much more cheaply than from overseas sources. This could result in a lower estimate for the cost of neutralisation of the open cut.

#### 7.3.1.3 Treat Water and Refill with Waste Rock

The third alternative, consisting of creating barriers in the open cut, could give rise to several variations of an overall solution which broadly involves refilling the open cut with rock and/or earth fill. Water currently occupying the open cut would be displaced during the operation and would need to be treated before release to the river system.

Three variations of such a proposal are discussed below.

### SCHEME 1 - SEAL ACTIVE ZONES AND ALLOW REMAINING OPEN CUT-OPEN TO THE EAST FINNISS RIVER

This proposal would involve partial backfilling of the pit with barren material, which could possibly be Dyson's Overburden Heap since this material has a low sulphur content and a somewhat high clay content, and would assume prior dumping of the Heap Leach Pile into the pit.

Treatment of water in the open cut would principally involve treatment with lime (to a pH of between 8 and 10) in order to achieve precipitation of heavy metals, particularly manganese. Overflow water may need further treatment before discharge to the river system.

Dumping of the heap leach pile and Dyson's overburden in the open cut would leave an unfilled volume of about  $1.1 \times 10^6$  cubic metres. The East Finniss River could be diverted back to its original course and through the remaining open cut but at the present the working group is of the opinion that it should continue to flow through the diversion channel. It is possible that the lake created could eventually be utilised as a recreation area, depending on water quality achieved.

The placement of this barrier in the pit, the reduction in volume of the remaining open cut and the re-opening to the annual flushing of the East Finniss River could provide a satisfactory solution. This scheme is depicted in Figure 12(a).

This proposal would cost about \$5.00 million.

## SCHEME 2 - SCHEME 1, WITH THE INTERMEDIATE OVERBURDEN ALSO RELOCATED

A further variation of Scheme 1 with a greater likely reduction in overall pollution load originating from the mine site, would be to also relocate the Intermediate overburden heap  $(0.8 \times 10^6 \text{m}^3)$  in the open cut prior to backfilling with barren material. This scheme, which would probably fill the open cut to about the level of the water table is illustrated diagrammatically in Figure 12(b). It would cost about \$7.33 million.

#### SCHEME 3

A more costly variation of the abovementioned proposal but with added benefit would be to completely refill the open cut to approximately an original surface profile. This would require up to an additional half million cubic metres of fill. This Scheme, which is illustrated in Figure 12(c), would cost about \$9.00 million.

#### 7.3.1.4 Discussion and Conclusion

Such schemes for refilling the open cut (cuts) have not been examined closely and require further detailed engineering evaluation. However, the present discussion circumscribes the problems, the alternative solutions and their likely costs.

Having in mind the various alternatives considered above, and the effectiveness, difficulties and costs of their implementation, a practical alternative is expected to emerge following more detailed evaluation. Such a proposal could involve partial treatment of water in the open cut, dumping the heap leach material from several locations on the rim, dumping of barren material on top of this, further treatment of overflow water, and possibly diverting the East Finniss River

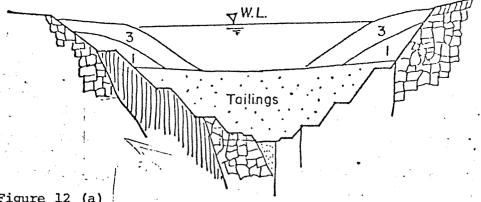


Figure 12 (a)

Scheme 1 : Partial refill with Heap Leach Pile and Dyson's Overburden

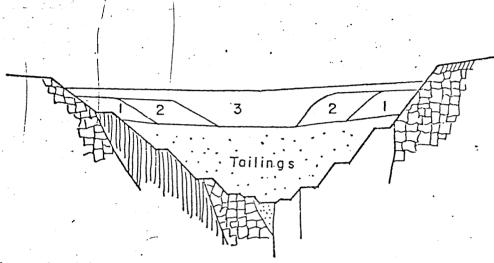
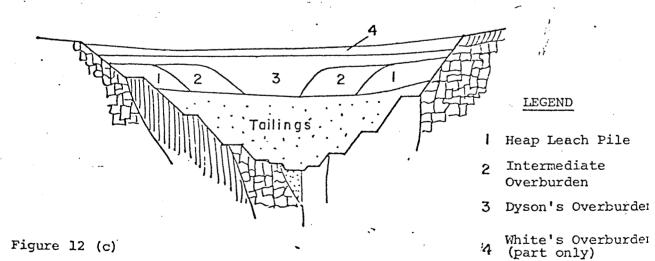


Figure 12 (b)

Scheme 2 : Partial refill with Heap Leach, Intermediate Overburden and Dyson's Overburden



Scheme 3 : Complete refill with Heap Leach, Intermediate and Dyson's Overburden and part of White's Overburden

Q	100m
<u> </u>	

through the remaining lake. The cost of this type of proposal would most likely be covered by the cost estimates for Scheme 2 considered above.

#### 7.3.2 <u>Intermediate Open Cut</u>

The Intermediate open cut is a small contributor to the overall pollution load, contributing about 3% of the copper, 4% of the manganese and less than 1% of the zinc. Removal of the heap leach pile would remove's source of contaminated seepage entering the open cut, and, as a result, the quality of water in the open cut could be expected to improve. With backfilling of White's open cut, thus reducing a further source of contaminated seepage believed to be reaching the Intermediate open cut via the main shear zone, the water quality would be expected to improve even further.

Unlike White's Open cut the Intermediate open cut is a somewhat more healthy body of water (refer to Tables 9(a) and 9(b)) owing to factors, which although not entirely understood, are reflected by the differences in their respective dissolved oxygen profiles.

# 7.3.2.1 <u>Treat Water and Divert East Finniss</u> River through Open Cut

As discussed under Section 7.3.1.2, water in the Intermediate open cut could also be treated in a manner similar to that suggested for White's open cut. Following precipitation of heavy metals the East Finniss River could possibly be diverted through the open cut. A better assurance of eventually attaining reasonable water quality (than for White's open cut) could be anticipated because of its smaller size and different water quality and contamination mechanisms. This alternative could cost approximately \$0.25 million.

#### 7.3.2.2 Treat Water and Refill with Waste Rock

The Intermediate open cut could be partly or completely refilled in a similar manner to schemes suggested in Section 7.3.1.3 for refilling White's open cut. The proposal for complete refilling with, for example, the Intermediate Overburden, would cost approximately \$2.4 million.

Similar detailed engineering evaluation would be needed for proposals for refilling the Intermediate open cut as were discussed for White's open cut. However, a practical solution could also be expected as was discussed for White's.

#### 7.3.2.3 Environmental Research Model

Should/it be decided that the two alternatives discussed above are considered ineffective or inappropriate, a third alternative remains. It has been suggested that the Intermediate open cut could very usefully serve as a scale model for environmental research for the future Jabiluka II (Pancontinental) open cut, owing to its similarity with this open cut. The opinion of the Supervising Scientist is required on this matter.

However, this is only a short term use and eventually rehabilitation of the open cut would need to be considered.

#### 7.3.3 Dyson's Open Cut

Dyson's open cut contributes very little to the overall pollution load. The particular requirement for rehabilitation of this area is principally to remove the embankment in the eastern extremity to allow drainage, and to then cover tailings in the pit with rock and topsoil and to establish vegetation.

The technique and its costs are discussed in Section 8 dealing with the Old Tailings Dam. The estimated cost of removing the embankment, covering the tailings with rock and soil and establishing a vegetation cover is about \$0.15 million.

#### 7.4 Conclusions

Alternatives for the amelioration of the problems associated with the open cuts have been examined. Tailings in Dyson's open cut could be rehabilitated by establishment of vegetation on a rock and topsoil cover following breaching of the water retaining embankment.

Amelioration measures for White's open cut, in order to provide a solution with some reasonable level of assurance, are necessarily large in scale and consequently are somewhat expensive. A solution can be anticipated, following a more detailed engineering evaluation, in which a high degree of confidence could be expressed. This would probably involve partial treatment of water in the open cut followed by partial filling with the Heap Leach pile and Dyson's Overburden Heap material. Overflow water would need further treatment before release to the river system.

The Intermediate open cut could be partially refilled in a manner similar to that which could be anticipated for White's open cut. Possibly it could be reopened to the East Finniss River following treatment of water contained in the pit. It could also be used for environmental research, but its rehabilitation would eventually need to be considered.

The state of the s

Alternatives considered for White's open cut and the Intermediate open cut do not immediately present a clear choice of solution. Although some further evaluation is necessary, a practical engineering solution can be expected to emerge, the approximate cost of which would most likely fall in the middle of the range of cost for schemes discussed in Section 7.3.1.3.

If sulphur bearing minerals (i.e. the heaps) are deposited in an open cut in water which is devoid of oxygen, there is unlikely to be acid formation and dissolution of heavy metals.

However, strategies for refilling White's open cut or the Intermediate open cut, will need to consider the possible effects of such proposals in further detail having in mind the possibility that groundwater could be oxygenated, that bacterial oxidation and subterranean leaching may continue, and that groundwater may continue to be contaminated.

#### 8. THE OLD TAILINGS DAM

#### 8.1 Introduction

In the first six years of treatment plant operations from 1953 to early 1961 approximately 640,000 tonnes of tailings material were deposited in a large flat gently sloping area of about 30 hectares immediately north of the plant site.

These tailings are the finely ground acid-leached waste from processed ore which was treated for uranium and copper. The average depth of tailings is reported to be about 1 metre with maximum depths in the eastern areas of 2 to 3 metres.

The tailings were discharged, without being neutralised, as a slurry; the solids material settled out and the supernatant liquor, at about pH 1.5, drained into Old Tailings Creek.

The tailings material itself is quite sterile and completely inhospitable to plant growth. Encroachment and growth of natural vegetation species on the tailings material has not occurred at all.

#### 8.2 The Problem

The tailings area, although it is a large barren area completely inhospitable to vegetation, nevertheless is not a major contributor to the annual pollutant load entering the East Finniss River.

The tailings contain high levels of heavy metals and sulphates and have a low pH; these conditions preclude the establishment of any vegetative cover by natural means and significant treatment would be needed to promote permanent vegetative cover. The absence of a stable vegetative cover promotes several problems.

#### 8.2.1 Water Erosion

In the wet season tailings material is eroded from the surface generally and erosion gullies in particular, resulting in the movement over the whole area of up to local depth of tailings per year. Much of it is deposited in the area immediately west of the tailings, leading to a continuing westerly expansion of the area. Significant quantities of tailings material do, however, enter the creek system and deposited tailings material can be observed in the bed and on the banks of Old Tailings Creek and East Finniss River to the junction with the Finniss River.

#### 8.2.2 Wind Erosion

In the dry season the surface of the tailings material dries out due to high evaporation. The surface becomes encrusted with metal salts when moisture, which is brought to the surface through capilliary action, is evaporated away. Under windy conditions fine dust becomes airborne and small local dust storms can often be observed. Radioactive daughter products from the uranium decay chain would also become windborne, thus contributing in a small way to health hazards.

#### 8.2.3 Water Pollution

The tailings area does not contribute greatly to the chemical pollution of the Finniss River system. However, runoff from this area is contaminated with copper, manganese, sulphate, etc. Estimates of the annual heavy metal load originating from the tailings area are about 5 tonnes of copper and about 3.5 tonnes of manganese.

#### 8.2.4 Radiation and Radioactivity

The tailings contain the radioactive daughter products of the uranium decay series originally present in the uranium ore, although some was undoubtedly discharged with process effluents to the river system.

Tailings material discharged to the tailings area contained about 380 Ci of radium. Recent analyses of samples taken from the tailings indicate that most of this radium is still present in the tailings although some migration downwards through the tailings is evident.

Radiation (gamma radiation) levels above the tailings resulting from radioactivity contained in the tailings have recently been surveyed. Radiation levels are some four times higher than the general natural background levels of the area. Radiation exposure which could result from these levels is of no hazard provided that access by members of the general public is restricted to that of a transitory nature.

A recent radon emanation survey showed that contamination from the tailings dam are similar to those from the surrounding areas.

#### 3.3 / Alternative Solutions

There are basically two feasible alternatives to providing satisfactory rehabilitation of the tailings dam area.

- (a) remove the tailings material to one of the open cuts and revegetate the area
- (b) vegetate the tailings in situ.

## 8.3.1 Remove tailings to open cut and revegetate site

This alternative would involve removal of approximately 640,000 tonnes of tailings, neglecting the amount (unknown) already lost by erosion to the river system, and the now contaminated layer of original soil underlying the tailings.

Removal of the tailings may not be a simple earthmoving operation owing to the perched water table and very boggy conditions which may be encountered. Alternatively it could be more feasible to remove the tailings by a slurry pumping method.

Consideration would also need to be given to radiation hazards to the workers which may result particularly from inhaled dust.

Following removal of the tailings, and possibly the removal of contaminated topsoil, the area would need to be revegetated by a technique which would most likely involve a combination of ripping, application of lime, mulch, topsoil, seed and fertiliser. The estimated cost of these works is approximately \$1.00 million.

#### 8.3.2 Establish vegetation on the tailings in situ

Establishment of vegetation on tailings material has been attempted in many locations of the world, on many different types of material, with each particular situation presenting specific difficulties.

In general tailings material is usually so inhospitable that it cannot be revegetated directly, and must first be covered with material that will support vegetation. Particular attention would have to be paid to neutralising acidity and preventing toxic heavy metals from reaching the root zone in topsoil by capilliary rise. Attention would also have to be paid to the construction of an adequate drainage system to provide for storm runoff. Unless this is done there is a high probability that topsoil and seed will erode rapidly.

This solution is estimated to require landscaping, drainage control, application of lime to reduce acidity, a layer of rock, gravel or other graded coarse material for underdrainage and to prevent the upward capilliary rise of contaminated groundwater toxic to plant growth, and the application of topsoil, seed and fertiliser.

The estimated cost of these works is approximately \$0.58 million. These costs are an upper estimate for works which are estimated to provide confidence of success and have been estimated without the benefits of field trials. Actual field trials could be undertaken prior to implementing works and could vary the requirements for the prescription costed, and hence the total cost could be lower. Some preliminary field-trials were commenced on the tailings in November 1978.

It is estimated that this prescription would provide for suitable rehabilitation. It would prevent erosion in the wet season, prevent tailings dust eroding and blowing in the dry season, reduce contaminants (Cu, Mn, SO<sub>4</sub>) entering the river system and substantially reduce radiation levels.

#### 8.4 Conclusion

Suitable techniques for rehabilitation of the tailings in situ have been evaluated and costed and confidence can be expressed in the success of vegetating the tailings in situ with the broad prescription discussed above.

# 9. ACID AND SWEETWATER DAM AREAS, WATER COURSES AND AREAS AFFECTED BY SEEPAGE

#### 9.1 <u>Introduction</u>

In about 1961-1962 a system of controlled discharge of effluents was introduced following abandonment of the Old Tailings Dam area and the Old Tailings copper cementation launders. New launders were constructed south of Dyson's open cut in conjunction with the disposal of tailings into Dyson's open cut.

The East Finniss River was dammed at the centre of the river bed area now known as the Acid Dam. The dam wall across the eastern side of White's open cut was rebuilt and extended across the river diversion channel, then around and across Fitch Creek. The walls beside the open cut and across the river diversion channel were equipped with sluice gates for controlled release of waters.

During the dry season, plant effluent that did not warrant treatment for copper was discharged into the downstream dam called the Lower Acid Dam. Otherwise all effluent was directed to Dyson's copper launders, from which the barren copper liquors were discharged into the Upper Acid Dam.

Waters backing up behind the dam across Fitch Creek were known as the Sweetwater Dam.

During the wet season the East Finniss River would flood the Upper and Lower Acid Dams; the Sweetwater Dam would also flood. At this stage sluice gates would be opened into White's open cut to allow release into White's open cut of "fresh" water. Releases would also be made, into the diversion channel, of diluted acid waters. It was hoped that wet season dilution would permit safe release of acid process effluents, though this is now known not to be the case.

Later a pipeline was constructed from the Sweetwater Dam to the sluice culvert through the dam adjacent to White's open cut in order to provide clean flushing of White's from Fitch Creek. However, by this time the Sweetwater Dam was already receiving contaminated seepage from the eastern seepage springs from White's overburden heap.

Following diversion of tailings and acid process effluents to White's open cut in 1969 the dams did not receive plant effluents. However they were already contaminated and continued to receive contaminated seepage from Dyson's and White's Overburden heaps.

#### 9.2 The Problems

Waste disposal practices during the mining and the treatment operations resulted in considerable damage to the areas under consideration.

Vegetation in the bed and along the banks of the East Finniss River was completely eradicated by contaminated water which was stored in the acid dams, for about 1.5 km upstream of the lower Acid Dam structure. Vegetation is beginning to re-establish in these areas now, particularly in the area of the Upper Acid Dam structure. It seems that the deposition of fresh sand and silt in the bed, due largely to the presence of the Upper Acid Dam wall, has been largely responsible for regrowth in this area.

The Lower Acid Dam has a quite different character. The bed consists principally of a finer silty clay fraction and sand and silt are largely absent. These observations are consistent with sediment transport effects which could be expected from the location and influences of the two acid dams.

The area of the lower acid dam is strewn with dead tree stumps and fallen trunks, vegetation having been likewise decimated. The only vegetation re-establishing currently are herbaceous plant species. Trees and shrubs have only reappeared near the high water line.

Fitch Creek has been affected in a similar manner for about 0.6 km upstream of the dam. The area is similarly denuded and strewn with dead tree stumps and fallen trunks and revegetation is not occurring. This area is continuously being affected by contaminated seepage from White's overburden heap.

The banks of the diversion channel have revegetated rather successfully by natural processes and the diversion channel cannot be considered a problem from bed and bank stability point of view.

Old Tailings Creek, with a length below the tailings dam of approximately 1.0 km, was badly affected and cannot be expected to recover while the bed and banks are contaminated with tailings, and while the tailings dam itself remains in its present state.

The East Finniss River downstream of the junction of Old Tailings Creek has also been significantly affected. The loss of stabilising vegetation in the bed and on the banks of the river in the early days of the operation has led, and continues to result in erosion when river flow is high. Tailings material can be found deposited along the course of the river to its junction with the Finniss River some 20 km downstream.

#### 9.3 Solutions

#### 9.3.1 Acid dams and Sweetwater Dam area

Rehabilitation of these areas requires the implementation of several simple essential steps that are prerequisite to rehabilitation. Providing appropriate physical conditions are established it is considered that the areas will largely revegetate through natural processes, though initial assistance is desirable.

As a first step, drainage through the area should be returned to what would originally have been an evenly graded longitudinal stream bed profile. This would allow free drainage of all stream bed areas in the East Finniss River upstream of the Lower Acid Dam and in Fitch Creek upstream of the Sweetwater Dam.

Although dam earthworks were breached following closure of the mine they were never completely removed. As a result high points exist across the entrance to the diversion channel, and across the entry of Fitch Creek to the East Finniss River just upstream of the early site of the bridge. The effect of these high points, which are some two metres or so above the lowest points in the bed some 50 or so metres upstream, is to

retain water in the site of the Acid and Sweetwater Dams at the end of the wet season. Consequently the areas never dry out sufficiently to promote recovery of vegetation. During the dry season, as the water evaporates, contaminants diffusing from sediments or entering from White's and Dyson's Overburden seepage springs, concentrate in the diminishing pools. The combined result is the appearance at the end of the dry of stagnant pools highly contaminated with acid and heavy metals.

The solution to this drainage problem would be to clear the obstructions in the bed and provide an evenly graded longitudinal bed profile from Dyson's area to the road bridge at the entry to the site. This would principally involve removal or proper breaching of

the Upper Acid Dam

- the Lower Acid Dam section across the entrance to the diversion channel

the Sweetwater Dam

obstructions in the diversion channel (e.g. the dolomite outcrop south of White's open cut), or in the old bed of the East Finniss River if diverted back to its old course.

(See Section 7.3)

These works are of a relatively minor earthmoving nature and would cost the order of \$0.02 million.

As a second step, the entire affected areas should be cleared of dead tree stumps and fallen trunks. Preferably they should be stacked and burned in the dry season. Minimal effort is required for this operation, and the estimate would not exceed \$0.02 million.

As a third step, the entire areas could be cultivated, recontoured for drainage control while at the same time providing for soil erosion control, and should be revegetated using species known to inhabit bed and bank areas. Some lime may need to be applied to counteract acid soil conditions, and fertiliser is also likely to be required. Adequate techniques to achieve a rapid revegetation would require soil tests. It is not considered that an imported topsoil cover would be necessary for the successful rehabilitation of these areas. The following areas require treatment in the manner described above -

Acid Dam - upper	ll ha
Acid Dam - lower	17
Sweetwater Dam	8
White's - areas affected by seepage	. 9
Dyson's - areas affected by seepage	3 .
Old Tailing's Creek	3
3.6	51 ha

This treatment would cost about \$0.14 million.

The total cost for rehabilitation of all areas is estimated to be approximately \$0.18 million.

#### 9.4 Conclusion

Implementation of these three basic elements will most probably lead to satisfactory rehabilitation. Further establishment of vegetation by natural processes over a period of years will gradually revert the area to a condition similar to its former state.

#### 10. ALTERNATIVE REHABILITATION STRATEGIES

#### 10.1 Introduction

Throughout sections 5-9 of this Report a number of remedial measures have been discussed. Each, if applied alone, would make some improvement to the relevant problem area of the site through improvement in its aesthetic appearance, a reduction or elimination of public health and safety risks, or by a reduction in pollution originating from the site. To achieve effective rehabilitation it will be necessary to apply a number of measures together. As alternative measures for several sites have been suggested the number of possible combinations are many.

In this chapter, various individual measures, and a number of selected combinations, that is, alternative rehabilitation strategies, are examined in terms of costs, benefits and other considerations of effectiveness.

#### 10.2 Cost/Benefit Considerations

Because of the different nature of the three kinds of improvement which are necessary, work which would achieve an improvement in one respect may or may not be effective with regard to the others. To arrive at an assessment of the overall benefit of different measures or strategies it was necessary to evaluate the present state of the site with respect to the three forms of site degradation and the changes in these, that is the benefits which might be derived from any proposed action.

A methodology was developed for this purpose.

\*No attempt was made to evaluate economic damage or benefits which in terms of current land use options for such areas in the Northern Territory, would be very small and of minor consequence.

Whereas the present state of chemical pollution in the area has been subjected to actual measurements (Tables 1 and 2), the assessment of the present aesthetic state, or degree of risk to public health and safety depends largely on subjective judgements. Nevertheless, in order to judge the cost effectiveness of different strategies, an attempt has been made to express these, and the benefits arising from various kinds of action, in quantitative terms.

It was the opinion of the Working Group that the average member of the public viewing the site was likely to place approximately equal importance on pollution as on the other factors of degradation combined, namely, aesthetic and public risk. Further, that the nature of the aesthetic damage gave it greater importance than the nature of the public risks. On a point scale of 100 for site degradation, the Working Group allotted 50 to pollution; 35 to aesthetic damage, and 15 to public risk. The individual values allotted to each of the problem areas, that is, to each of the sources contributing to one or more kinds of site degradation, are given in Table 10.

For determining the relative contribution of pollution from each source the estimated percentage annual contribution of copper (Table 2) was used since copper has been considered throughout this report as the most important pollutant and the best indicator of overall pollution.

Points for aesthetic and public health and safety factors were distributed subjectively to the various site components on the basis of their estimated relative contribution to environmental degradation as might be perceived by a member of the public.

To arrive at a cost-benefit assessment it was also necessary to quantify the degree of improvement expected to result from alternative remedial measures applied to each site component.

Estimates for the expected reduction in pollution levels, aesthetic damage, and public risk which are contributed by alternative remedial measures applied to each site component are given percentages in Table 11. To each figure is attached an error margin indicating the degree of uncertainty attached to the estimate.

Estimation of the order of magnitude of chemical pollution reduction which could be achieved by each possible remedial measure was difficult because of the lack of practical experience on the site or elsewhere. The degree of improvement of the aesthetics of the site and the degree of reduction or elimination of public health and safety risks were estimated subjectively. So far as was possible, known chemical, physical and biological phenomena were taken into account in arriving at these estimates.

All estimates were arrived at by consensus of the Working Group. In arriving at these estimates the Working Group was also influenced by considerations of what should or could be achieved providing the appropriate effort and expenditure were applied.

TABLE 10

# ESTIMATED CONTRIBUTIONS TO OVERALL ENVIRONMENTAL DEGRADATION AT THE RUM JUNGLE MINE SITE FROM THE VIEWPOINT OF MEMBERS OF THE PUBLIC

Areas	Pollution	Aesthetics	Public Health & Safety Risks
Heap Leach Pile	16	5	E
White's Overburden Heap	16	5	5
Intermediate Overburden Heap	· 9	2.5	• <u>•</u>
Old Tailings Dam	2.5	7.5	2.5
Dyson's Overburden Heap	0.5	2.5	
Dyson's Open Cut	0.5	2.5	<b></b> '
Acid and Sweetwater Dams, etc.	· -	5	2.5
Intermediate Open Cut	1.5		2.5
White's Open Cut	4	5	2.5
	50	35	15
TOTAL		100	

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The Street	H. ATIVE
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0.4	ULT FIR
	TO RES

Alternatives	Estimated percentage Aesthetics Public Health reduction of pollution and Safety from sources
1. Heap Leach	
ton.	. 15
)•)•) nemove to wnite's open cut - Scheme i - Scheme 2	1000
	10
2. Overburden Heaps	
0.2.1 Establish Vegetation using simple techniques 6.3.2 Cover and establish vegetation	20 + 10
Remove to open cut: Scheme 1 -	- T
Scheme 2 - Dysons	
Scheme 3 - Dysons	
ı	, 01-1 1+1
- White's (Part*)	1-1-1
3. Open Cuts	
White's Open Cut	
	110
- Scheme 2	75
Scheme	100 100
Intermediate Open Cut	• •
and refill	100 - 100 - 100 - 100
0	
7.5.3 Cover tailings and establish vegetation	80 ± 16
4. Old Tailings Dam .	
8.3.1 Remove tailings to White's open cut, revegetate site 8.3.2 Cover and establish vegetation	80 + 10
5. Acid and Sweetwater Dams, Watercourses and areas affected by seepage	
Clear, landscape, grade stream, revegetate	40 ± 20 €

m'; this could be obtained from White's (North) \* Volume of additional fill material required could be up to  $0.5 \times 10^6$  Overburden Heap (0.32 x  $10^6$  m<sup>2</sup>) or White's Overburden Heap itself.

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#### 10.3 Discusion of Possible Remedial Measure

Throughout this report various possible measures have been examined for the rehabilitation of particular problem areas of the Site. In this section, the advantages and disadvantages of each are discussed briefly prior to discussion of alternative overall rehabilitation strategies in Section 10.4. A summary of possible remedial measures, costs and benefits is presented in Table 12.

It would not be possible to completely prevent all pollution from all sources from entering the river system. The best which can be hoped for is that contaminants in the river system are reduced to a level approaching what might have been a pre-mining level (i.e. early 1950's), having in mind that the original drainage was through a mineralized area and must have been contaminated naturally. Unfortunately, no data are available on the original natural pollution level in the East Finniss River.

Aesthetic improvements which would result from various remedial measures would not necessarily return the site landscape to the same condition existing prior to mining. This is considered to be neither necessary nor practicable. Various measures will achieve different levels of visual rehabilitation of the site. Some would return it to a condition comparable with that prior to mining.

Furthermore, it is neither necessary nor practicable to rely on using only native vegetation species for the initial establishment of a vegetation cover on rehabilitated areas. Effective establishment of vegetation in this area is best achieved by using a mixture of native and exotic cover to stabilise the soil against erosion. Re-establishment of native species would follow.

Remedial measures are also designed to reduce or eliminate public health and safety risks in the site area. In this respect not all risks are to be totally eliminated but only the unacceptable risks remaining as a consequence of the mining operations, e.g. acidic sludges in the river beds. Hazards of a similar nature to those which can be found in the surrounding environment, e.g. steep cliffs, are not included.

#### 10.3.1 The Heap Leach Pile

The first priority for reduction of pollution and particularly copper, originating from the mine site is either to seal or to remove the heap leach pile.

Landscaping and establishment of vegetation on the area would achieve an aesthetic result and would : eradicate the hazards, but it is unlikely to reduce pollution satisfactorily in the long term.

COSTS AND REMERITS TABLE 12 - SUMMARY OF POSSIBLE PROBES,

			•
Reason for Action	Alternative Proposals	Sost (#millions)	Benefits
<ul> <li>Heap Leach Pile</li> <li>contributes about a third of copper pollution</li> <li>aesthetically unsatisfactory</li> <li>public safety hazards</li> </ul>	5.3.4 Landscape, cover and establish vege-tation in-situ	0.30	<ul> <li>Landscaping and establishment of vegetation;</li> <li>aesthetic rehabilitation of the area—</li> <li>Elimination of hazards</li> <li>Reduction of vollution from this source 55% ± 15</li> </ul>
	5.3.5 Remove to White's Open cut	0.75	rehabilitation of the area of pollution from this source of $70\% \pm 10$ $80\% \pm 10$
2. Overburden Heaps occupy a quarter of the affected site area contribute about half of the copper, third of the manganese, all of the zinc aesthetically unpleasing	6.3.1 Establish vegetation using simple techniques  White's overburden heap (Mt. Winpey) White's (North) overburden heap Lyson's overburden heap Intermediate overburden heap	0.25 0.04 0.08 0.07 0.44	• 50% improvement in appearance of heaps by establishment of vegetation (using low cost techniques) • Improved drainage of storm runoff, reduction of erosion • Modest reduction of contamination of surface runoff and of infiltration and leaching • Reduction of pollution from these sources by 20% ±
	6.3.2 Landscape, cover and establish veretation in-situ White's overburden heap (Mt. Wimpey) White's (North) overburden heap	1.10	90% improvement in appearance of heaps by landscapin and establishment of vegetation (using superior techniques) Improved drainage of storm runoff, marked reduction erosion

Reason for Action	Alternative Proposals	Cost (#millions)	Benefits
	6.3.2. (Cont'd) Dyson's overburden heap Intermediate overburden heap.	0.39 0.28 1.94	• Marked reduction of contamination of surface and of infiltration and leaching. Reduction pollution by 70% - 10
	6.3.3 Remové heaps to open cut byson's overburden heap to White's open cut Establishment of vegetation on site.  Intermediate overburden heap to White's open cut Establishment of vegetation on site.	3.12 0.13 3.25 2.3 2.4	Femoval of heap, thereby eliminating contaming from these sites  Rehabilitation of vacated sites by establishme vegetation  Reduction of pollution  Dyson's: Scheme 1 50% + 10  Scheme 2 75% + 10  Scheme 2 80% + 10  Scheme 2 80% + 10  Intermediate: Scheme 2 80% + 10
	6.3.4 Collection and Evaporation of Seepage from White's, Dyson's and part from the Intermediate overburden heaps.	0.30 -0.70	• Collection, retention and treatment of runoff seepage spring flows (but requires continued and supervision) • Evaporation pond will be an unattractive featuaite
7. Open Cuts Octupy about a tenth of the affected site area Contribute about a tenth of the copper, half of the manganese	7.3.1.3 Treat water and refill with waste rock Scheme 1 - partial refill with heap leach, and Dyson's overburden. Scheme 2 - partial refill with heap leach, Dyson's and Infermediate overburden	5.00	. Reduction/elimination of water quality hazards . Reduction of pollution by 50% ± 10 . Reduction of pollution by 75% ± 10

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Benefits	. Reduction of pollution by 90% - 10  50 - 100% improvement in aesthetics, and reduction risks according to Scheme adopted	. Reduction/elimination of hazards . Reduction of pollution 70% ± 10 . Reduction of pollution 80% ± 10 . Reduction of pollution 90% ± 10	. 80% aesthetic rehabilitation by establishment of vegetation . Reduction of radiological hazard . Reduction of pollution by 80% ± 10
Cost (\$millions)	9.0 (Figures include cost of removing heaps, establishing vegetation, water treatment etc.)	0.25	0.15
Alternative Proposals	7.3.1.3 (Cont'd) Scheme 3 - complete refill with heap leach Dyson's, Intermediate and part of White's overburden	7.5.2.1 Treat water and divert East Finniss River 7.5.2.2 Treat water and partly fill with waste rock "Treat water and completely refill with waste rock fill with waste rock rock	7.3.3 Cover tailings and establish veceta-tion in-situ
Reason for Action	Water unfit for recreation or consumption  a) White's Open Cut  Assthetically unsatisfactory  Public health and safety hazards  Contributes about 8% of	copper, 40% of manganese to pollution load.  b) Intermediate Open Cut.  Aesthetically unsatisfactory.  Public health and safety hazard.  Contributes about 3% of copper, 4% of manganese and about 1% of zinc.	Aesthetically unsatis- factory Public health and safety hazard Contributes about 1% of copper, 4% of mangenese

Cont'd/...

	(#millions)	<u>  •                                     </u>	• Marked reduction of radiological health risk but risk	• Reduction of dispersal of tailings by erosion • Reduction of pollution from this source by 80% = 10 • 90% aesthetic rehabilitation by establishment of	• Reduction of radiological health risks • Prevention of dispersal of tailings by erosion	• 70% aperture.	1 in stream bed, removing debris and establishment of O.02 Removing the stablishment of O.02 Removing the O.02 R	0.14 • Reduction of pollution from these areas h. 10.7 +	2 - 40.4 · 60		Restriction of Protection of	by native and feral animals
Reason for Action	Alte	S.5.1 Remove to White's Open Cut and establish Vereta	erosion es about 5% of d about 6% of	8.3.2 Landscape, cover and establish vegetation in-situ	leid and Sweethat		cally Remove dead trees,	Establish vegetation	id dam contributes out 17% of manganese	nately 10km of	1 encing 0.05	

The second secon

A possible improvement would be to landscape the pile, seal it by covering it with a well designed clay/rock/topsoil layer (Section 5.3.4) and establish a vegetation cover on this. This could be achieved for a cost of about \$0.30 million. Using such a technique the appearance would be improved and the copper contribution from this area could be reduced by an estimated 55% + 15, representing a reduction in copper from the whole site of about 18%.

Severe doubts, however, are expressed about the stability of such a solution in the long term. The sealing profile may fail due to erosion and in this event leaching could be expected to continue. This cover would therefore most likely require continuing maintenance. For these reasons this particular solution is not considered acceptable.

Alternatively the pile could be dumped into White's open cut and the area rehabilitated (Section 5.3.5) for a cost of about \$0.75 million. The effect that this action would have on water quality in White's open cut is not entirely certain and requires further investigation (See Appendix 2). However, it is not likely to be satisfactory unless other measures are also taken, such as treatment of the water in the open cut and covering the heap leach material dumped in the cut with barren fill.

Some of the pollution load from the pile could continue to reach the environment via the surface or groundwater systems but it is estimated that this would be reduced by from 70% + 10 to 90% + 10 depending on which overall solution is chosen for White's open cut. The reduction in total pollution from the site would be of the order of 22 - 29%.

The Working Group agreed unanimously that the heap leach pile should be transferred to White's open cut. This would ensure satisfactory disposal of this source of pollution as well as contributing to the overall solution for White's open cut itself. The area occupied by the pile would be satisfactorily rehabilitated.

#### 10.3.2 The Overburden Heaps

The four overburden heaps together contribute about half of the copper, about a third of the manganese and virtually all of the zinc. Remedial works to reduce pollution from them and to improve their appearance; should have high priority.

By providing better surface drainage on the heaps and using low cost methods of establishing vegetation (Section 6.3.1) it would be possible to achieve some aesthetic improvement and to reduce contamination of surface runoff water. However, this technique could not be expected to adequately reduce infiltration of water into and leaching of contaminants from the heaps.

It has been estimated that this technique could be expected to reduce the contaminant load from the heaps by only about 20% + 10 and from the whole site by 5 - 15%.

Rehabilitation of the heaps in this manner would cost approximately as follows:

White's Overburden Heap \$0.25 million White's (North) Overburden Heap \$0.04 million Intermediate Overburden Heap \$0.08 million \$0.07 million \$0.04 million \$0.08 million \$0.07 million \$0.04 million

To substantially reduce infiltration and leaching would require sealing of the heaps using some form of carefully designed clay and topsoil cover (Section 6.3.2). Rehabilitation of the heaps in this manner would cost approximately as follows:

White's Overburden Heap \$1.10 million
White's (North) Overburden Heap \$0.17 million
Intermediate Overburden Heap \$0.28 million
Dyson's Overburden Heap \$0.39 million
\$1.94 million

This technique would improve the appearance of the heaps substantially and could be expected to reduce contamination of surface runoff and to reduce infiltration and leaching from the dumps by about 70% + 10. The overall reduction from the site being 30 to 40%. The long term effectiveness of such a measure for the heaps is considered more likely to be successful than for the heap leach pile.

There is also the possiblility of removing some of the heaps to the open cuts. Such action could possibly reduce contamination from the heaps by as much as 90% + 10 and from the site as a whole by 40 - 50%, depending on the scheme chosen. (See Table 11 for pollution reduction factors). Such schemes are discussed below in conjunction with alternatives for the open cuts.

#### 10.3.3 The Open Cuts

The three open cuts at the mine site contribute only about a tenth of the copper, but about half of the manganese. They contribute virtually no zinc. Although the manganese contribution is high it is believed to have less environmental significance on downstream aquatic life than copper and zinc. Substantial increases of manganese on the Finniss River plains might prove harmful to livestock.

#### 10.3.3.1 Dyson's Open Cut

The tailings in Dyson's open cut could be satisfactorily rehabilitated by breaching the water retaining embankment, covering the tailings with rock and topsoil and establishing vegetation on this cover. This action would achieve an aesthetic improvement. It is also estimated to reduce pollution from this source by about 80% ± 10 but contamination from this source is small and the effect on the site as a whole would be only a reduction of about 1%. These works would cost about \$0.15 million.

#### 10.3.3.2 Intermediate Open Cut

Although the Intermediate open cut could be used for environmental research in the short term, rehabilitation will eventually need to be considered. It is considered that following treatment of the water it is highly likely that this open cut could be re-opened to the East Finniss River and that this would then maintain a satisfactory water quality. It has been established that this could achieve a reduction of about 70% + 10 of the rather small amount of contamination originating from this open cut, hence reducing by only about 2% contamination from the whole site. Such works would cost about \$0.25 million. The Working Group considered this should provide an adequate solution with the possibility of establishing an attractive lake for recreation purposes.

Alternatively, the Intermediate open cut could be refilled with waste rock, after treatment of the water. It has been estimated that this could achieve a reduction in contamination originating from the open cut of about 90% ± 10, but only about 3% in the total pollution from the site. Complete refilling of the pit would cost about \$2.65 million.

#### 10.3.3.3 White's Open Cut

White's open cut presents the most costly problem of the three open cuts. It has been estimated to contribute about 8% of the copper and 40% of the manganese from the whole site. In view of the possible need in the long term of developing the Finniss River as a water supply for Darwin no rehabilitation strategy would be complete without reducing contamination originating from this open cut. Apart from this, the need to maintain the open cut as a restricted area because of its present water quality makes it unacceptable as a permanent feature of the site.

The only solution for White's open cut, in which a satisfactory degree of confidence can be expressed, is a scheme of at least partially refilling it. Several schemes were considered, varying from partial refill to complete refill. Although such proposals would require a rather large expenditure they would at the same time achieve disposal of the heap leach pile and Dyson's Overburden (Scheme 1, Section 7.3.1.3) and possibly also the Intermediate Overburden Heap (Scheme 2), Section 7.3.1.3) as well. These three heaps together contribute about half of the total copper, a tenth of the total manganese and nearly half of the zinc annually entering the Finniss River system.

Such strategies could be expected to substantially reduce the copper and managnese contribution currently released from White's open cut. It is estimated that the Schemes discussed in Section 7.3.1.3 would provide the following reduction in contaminant load originating from White's open cut itself:

Scheme	1	50% +	10)	Tì	ne o	overal:	l reduc	ction			
Scheme				in	ı c	ontamir	nation	from	tl	ie.	
Scheme	3	90% ∓	10)	, s:	Lte	would	range	from	2	to	3.5%

In addition, such strategies would also substantially reduce the pollutant contributions from the heap leach pile and the two overburden heaps, depending on which strategy is chosen. For estimates of reduction factors see Table 11.

It is therefore evident that such proposals, and particularly Schemes 2 and 3, would largely eliminate the copper and the manganese annually released to the river system from the principal—sources. They would also remove the necessity of maintaining White's open cut as a restricted area. It is in this perspective, along with the possible need in the future of improved water quality in the Finniss River, that this proposal should be considered.

#### 10.3.4 The Old Tailings Dam

Although the old tailings dam is not a major contributor to the overall pollution load, nevertheless a high priority exists, for aesthetic and public health reasons, as well as for pollution control, either to remove it or to cover it and establish permanent vegetation on the area.

Covering and vegetating the tailings in situ would provide aesthetic rehabilitation, reduce gamma radiation levels over the tailings, eliminate erosion and reduce the contaminant load originating from the tailings by about 80% ± 10 with reduction of total pollution from the overall site of 2%. Depending on the type of cover used this proposal would cost from \$0.6 million to \$1.0 million.

Alternatively the tailings could be dumped into White's open cut and vegetation established on the area. This would cost about \$1.0 million. Containment of contaminants in the tailings within the open cut will depend on the overall solution chosen for White's open cut. It has been estimated that this proposal would reduce contamination from this source reaching the surrounding environment also by about 80% + 10.

However, removal of the tailings to the open cut may prove to be a difficult operation because of the perched water table within the tailings and the very boggy conditions which may be encountered. The operation may, as a result, be considerably more expensive. It may be necessary to remove the underlying original surface layer of now contaminated soil. Further, radiological hazards to workers involved in such an operation, particularly their exposure to radioactive dusts, is considered to be a major disadvantage of this alternative.

Following consideration of the advantages and disadvantages of the alternatives the Working Group considered that the tailings should be covered in situ and that permanent vegetation be established.

# 10.3.5 Acid and Sweetwater Dams, Watercourses and Areas Affected by Seepage

Rehabilitation measures proposed for these areas are relatively straightforward. Priority exists for works in these areas principally for aesthetic reasons, although safety hazards would also be eliminated. These works would cost about \$0.18 million. It was estimated that these works could possibly increase the contaminant load originating from this source in the short term due to the disturbance of the topsoil profile during revegetation. However, in the longer term this contribution is most likely to be reduced. Pollution reduction from these sources was estimated at about  $40\% \pm 20$  although the reduction in total pollution load from site is almost negligible.

#### 10.3.6 Fencing of the Site

The success of establishing and maintaining permanent vegetation cover on rehabilitated areas, including the Old Tailing's Dam, the Overburden Heaps and the Acid and Sweetwater Dam areas will depend very much on vegetation becoming well established in the first few years. Buffaloes, wallabies and kangaroos will graze on vegetation as it becomes established, and therefore the site should be fenced. Although it is difficult to totally exclude these animals, it is essential that buffalo be excluded from the area until vegetation

As natural seeding and regeneration of vegetation are to be relied upon for the becomes firmly established. regeneration of vegetation it is essential that firm establishment of vegetation it is essential that annual species be allowed to mature and seed. perimeter fence to exclude large animals from the site area would cost about \$0.05 million.

# Alternative Rehabilitation Strategies

From the examination of the remedial measures which have been considered a number of overall alternative rehabilitation strategies emerge using various combinations of measures.

Eight rehabilitation strategies were considered. were based on various combinations of alternative treatments for the Heap Leach pile, the Overburden Heaps, and White's open cut. They are listed as strategies A to H and are described in Table 13 which also includes data on their relative costs and

It was agreed by the Working Party that essential elements of each of these strategies should be the following benefits. relative low cost measures.

- The Old Tailing's Dam should be landscaped and covered and vegetation should be established on 1. this cover.
- Tailings in Dyson's Open Cut should also be covered and vegetation established. 2.
- The Acid and Sweetwater Dam areas, watercourses and areas affected by seepage should be treated as 3. proposed (See Section 9).
- Water in the Intermediate Open Cut should be treated and the East Finniss River diverted through 4. the open cut.
- That a strong fence be erected around the site to protect vegetation established on rehabilitated

It was agreed that in evaluating and comparing strategies, their contributions to aesthetic improvement, reduction or elimination of public health and safety risks, and reduction of pollution should all be taken into account.

With respect to pollution control the Working Group considered what level of pollution reduction in the river system should be aimed at, having in mind the following water quality related problems which have been considered throughout this study:

(a) early wet season fish kills in the Finniss River at the junction of the East Finniss River.

TABLE 13 - ALTERNATIVE REHIBILITATION STRATEGIES - BENEFITS AND COSTS

	Cost millions			1.63	2:37	3.87	66.9	Cont'd.
	Heavy from Site	Zn		N£1	50	02	50	
	% Reduction of H Metal Pollution for	Mn	<u>-</u>	6,	24	38	.46	ş
		Ca		<b>ω</b>	36	40	44	
	Benefits	Total Out of	- <del>-</del>	24	51	57		-
	Estimated Notional Be	Acsthetic Rehabilita- tion etc.		50	33	37	070	
	Estimated	Pollution Reduction (Copper)		4.	18	. 50	35	
		Description of Strategy	The following items are common to all strategies except H where the Intermediate open cut is filled: Old Tailings Dam - cover and establish vegetation) Dysor's Open Cut - cover tailings and establish )	vegetation Acid and Sweetwater dams, watercourses, etc clear, grade streams and revegetate Intermediate Open Cut - treat water and divert East Finniss River through open cut Fence site	A. Heap Leach - cover and establish vegetation Overburden Heaps - establish vegetation using simple techniques White's Open Cut - no action	B. Heap Leach - cover and establish vegetation Overburden Heaps - landscape, cover and establish vegetation White's Open Gut - no action	C. Heap Leach - dump into White's open cut, cover with Dyson's overburden Overburden Heaps' - establish vegetation using simple techniques White's Open Cut - partly refill, treat water - Scheme 1	

# TABLE 13 (Cont'd)

		ns n			•		
	Cost	\$ millions	  - 	8.18	9.25	10.23	
	Heavy from Site		Zu	70	46		
	% Reduction of H Metal Pollution f		Mn	56	09		
		•.	Çn	70	. 09	. 92	
	Benefits	Total	Out of	78	75.	85	· .
	Notional	Aesthetic	Rehabilita- Lion etc.	43	45	47	
	Estimated	Pollution	uction pper)	35	30	38	
	Doconintion of Stuatoms	הפסכדון סד הימיהפאל		D. Heap Leach - dump into White's open cut, cover with Dyson's overburden Overburden Heaps - landscape, cover and establish vegetation White's Open Cut - partly refill, treat water - 'Scheme 1	E. Heap Leach - dump into White's open cut, cover with Intermediate and Dyson's overburden Overburden ("White's) - establish vegetation using simple techniques White's Open Cut - treat water, refill - Scheme 2	F. 'Heap Leach - dump into White's open cut, cover with Intermediate overburden and Dyson's overburden. It is not possible to estimate precise Volumes of materials when disturbed for removal to the pits. It is possible that 'Strategy F would fill White's Open Cut, if so, overburden (White's) - landscape, cover and establish vegetation White's Open Cut - treat water, refill - Scheme. 2	

T. 'LE 13 (Cont'd)

					,	•	
	Astimate.	Estimated Notional Be	Benefits	% Reduction of Metal Pollution		Heavy from Site	Cost
Description of Strategy	Follution Reduction (Copper)	Aesthetic Rehabilitation etc.	Total Out of 100	Çn	Mn	Zn	`\$ million:
G. Heap Leach - dump into White's open cut, cover with Intermediate overburden and Dyson's overburden (White's) - landscape, cover and establish vegetation White's Open Cut - 'treat water, completely refill to original profile - Scheme 3	41	47	88	85	76	74	11.83
H. As for F (above) but completely refilling the Intermediate open cut	39	47	98	78	78	92	12.63
		1		-			

- (b) the slow rate of natural regeneration of vegetation along the polluted course of the East Finniss River from the mine site to its junction with the Finniss River.
- (c) improvement of water quality in waters of the Finniss River system in view of the possible need for its development as a water supply for Darwin.
- (d) transient unsuitability of water quality (for potability) in the Finniss River due to the slug of pollutants in the first flush of the wet.

In the absence of firm data on which to make an objective evaluation the Working Group considered that a minimum reduction of copper pollution by two-thirds is desirable. Whilst the Working Group considered that copper was the most serious contaminant it also considered that substantial reduction (greater than 50%) must also be achieved for manganese and zinc. The Working Group considered that these reductions would achieve:

- (a) elimination of the fish kills in the Finniss River in so far as they are attributable to effluents from the mine site.
- (b) elimination of transient unsuitability of water quality in the Finniss River, attributable to the same cause, and
- (c) contribute to the natural regeneration of vegetation and aquatic life along the course of the East Finniss River below the mine site.

The estimates of notional benefits gained shown in Table 13 were derived by applying the percentages shown in Table 11 to the figures in Table 10 for each combination of measures constituting a strategy.

# 10.5 Consideration of Alternative Strategies and Adoption of Options

Of the strategies that have been reported in Section 10.4, the Working Group rejected Strategies A, B and C because the degree of pollution reduction which would be achieved is insufficient. It also rejected Strategy E because, as can be seen in Table 13, it has a higher total cost and would achieve lower total notional benefits than Strategy D. Strategy H was not preferred as it would achieve lower total notional benefits at a higher cost than Strategy D and it need be considered only if it is deemed desirable to fill the Intermediate pit. This leaves Strategies D, F and G which are considered as viable, options for decision.

Strategy D is considered to be the minimum satisfactory Strategy for achieving the objectives. Table 13 shows that estimated total notional benefits of 78%, and 70% reduction of pollution.

Strategy F for a total cost of \$10.23 million is estimated to achieve total notional benefits of 85%, with 76% reduction of copper, 68% reduction of manganese and 74% reduction of zinc pollution. It is possible that Strategy F could result in almost complete refilling of White's Open Cut. approach those of Strategy G. Therefore Strategy G may become redundant.

The Working Group consider that the estimated benefits from Strategy F would effectively return the site to a condition substantially similar to that prior to commencement of the mining operations. The Working Group therefore considers that the additional benefits of Strategy F over strategy D, for the additional expenditure of \$2.05 million, preferred option.

The Working Group considers that the order of preference of bf Strategies should be F and D followed by H only if it is deemed desirable to fill the Intermediate Open Cut.

A significant benefit that has not been quantified and which can be expected to result from the rehabilitation of Rum Jungle is the experience which will accrue in rehabilitating an abandoned mine site. This will be particularly valuable in the environmental management and rehabilitation of new uranium mines in the Alligator Rivers Region and will provide useful generally.

# 10.6 Implementation of a Rehabilitation Program

# 10.6.1 Establishment of and Funding of a Project Group

Following consideration of this report, and a decision on the nature and scope of rehabilitation thought desirable, the program can proceed immediately to the next stage of works provided that funds are made available. A small project group would need to be established to provide and/or co-ordinate detailed engineering feasibility and design services which will be required. Much of the work requires minimal engineering design and can be handled by staff available within organisations included in the Working Group. A number of particularly those discussed for White's and the need to be resolved by the project group since a final rehabilitation strategy could only be completed following detailed evaluation and design.

The Working Group proposes that a Steering Committee be established to advise on and review the operations, and that one or more full time persons with appropriate qualifications and experience be allocated to the Project Group.

Matters requiring consideration in reaching a decision on the manner, and the degree of rehabilitation thought desirable, include the possible duration of an overall rehabilitation program. It is evident that much of the work could be completed in a single dry season provided adequate funds, labour and equipment are made available. However, should a strategy involving substantial backfilling of the open cuts with overburden heaps be chosen, this could considerably extend the duration of a rehabilitation program. Should it be thought desirable to have works substantially completed in the shortest possible time, possibly as little as two dry seasons, commitment of extra funds, labour and equipment would be required.

#### 10.6.2 Establishment of a Monitoring Program .

'At the commencement of the works a monitoring program should be established in order to evaluate the success of the operation. A monitoring program would provide considerable information on the effects of various techniques, which would be useful not only in rehabilitating future uranium mines but heavy metal mines generally. A monitoring program would also provide data on the degree of reduction of pollution achieved by various remedial works. Such a monitoring program could be established by the Department of the Northern Territory and the Australian Atomic Energy Commission.

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PENDIX 1:

# REPRESENTATION ON THE WORKING GROUP

## Department of the Northern Territory

Mr R.J. McArthur (Chairman)

Planning, Development and Co-ordination Branch

Miss B. Singer

Environmental Officer, Planning Development and Co-Ordination Branch

Mr D. Kingston

Water Resources Branch

Mr J. Jones

Water Resources Branch

Mr A. Waugh

Water Resources Branch

Mr P. Braham

Mines Branch

Mr J. Shields

Mines Branch

Mr C.S. Robinson

Land Conservation Section

Mr R. Richards

Land Conservation Section

Mr L. Gwynne

Forestry Section

Mr G. Green

Forestry Section

## Department of Construction

Mr L. Boord

Director of Construction

Mr D. Hastings

Acting Associate Director, General Works

(Joined at Third Meeting)

# Australian Atomic Energy Commission

Mr L.H. Keher

Environment and Public Health Unit

Mr P.J. Rafferty

Environment and Public Health Unit

Mr N. Conway

Health Physics Research Section

## Conzinc Riotinto of Australia

Mr D. Fairweather

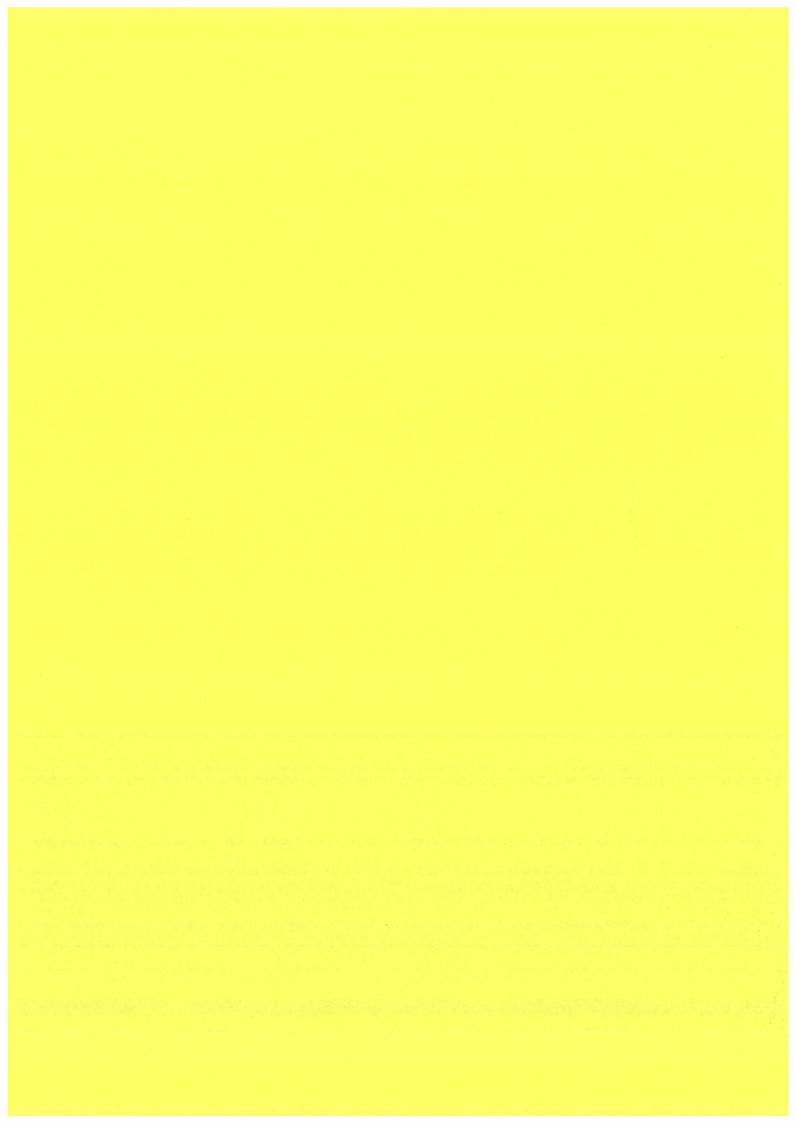
General Manager, General Mining Division

APPENDIX 2

#### FURTHER INFORMATION REQUIRED

- 1. Bench or pilot scale water treatment tests with Ca0/Ca(OH)<sub>2</sub> to pH 6, 8, 10 and analysis of precipitation of heavy metals, particularly manganese, for water in White's and Intermediate open cut.
- Bench or pilot scale water treatment tests with CaO/Ca(OH)<sub>2</sub> simulating treatment of overflow water following dumping of the heap leach pile, Dyson's overburden and the Intermediate overburden.
- 3. Groundwater flow tracing of seepage from White's Open Cut.
- 4. Investigation of chemical and microbiological activity in White's Open Cut.

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Strategy	'D'
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Old Tailings Dam			
Scil cover and establish vegetati	on	\$	2.750M
Dyson Open Cut			
Cover tailings and establish vege	tation	\$	.160M
Acid and Sweetwater dams watercou			
Clear, grade streams and vegetate		\$	.290M
Intermediate Open_Cut			
Treat water and divert		\$	.250M
Fence Site		\$	.220M
	Sub Total	<u> </u>	3.670M
	10001	۲	3.07011
Heap Leach		*	
Dump into White's open cut		Ś	.540M
Dyson Overburden		7	
Dump into White's open cut		\$	3.050M
South White's Overburden		•	
Cover and vegetate		\$	2.900M
North White's Overburden		•	
Cover and vegetate		\$	.500M
White's Open Cut		• •	,
Treat water		\$	.480M
Intermediate Overburden		·	•
Dump in White's open cut			_
Intermediate Overburden			•
Cover vegetate		\$	.870M
White's Overburden			
Dump 0.5M m³ into White's open cu	t,		
minimum cover, vegetate			
Base of North White			
Revegetate			<del>-</del>
Total Esti	mated Cost	\$1	2.000M
	In Report	\$	8.180M

Rum Jungle area. Units Land in Tiguro (interpretation only) 0/b. 3 b 3 b 3 b oid tailings? Granific oreo 20/25 2c/2b EGEND Ö. Whites road cut waterway Int. CUI tailings arga land unit

#### ef Land Unit Description

#### Description

Hills, ridges, footslopes - skeletal soils.

Erosional slopes, some rock outcropping - lithisols and shallow gravelly yellow earths. Sandy and predominantly loamy red earths, massive and earthy throughout. Textures range from fine sandy clay loam to loam at the surface and increase to heavy clay loam at 160 cm.

tes

1 jb

Section 1

land unit information here has been derived solely from interpretation of aerial photographs without any field checking. Interpretation was done by an agronomist familiar the land units of the area. Once topsoil requirements have been ascertained, detailed field iffication of suitable borrow areas should be done. The 3b units adjacent to the OTD appear promising topsoil sources. The possibility of utilising borrow pits as sediment traps in the possibility of utilising borrow pits as sediment traps.

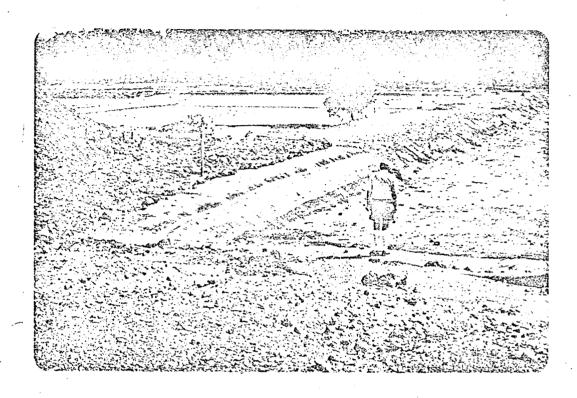
#### (1) GENERAL

- 1. The estimate has been made by analysing the plant requirements for the work. We have adopted methods and plant known to be common for the work. Plant Hire rates for Darwin effective in April, 1979 have formed the basis for the costing of the work. The costs have been compared with some previous projects escalated for inflation, Northern Territory and Remote Location.
- 2. As the only information available to us shows a possible location of Borrow for soil as the Land Unit 3b of the attached plan, we have assumed the borrow area to be located at the junction of the East Finniss River and the Old Tailings Dam Creek for the purpose of calculating Eaul distance.
- 3. Where we call for soil compacted to a % figure of S.M.D.D., we require a gravelly clay soil. The Plasticity Index of the soils in the area is low and we prefer soil with a P.I. not lower than 4 to 6 and not higher than around 15.
- 4. Borrow Pit yield after stripping has been assumed at 2 m.
- 5. Soil for growing plants need not be the same as the soil specified to be compacted. It would most likely be obtained from the same borrow pits.
- 6. Where we call for soil to be compacted to a % of S.M.D.D., we require conditioning in the borrow pit under strict controls to optimum moisture + 1% to enable the tight impervious layer to be achieved.
- 7. Our estimates are based on the information contained in the Working Group's Report. Our estimates are dependant upon the accuracy of this report. Further Topographical, Chemical and Radiological surveys would be necessary to design and estimate with confidence.
- 8. Assumptions have been made as to the availability of suitable covering soil. Soil investigations will be required to establish haul distances and volumes of borrow pits.

45.00

9. Radiological advice as to the adequacy of our treatment of the Old Tailings Dam could have a bearing on the cost.

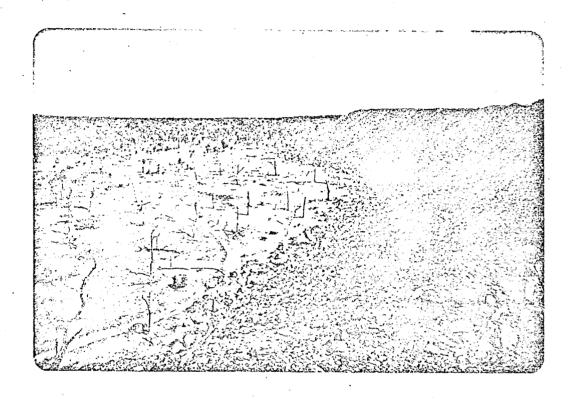
#### (2) HEAPLEACH



- "A view of the Barren and Oxide Ponds, Heap leach experiment. looking NW (4.8.79)."
- 1. Load, haul and dump using Front End Loaders and Trucks to one location only. Dump on natural ground and push into White's open cut by dozer.
- 2. Re establish the haul road with an average haul of 0.6 km.
- 3. Treat Heapleach with line at point of loading before dumping in White's Open Cut. We assumed 40 kg per truckload.
- 4. Neutralise and precipitate heavy metals from the ponds before discharging.
- 5. Doze in ponds and bury structures.
- 6. Lime site with CaCO, before ripping and covering with 300 mm soil (firmed by equipment only).
- 7. Revegetate the area, with minimum CaCO, and fertiliser, and irrigate for the initial period prior to the first wet.

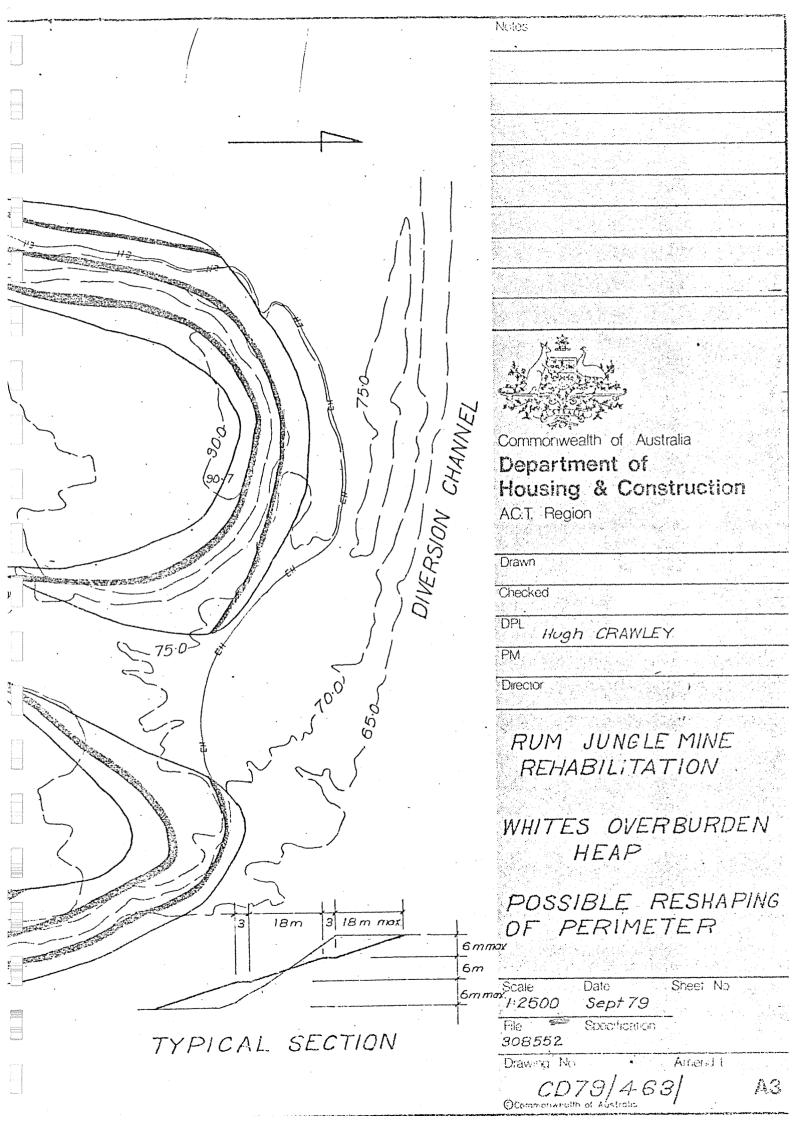
- 8. Suitable soil assumed to be won from a borrow area in the vicinity of the junction of the East Branch of the Finniss River and the Old Tailings Creek. Haul distance 1.5 km by scraper.
- 9. Volume of Heap Leach pile assumed to be the same as the report.

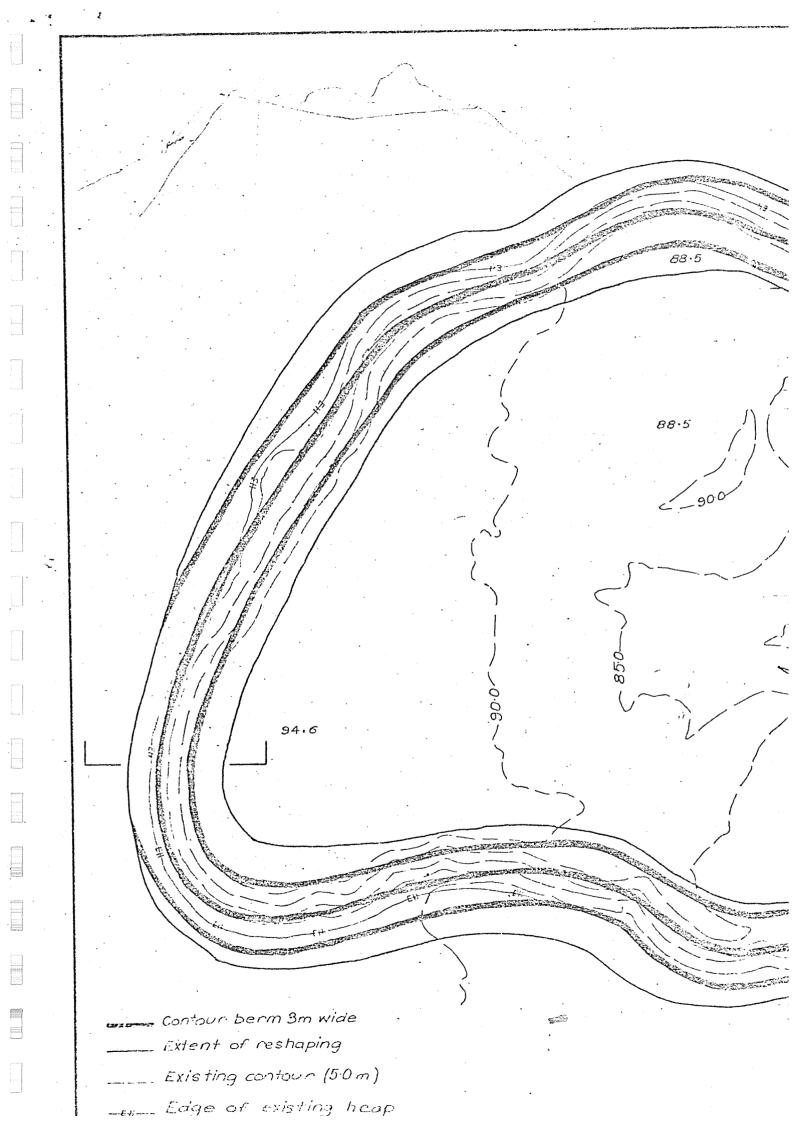
(3) LANDSCAPE, COVER AND ESTABLISH VEGETATION INSITU-WHITES
OVERBURDEN HEAP



"A view of Whites Overburden Heap East Perimeter Edge looking S (6.4.79)."

- 1. In order to reshape the top of the heap to control the infiltration and drainage it will be necessary to push the existing uncontrolled dumping by dozers to establish a smooth controlled slope. The steep slopes within the top surface should be flattened to enable an impermeable layer to be placed and compacted. The maximum desirable slope is 1 vertical to 3 horizontal. The volume of material to be shifted is estimated at 240,000 m. The surface should be compacted to give a crushed surface.
- 2. Directly on top of the shared heap we have estimated to place and compact a minimum thickness of 200 mm of impermeable soil compacted to 95% of standard maximum âry density. The volume of this material is estimated at 39,200 m<sup>2</sup> in place. This material is very important to the concept of sealing the heap to minimise the movement of oxygen, and also to minimise the infiltration and consequent leaching of the acids. This material must be conditioned in the borrow pit under strict controls to optimum moisture ± 1% to enable the tight impervious layer to be achieved.





3. Bob Richards of the N.T. Government conservation branch advised us that 300 mm min of soil is required for growing. This layer does not require compaction for engineering purposes so we have estimated only to tighten up the layer by light rolling only.

The volume of material estimated for this layer was 58,800 m<sup>3</sup>.

4. A considerable proportion of the plan area of Whites Overburden Heap is the walls. These are up to 27 metres high at the angle of repose of 37 to 38 degrees i.e. 1.3 hor. to 1 vertical.

The movement of oxygen through the walls is a large contributor to the oxidation of the heap.

The provision of an impervious barrier will stop the flow of oxygen and water through the walls.

Soil placed on slopes of 1.3 to 1 is unstable and when saturated will slump.

We have allowed earthworks on the walls to flatten them to 3 hor. to 1 vertical with horizontal berms at 6 m vertical intervals. The berms would be wide enough for minimum vehicular access say 3 m wide.

We have estimated the earthworks required to shape the walls to be  $240,000~\text{m}^3$ . The shaping envisaged minimum pushing down hill only so the final contours of the walls follows the general shape of Whites.

5. The cover proposed for the reshaped walls is the same as for the top.

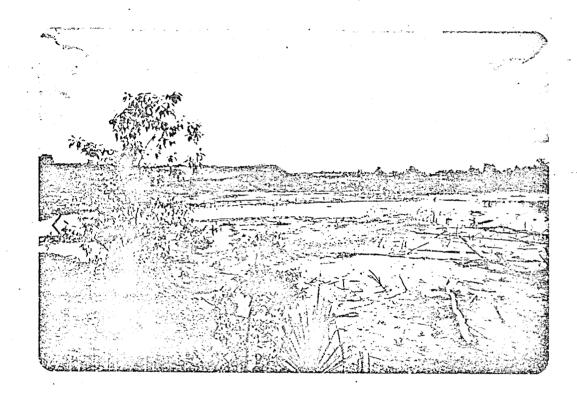
The estimated volumes are

- (i) 200 mm (engineering 95% S.M.D.D.) 18,400 m<sup>3</sup>
- (ii) 300 mm (growing) 27,600 m<sup>3</sup>
- Contour drains of compacted earth are envisaged dividing the top surface into terraces and discharging into a concrete drain which follows the approximate line of the existing haul road. Where necessary concrete drains down the reshaped walls should be provided. We have been unable to carry out hydraulic designs for these drains without the necessary topographical data, however we have made an allowance based on previous experience.
- 7. Revegetation is anticipated to require only minimum CaCO, and fertilisers as it is not expected that an acid environment will be a problem.

We feel that under some circumstances it would be desirable to have a vegetative cover prior to the first rains of the wet season so we have allowed for some irrigation of the flatter slopes and some straw mulching of the steeper slopes during the last month of the first dry season.

- 8. It is not anticipated that irrigation would be carried out to promote growth, only to produce germination to ensure establishment prior to the first wet.
- 9. Consolidation would reestablish failed and scoured areas up to the end of the wet season 12 months after the initial wet season.
- 10. We have not allowed for any specific species of vegetation. This could be determined after extensive trial plots using the proposed cover systems.
- 11. Inspite of the cover of compacted soil it is expected that a flow of liquid from the treated heap will continue (although on a much reduced scale). This should not be contained within the heap where it will cause saturation and unstability of the covering layers. Drains should be provided to release and then convey any liquid from spring locations.
- 12. An earth drain around the heap will prevent the overland flow of any leachate and restrict any residual polution to the immediate vicinity of the heap.
- 13. We have allowed for haul roads and the reestablishment of a bridge over the diversion channel.
- 14. If suitable engineering soil is not available at the assumed borrow area and must be obtained from e.g. Meneling Station 10 km from the Mill the cost of the compacted layer would increase by approximately \$280,000.

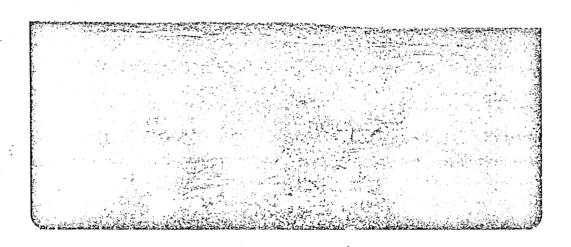
(4) LANDSCAPE, COVER AND ESTABLISH VEGETATION INSITU-WHITE'S (NORTH)
OVERBURDEN HEAP



- "A view of Whites (North) Overburden Heap from Sweetwater Dam looking NNW (6.4.79)."
- 1. The top of this heap consists of boulders. Before reshaping can commence these should be removed. We have estimated to load haul and dump these into White's open cut along with the Heap Leach. The estimated volume of these boulders is 60,000 m<sup>3</sup>.
- 2. The heap should be treated in a similar manner to Wnite's Overburden Heap.
- 3. Estimated Quantities are:
  - 1. Cover top\_200 mm soil @ 95% standard maximum Dry Density 6,000 m<sup>2</sup>.
  - 2. Cover top 300 mm soil lightly compacted 9,000 m<sup>3</sup>.
  - 3. Shape the walls 12.4 m max height (av. 8 m height) with 3 m berm to 3 hor. to 1 vert. slope 18,000 m<sup>3</sup>.
  - 4. Cover the walls 200 mm soil @ 95% standard maximum dry density 4,200 m<sup>2</sup>.
  - 5. Cover the walls 300 mm soil lightly compacted 6,300 m<sup>3</sup>.

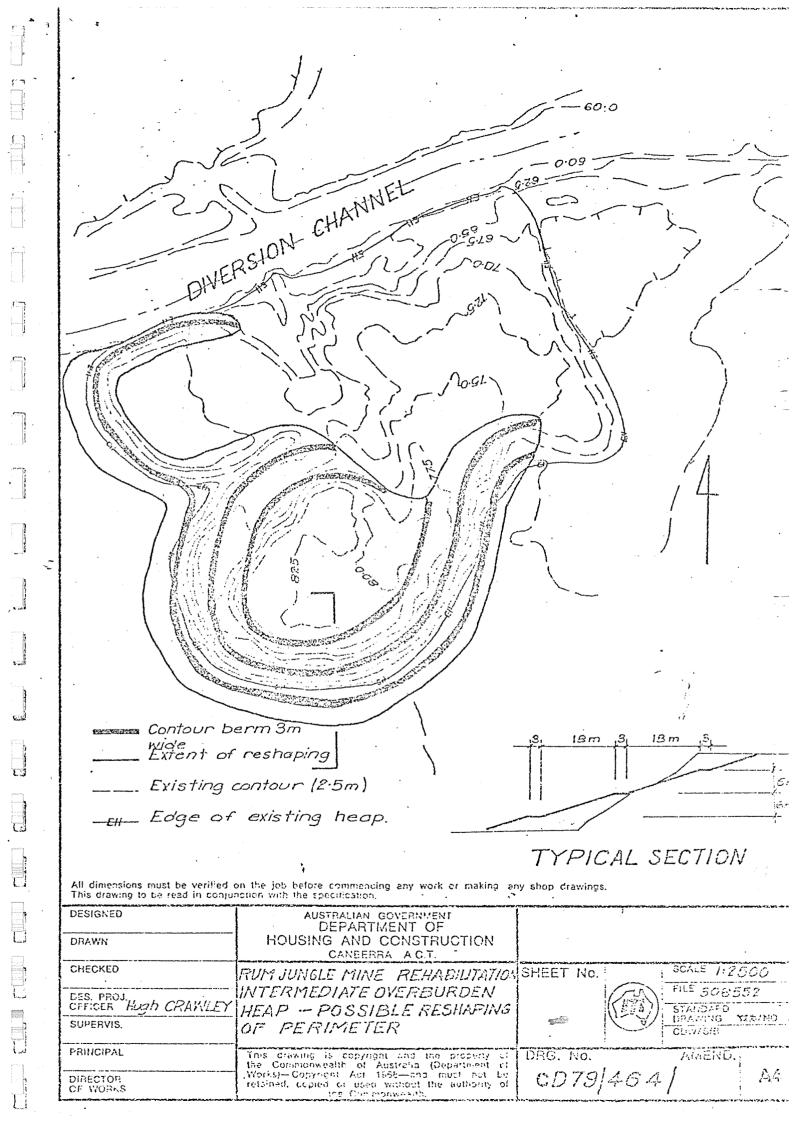
4. If suitable engineering soil is not available at the assumed borrow area and must be obtained from e.g. Meneling Station 10 km from the Mill the cost of the compacted layer would increase by approximately \$62,000.

(5) LANDSCAPE COVER AND ESTABLISH VEGETATION INSITU
INTERMEDIATE OVERSURDEN HEAP



"A view of Intermediate Overburden Heap from White's Overburden Heap looking NW (6.4.79)."

- 1. The top of this heap consists of a flat area and two spiral/heaps with steep sides. The surface is covered with rubble piles for much of the area. We have estimated to flatten the top of the heap by dozing over the edge of the heap thereby increasing the flat area. We have estimated the volume to be moved in this way is 110,000 m². After reshaping, the rock surface should be dozer graded and compacted with a vibrating drum roller to give a crushed rock surface for further layers.
- 2. The heap should be treated in a similar manner to Whites Overburden Heap.
- 3. The estimated quantities are:
  - (i) Cover top 200 mm soil @ 95% standard maximum dry density 12,600 m<sup>3</sup>.
  - (ii) Cover top 300 mm soil lightly compacted 18,900 m<sup>3</sup>.
  - (iii) Shape the walls 10 m average height (with 3 m berms) to 3 hor. to 1 vert. slope 40,000 m<sup>3</sup>.
  - (iv) Cover the walls 200 mm soil @ 95% standard maximum compaction 6,800 m<sup>2</sup>



- (v) Cover the walls 300 mm soil lightly compacted 10,200 m<sup>3</sup>.
- 4. If suitable engineering soil is not available at the assumed borrow area and must be obtained from e.g. Meneling Station 10 km from the Mill the cost of the compacted layer could increase by approximately \$106,000.

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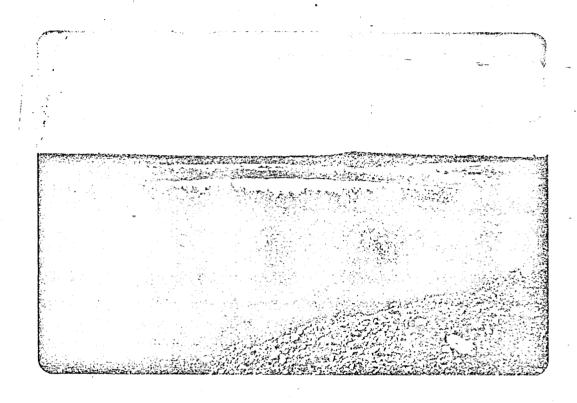
#### (6) REMOVE HEAPS TO OPEN CUT, DYSONS OVERBURDEN TO WHITES OPENCUT

- 1. The haul roads used during mining will require considerable upgrading and eventual reinstatement. We have allowed 1.3 km from Dysons to Whites and a further 1 km around Whites.
- 2. The material from Dysons is assumed to be suitable to seal the walls of whites Open Cut and will not accentuate the production of acids and solution of heavy metals.
- 3. In dumping the Dysons Overburden into Whites Open Cut we have assumed that the tailings on the floor of the reservoir are not stable enough to support concentrated loads. We have assumed that loads will be dumped on the undisturbed perimeter of the Open Cut then pushed by dozer towards the centre of the open cut.
- 4. Loading of the Dysons Overburden material will be by means of front end loaders and hauling by off highway rock trucks.
- 5. It will not be possible to achieve the shape of scheme 1 of figure 12 of the working group report and this figure is assumed only to show the intent of the strategy not the final shape.
- 6. After the removal of Dysons Overburden it is assumed that the original soil will remain. This will not require covering with imported material but before sowing for revegetation will require ripping, treatment with CaCO, and fertiliser. It is not proposed to irrigate this area.
- 7. The volume of Dysons Overburden heap is assumed to be the same as that indicated in the report. A small portion of the heap will be used to cover Dysons Open Cut.

# (7) REMOVE HEAPS TO OPEN CUT, INTERMEDIATE OVERBURDEN HEAP TO WHITES OPEN CUT?

- Establish a new haul road to the nearest point on Whites Open Cut. Utilise the perimeral haul road estimated in Dysons to Whites. Re-establish a bridge over the diversion channel.
- 2. Haul to be by off Highway trucks loaded by front end loaders from the top of the heap. Dumping on firm material away from the endge and pushing into the final position by dozers.
- 3. The material from Intermediate is assumed once covered by Dysons Overburden to be suitable and not to produce acids and heavy metals in solution.
- 4. Revegetation of the soil under this overburden heap may require a soil growing layer so ripping, CaCO<sub>2</sub> treatment, soil cover of 300 mm, fertiliser and sowing has been allowed. Irrigation has not been allowed for.

White Division Chemists when the charles that there were proposed - the are wone WHITES DEEN OUT, TE AT VATER AND REFILL WITH WASTE ROCK



- "A View of Whites Open cut from Whites Overburden Heap looking N (6.4.79)."
- 1. We have given consideration to two methods of treating the 'water. The costs of either are dependent upon the chemical make-up of the water. In raising the pH of the water by the addition of lime (Ca 0) the nature of the chemical reactions in producing precipitation is vital to the total demand for chemicals and the time required to achieve adequate neutralisation.
- 2. The establishment of a treatment plant complete with pumps, flow meter, pH meter, lime feed control mixing chambers and settlement ponds was considered by the Working Group and estimated to cost \$510,000.00 total at 1977/78 prices. We have investigated this proposal and have found that the settlement ponds required, to give adequate retention time for neutralisation and precipitation of sludges to occur, are very large. Precipitated sludges would require disposal.
- 3. We have recently conducted trials whereby we have been able to destratify a reservoir by the infusion of compressed air. This process is relatively inexpensive. It is proposed that the water in the open cuts be turned over for a considerable period while? CaO/Ca(On) is added to the moving water. Frecipitents would be deposited at the pottom of the Open Cut; where they would be covered by the overburden heaps.

.4. We do not propose to pump the water from White's Open Cut but we do propose to allow the water to be displaced by the dumped overburden heaps so it will flow along the old bed of the East Finniss River to be discharged into the Intermediate Open Cut before being discharged into the stream.

Before dumping of overburden can commence this scheme will require that both White's and Intermediate Open Cuts are treated to neutralise the water, that treatment of the Intermediate Open Cut continues to ensure that the effluent is at a suitable pH and that heavy metal ions are precipitated out.

- 5. It is anticipated that the addition of the heaps to the water will lower the pH and increase turbidity and so under the treatment of the Heap Leach, we have allowed for the addition of a predetermined dose of CaO to counteract this effect and to maintain a neutral environment within the dumped material.
- 6. The rate of dumping anticipated is approximately 1,000 m<sup>2</sup> per hour. The water displaced by this operation would be approximately 700 to 800 m<sup>2</sup> per hour. If a treatment plant were set up it should be capable of treating, at a minimum, the day's production over 24 hours; i.e., 1,000 m<sup>2</sup> x 10 hr

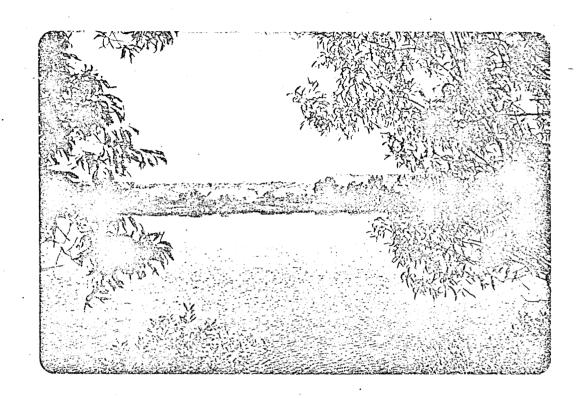
  i.e., 420 m<sup>3</sup> per hour.

Break down of the treatment plant may cause cessation of the dumping or a means of storing the displaced water be considered.

- 7. It is proposed that dumping could be carried out during the wet season allowing discharges to be made into the East Finniss at a time when maximum dilution would occur.
- 8. The supply of lime (CaO) is a major cost of the treatment and at the moment is very costly. With the prospect of mining in the Alligator Rivers Region it is possible that the demand for lime will increase producing cost reductions for bulk supply.
- 9. We have been advised that once the heavy metals are precipitated by raising the pH they are not likely to reassolve should the pH drop again.
- 10. Vital to the success of the treatment is a consistent regular monitoring by daily sampling and testing at various locations.

  The monitoring would indicate progress towards definitive objectives and allow flexibility to achieve maximum effectiveness.

(9) INTERMEDIATE OPEN CUT, TREAT WATER AND DIVERT EAST FINNISS RIVER



- "A view of Intermediate Open Cut, Whites Overburden Heap, Intermediate Overburden Heap looking ESE (5.4.79)."
- 1. We have estimated to use the same plant as was used to treat White's Open Cut, i.e., the infusion of compressed air into the lower layers of the reservoirs, thus lowering the density of the lower layers which will then rise creating a circulation throughout the reservoir. The chemical(s) would be added to the circulating water.
- 2. The comments relating to White's Open Cut apply to the Intermediate Open Cut however the water from this source will be released into the stream and so control of the water quality may need to be closer than the control applicable to white's O.C.
- 3. We have considered the diversion of the East Finniss River into the Intermediate Open Cut. Our preferred strategy is determined by the problems associated with the cleaning and grading of the Acid and Sweet water dams area and the maintenance of raised pH in the White's and Intermediate Open Cut area. We prefer to re-establish the old river bed of the East Finniss River through White's Open Cut, into the Intermediate Open Cut. This would allow for more positive grading of the streams through the difficult area near white's (North) Overburden Heap and by continued dilution would maintain the pH at an acceptable level and so prevent the heavy metal ions from going into solution.

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4. If our preferred solution is unacceptable then the diversion of the East Finniss from the Diversion Channel by cutting through the rock and forming a channel and diversion dam could be achieved for the same cost.

- (10) DYSON'S OPEN CUT, COVER TAILINGS AND ESTABLISH VEGETATION IN SITU NOTES ON THE ESTIMATE
  - The report of the working group states that the tailings had filled Dyson's O.C. to the lowest point on its perimeter and that the level of the tailings material is presently several metres below the rim of the pit. Our observations and discussions have shown that probably more than 50% of the area of the surface lies under water. Our estimate allows for:
    - Treatment of the water by simple means.
    - The breaching of the embankment at the narrow end of (i) (ii)
    - Pumping any remaining water out of the cut.
    - Filling to the lowest point with Dyson's Overburden. (iii) (vi)
    - Covering the whole surface area of tailings plus fill, with 600 mm layer of Dyson's Overburden. (v)

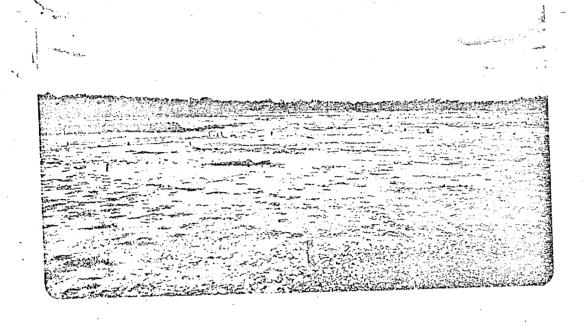
We have not allowed for a soil cover or irrigation of this area.

- We consider that the covering of the tailings should have some strength. Dyson's overburden heap contains material which, when 2. compacted, would be suitable.
- We have concluded that the appropriate strategy here is one of containment of the tailings rather than isolation from water and 3. oxygen.
- Covering would be achieved by off-highway trucks and front-end loaders with dozers to spread and grade the material. 4.

Quantities assumed are:

 $0.7 \times 10^6 \text{ m}^3$ Treat and release water 8,000 m<sup>3</sup> Fill volume under lowest point 36,000 m<sup>3</sup> Cover with 600 mm Dyson's O.B. 6 Ha Seed fertilise

# (11) REHABILITATION OF THE OLD TAILINGS AREA



"A view of the Old Tailings Dam."

- 1. Area Covered by tailings 34 ha.
- 2. Advice from Mr Keher and Mr Conway of AAEC:

"Tailings cannot be moved except by using special equipment and reduce operator work times due to radiation dangers.

If no equipment works directly on the tailings, no limit on operator time."

In producing our estimate we have assumed the following method:

For the first layer dump soil on the already covered area and

push out by dozer over tailings surface. Shaping of the surface

to reduce erosion by drainage is then obtained by extra thickness

of this first soil layer in covering low areas.

 Cover used: <u>first layer</u> - 200 mm soil minimum thickness with estimated average thickness of 500 mm to shape for drainage surfaces Compaction to 55 S.M.D.D.

Second layer - 200 mm soil compacted to 956 S.M.D.D.

Third layer - 200 mm soil for root zone of vegetation lightly compacted only.

Total volume required:	Compacted	Loose	•
Layer 1	170,000 m <sup>3</sup>	238,000 m <sup>3</sup>	
Layer 2	68,000 m <sup>3</sup>	95,000 m <sup>3</sup>	
Layer 3	68,000 m <sup>3</sup>	81,000 m <sup>3</sup> .	
Drainage dividing banks	1	12,000 m <sup>3</sup>	
	Total	426,000 m <sup>3</sup>	loose

#### 4. Cover minimum 600 mm

Cover average 900 mm

Mr Conway indicated, that for radiation suppression a cover of 1,000 mm could be required. Prior to design, radiation readings should be obtained over the total area on a grid system, spacing, say 30 m. The radiation is variable over the area and the design could take this into account in determining the cover thickness in various locations.

Minimum thickness required independent of radiation considerations (but no direct work on the tailings) would be:

Sealing layer 200 mm (average 500 mm)

For vegetation 200 --

Say 400 mm (average 700 mm)

This will reduce the cost to approx: \$1,900,000

#### 5. The drainage system proposed is:

Divide the area into approx. 20 separate drainage areas each discharging to outside the tailings area via a small concrete structure. The drainage area would have a cross fall of say 2% with collection against a bank providing a grass channel with 1% fall to the edge of the tailings area.

A bank to surround the tailings area, so that discharge is only via drainage structures and no discharge occurs over the bank.

The concrete structures to be designed to prevent scour at the exit and allow storage in the banked drainage channel to reduce the velocity of flow. This also will increase time of concentration. Suggested design: 1 in 50 year rainfall for dividing banks and concrete structures. 1 in 500 year rainfall for bank surrounding the tailings area. For minimum soil requirement, the most likely pattern of banks would be a herring bone pattern with the ridge following the east-west axis of the area.

#### 6. Soils required for covering the area:

First and second layer: a gravelly clay soil would be preferred. Plasticity index of the soils in the area appears to be low. Pl not lower than 4 to 6 would still be suitable.

From information obtained and visual surface inspection, areas to the east and north east may be suitable.

A small land unit map provided by Mr Richards of the N.T. Agriculture Branch show these soils as: sandy and predominantly loamy red earths. Textures range from fine sandy clay loams to loam at the surface and increase to heavy clay loam at 160 cm.

For the purpose of estimating the average yield after stripping has been set at 2 m. Other effective depth would vary the estimate slightly.

Layer 3 soil should be obtainable from the same area. Vegetation cover was assumed to be obtained by:

scarifying surface, lime and fertilise and incorporate into soil, spread seed and harrow.

Maintain up to start of wet season by irrigation. Some test sections for plant growing have been carried out on the tailings surface with less than 600 mm soil cover. Tailings have been deposited on these growing surfaces by wind action. It would be expected that selected vegetation on a fully covered surface would do far better.

- Failing the availability of suitable soil where assumed there is a possibility the first two layers may require haulage of 10 km this could increase costs for the first two layers by \$1.5 Million.
- 7. There is a large variation possible in treatment for the Old Tailings Area and the final solution will only be determined after continued investigation. Whilst we have presented our preferred solution the range of alternatives could vary from (a) if not below the highest ground water and flood levels requiring a rock pore pressure breaking layer between the lower soil layer and the growing layer, to (b) scraping up the spread tailings to reduce the area requiring treatment, depositing the scrapings in the remaining tailings area above the highest ground water and flood levels, which could be reshaped prior to covering with soil etc.

Alternative (a) would depend on the present and potential acidity of the tailings and the liability of this acidity to migrate upwards through the covering soil and then the effect of these acids on the root mat of the vegetation established in the top layer of soil.

Alternative (b) is an alternative considered to be the best engineering solution however this solution does not have the support of some officers of the Atomic Energy Commission. Our investigations have shown that the alternative has been considered in U.S.A. and may infact be possible. It would only be after research and with the support of the AAEC that this alternative could be adopted.

The cost of alternative (a) to replace layer 2 with rock has been estimated.

Sources of rock have not been investigated however it is known that crushed rock is available from

(i) a commercial Quarry off the road to Batchelor,

(ii) suitable rock outcrops within the Rum Jungle Mine Site which could be quarried and processed using a portable plant,

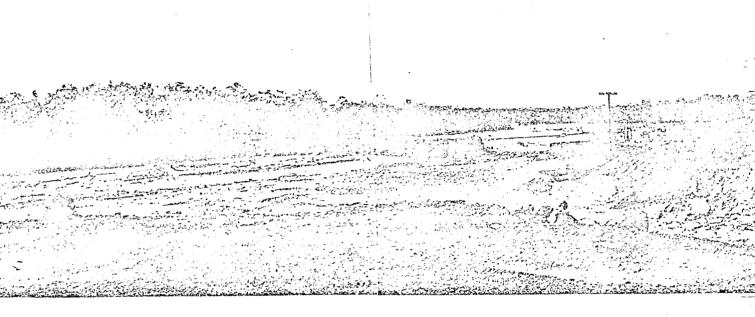
(iii) the most suitable source could be one of the overburden heaps. We have been told that only the heap at Rum Jungle south is not reactive and thus suitable for the layer.

We estimate the cost to substitute layer 2 with rock borrowed from the Rum Junge South Overburden Heap would be \$420,000.

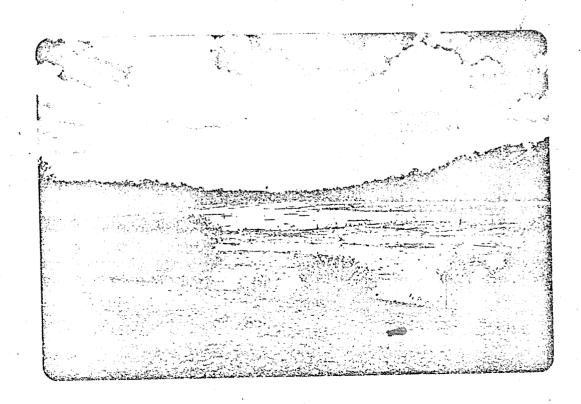
Alternative (b) has not been estimated, however as the tailings deposits we are considering are less than 1 m thick the cost to scrape up with a frontend loader would be small. The cost saving for layer 1, if preparation to design contours of the tailings were possible, could be large.

The cost per Ha to treat the Old Tailings Dam Area is \$81,000 and this would be the order of saving per Ha for alternative (b).

(12) ACID AND SWEETWATER DAMS, WATER COURSES AND AREAS AFFECTED BY SEEPAGE



"A view of Acid Dam and Sweetwater Dam looking E to SE (4.9.79)."



- 1. We have allowed to follow the methods of the Report of the working group and have allowed to remove the dams by spreading them in the area, grade the bed profiles by excavating in the bed from the down stream end during the Dry Season, clear the beds of obstructions and then to CaCO<sub>3</sub>, rip, fertilise, seed. We have not allowed any extra cover of soil.
- 2. We prefer to return the East Finnis River to its original course through White's Open Cut and Intermediate Open Cut. This will reduce the volume of cut required to return the stream to the bed. The entrance to the diversion channel is estimated to be approximately 2.5 m above the bed of the river. This would require deepening of the diversion channel for at least 500 to 1,000 m.

3. Areas estimated for are:

Acid Dam Upper 11 Ha
Acid Dam Lower 17 Ha
Sweet Water Dam 8 Ha
Copper Creek 2 Ha
Around White's OB 9 Ha
Around Dyson's OB 3 Ha
Old Tailings Creek 3 Ha

- 4. At our inspection the dams were showing some signs of natural vegetation, we expect that liming with CaCO, to neutralise the residual acids and contour ripping could be adequate to establish a grass cover for initial stabilisation. Natural recolonisation would then be encouraged.
- 5. We have not allowed for clean up and revegetation of ALL disturbed areas as this is not envisaged in the Report nor was it in our brief. We were shown areas which have vegetated naturally, the cover appears quite satisfactory.

### (13) FENCE

- 1. The purpose of the fence is to provide the vegetation measures with adequate protection to allow the measures to be successful.
- 2. We have allowed to fence the perimeter of the whole site including borrow pits. At the moment we can only assume the 10 km we measured from the maps is adequate. The most suitable location would be determined during the detailed design.
- 3. In order to be successful the fence must be strong enough to keep out largest animals and yet also exclude small animals.
- 4. Eradication would be necessary until the remedial measures were well established.