GUIDELINES FOR ENVIRONMENTAL
MANAGEMENT OF MINING
IN ARID AREAS

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FOREWORD

One of the key roles of the Department of Mines as the government agency responsible for the mining industry, is to ensure that the community of Western Australia receives fair return from exploitation of the State's mineral and petroleum resources and to ensure that proper attention is given to the environment. The Department therefore produces guidelines of this type in order to provide advice necessary to ensure that protection and rehabilitation of the environment is managed effectively and is given a high priority by the mining industry. This document is presented as a guideline and provides the basis for future research in the development of appropriate environmental management techniques.

Given that the key objectives outlined in the document are achieved, the approaches in this guideline are not intended to be rigidy prescriptive and unswervingly adhered to in all cases. Other valid approaches and methods may be applicable. It is anticipated that as the industry develops more familiarity with good environmental management and undertakes research of its own, a revised document will be prepared. This will help to keep the industry up to date with techniques and achievements in this area.

The Mining Engineering Division looks forward to feed-back from the industry on its achievements in the area of effective environmental management and expects this document to provide a useful reference.

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1. INTRODUCTION

Mining is by far the most commercially important industry in Western Australia. Mining production was valued at $6.29 billion in 1987 with approximately $190.0 million being paid in royalties. A wide range of minerals is produced, with many being subjected to further secondary processing within the State. There is a wide variety of types and scales of mining operations, subsequently, there are very large differences in the environmental affects of the different mining and mineral processing industries.

The Department of Mines has traditionally been involved with the issuing of mining tenements, the regulation of work practices and collection of royalties. In response to increasing environmental awareness in the community, the Department has become more involved with environmental aspects of mining and has recently made a number of changes to its organisational structure. These changes will enable the Department to respond more effectively to environmental issues by providing a more co-ordinated and integrated environmental assessment and monitoring service to the mining industry and other government agencies.

As part of the ongoing process of developing adequate environmental standards for the mining industry, this bulletin has been prepared to provide Guidelines to both existing and prospective operators on how environmental management can be integrated into the overall operations of a mine site.

While the information presented relates specifically to open cut mining, the general principles involved are relevant in all types of mining.

It is stressed that the information contained within this bulletin is presented as a guideline, and it is expected that individual operators will develop their own methods of achieving the objectives discussed in this document. As new techniques are developed and information from various case study examples become available, a revision of this document will be made to provide updated information regarding environmental and rehabilitation management in the mining industry.

2. PROJECT APPROVALS

All mining leases now granted in W.A. carry a primary condition that requires the holder to submit a written proposal to the State Mining Engineer, for assessment prior to any productive mining. In practice, this proposal document can range from a brief 3 or 4 pages in the case of very small operations in existing mining areas, through to the formal "Notices of Intent" or "Environmental Review and Management Programmes" required by the Environmental Protection Authority (EPA) for larger operations.

The Mines Department's Mining Engineering Division is responsible for the assessment of the proposals, and for co-ordinating the involvement of other agencies such as the EPA and Water Authority. The Department of Resources Development has the same responsibilities in the case of major projects that involve State Agreements.

There are three important steps to obtaining project approval. Firstly, the proponent should contact the Mining Engineering Division's District Mining Engineers and Environment Officers to discuss the proposed development and the appropriate level of assessment. Once the location, nature and scale of project is established, a set of guidelines for the proposal document is provided. together with an Environmental Protection Authority Works Approval Form. In the case of straight forward or routine developments, such as open pit gold developments, standard guidelines are available from the Mining Engineering Division. Where necessary, the standard guidelines are modified to suit the specific requirements of individual projects, e.g. where conservation reserves are involved the Department of Conservation and Land Management has a number of additional issues that need to be considered in the planning and development of the proposal.

Where a project has significant environmental impacts the Department of Mines formally refers it to the EPA for determination of the level of assessment required, togetherwith an appropriate recommendation. The EPA advises on any additional matters it may require to be addressed in the proposal documentation and joint Mines-EPA guidelines are issued. In this way the developer is assured that only one set of documentation is needed to meet the requirements of all Government agencies.

The second step is preparation of the proposal document, usually referred to as a "Notice of Intent". There are a number of ways in which this is done. The proponent may prepare the document using in-house expertise, specific consultants may be employed to produce specific sections or the whole exercise may be undertaken by a specialist environmental consulting firm. While all methods are acceptable the proponent is encouraged to undertake as much of the work as possible, as this results in a more integrated environmental management programme that can develop along with the rest of the project. The emphasis is placed on producing a document that clearly shows what the potential environmental impacts are and how they are to be managed. Basic commitments are required on the important areas such as waste and tailings management and rehabilitation.

In some ways the process of preparing the proposal document is more important than the final document. This is because most of the significant environmental aspects of a project will be dealt with in the course of the document preparation and any necessary changes to the project design will have already been made when the document is submitted.

The third step in project approval involves submission and assessment of the document. If possible draft documents should be submitted. This will help to resolve any problems with the document prior to formal submission. An Environmental Protection Authority "Application for Works Approval Form" (and prescribed fee) should be submitted, along with 5 copies of the document, to the Regional Mining Engineer.

Under the pollution control provisions of the Environmental Protection Act 1986, Works Approval is required before construction of prescribed premises. This means that Works Approvals are required for mines, treatment plants, milling and crushing works and tailing dams. When Works Ppproval is granted Pollution Licence application should be made to the Pollution Control Division of the Environmental Protection Authority.

When the document is submitted, it is assessed by the regional mining engineering staff and specialist environmental staff in the Mining Engineering Division. Other agencies comment on specific elements as required. A reasonable period of time (up to three months depending on the size of the operation and its environmental significance) is required for assessment and approval. On the granting of formal approval to proceed to productive mining, the proposal document and any additional conditions that are necessary, are made binding on the development by way of specific tenement conditions on the lease or leases involved. This is an important part of the ongoing environmental control process. The responsibility clearly rests with the developer to proceed with the operation in accordance with the undertakings given in the proposal document.

Where significant changes are required to a project such as increased production rates, new tailings dams or a change in waste dump location, a new proposal must be submitted for approval. It is, however, important that the original document is as comprehensive as possible, and if necessary covers alternatives likely to be considered in the longer term of the development. Proponents are encouraged to discuss proposals with District Mining Engineers in the early phase of the proposed development.

3. SITE PLANNING

Environmental management begins with the site planning and design phase of the project. As the orebody is the fixed item of the project site, it is the positioning of the other facilities which provide an opportunity for creative design solutions to be developed to minimise the impact of the project.

Before considering the options for the facilities, it is essential to establish clear final land use objectives, as it must be realised that the mining operation is only a temporary occupier of the land. The establishment of those objectives may require consultation with land owners, government departments and shire councils. The complexity of the requirements will depend upon many factors including the environmental significance of the site and the value of the land for other uses.

Long term objectives may range from an agreed commitment to rehabilitate the area to pre-existing vegetation quality in the case of areas of special significance such as reserved land. In agricultural areas the aim may be to return the land to primary production. In some cases land may be made available to residential or recreation use. In the arid part of Western Australia the primary objective may be to rehabilitate the site to a condition where the site is stable, non erodible and safe.

In some cases the end use objectives may change, however, planning for mine closure begins and develops throughout the life of the mine.

When the end land use objectives have been established, planning for the means by which these objectives are to be met can be commenced by the consideration of the operational and environmental constraints of the site.

This involves the development of an inventory of the basic resources of the site. Obtaining information about features such as the climate, geology, soils, vegetation, groundwater drainage lines, animals and existing land uses, will provide a framework in which successful site planning achieves the objective of minimising environmental disturbance.

The collection of this information will allow plans to be made regarding the best locations for facilities and will help to determine the achievable rehabilitation goals for the site.

A very important component of this inventory is the classification and description of the site.

The site can be classified into precise "land units" which is a fundamental basis of description. A land unit should be capable of delineation on aerial photography (suggested scale 1:10000); contain a single soil class; have uniform or consistent graduation in its characteristics and be manageable as a single entity. Examples from the Goldfields are:

- drainage lines in extensive alluvial plains in the mulga zone.

- valley floors with deep clay-loam soils supporting Eucalypts over saltbush and bluebush.

- sand sheet carrying sparse mulga and spinifex.

- ridges carrying sparse mulga with stoney surfaces.

The type of vegetation occurring on each soil type needs to be noted and characteristics of the soil should be obtained, (eg soil moisture, soil salinity, pH and soil nutrient levels). This information will be useful as baseline data to provide a measure of comparison for the final rehabilitation programme.

Effectively this mapping exercise provides important information about the types and quantities of recoverable top soil available for future rehabilitation programmes.

Determination of the best position for the various facilities should be based on the inventory which provides a familiarity with the physical and environmental features of the site.

Many aspects of the facilities to be located at the site need special consideration. In arid areas consideration needs to given to minimising the impact on drainage lines. This is because in arid areas plants are adapted to grow in accordance with particular hydrological regimes. Changes in regimes due to flooding or restriction of flows can be fatal to most plants.

Special attention should also be given to identification of groundwater systems; both from a resource and an environmental protection point of view.

In positioning the site infrastructure the following points should be considered;

- minimising sterilisation of ore reserves,
- minimising transport distance from the pit face,
- minimising impacts on any neighbouring residential area,
- minimising visual impact,
- the need for noise screens,
- the need for windshields,
- minimising destruction of existing vegetation and natural land form,
- minimizing rehabilitation costs.

Some facilities such as waste dumps and tailings dams are major changes to the landscape and the design and location of these requires special consideration.

The design of the waste dump should accommodate progressive rehabilitation to ensure a minimum area of disturbance at any one time, and to establish final rehabilitation at the earliest opportunity. Alternative uses for part of the material, such as in landfill or road construction, should also be considered.

The area of land required for waste dumping is an important consideration as it is essential to ensure that sufficient land is available. Adjoining leases may have to be pegged or purchased to accommodate all the material moved. Obtaining extra ground may seem expensive, however it is usually much cheaper than rehandling overburden at a later date.

The following basic objectives for waste dump need to be considered in the planning phase so that the parameters of final design can be considered early in the life of the operation.

- where possible (e.g. if open-pit design permits, or more than one open-pit is proposed), waste rock should be returned to previously excavated areas.

- the height, area and shape of the waste rock dump should be designed with regard to the area of land available, the general topography of the area and the vegetation in the area.

- all completed surfaces of the waste dump should be stable and able to resist long term erosion.

- previously stockpiled subsoil and topsoil should be spread on all completed surfaces where practicable, and re-vegetated with suitable vegetation.

- the design and construction of the waste dumps should be such that the completed outslopes do not exceed 20^{o} from the horizontal.

- drainage should be constructed to handle heavy rainfall events.

In meeting these objectives it is essential that consideration is given to the aesthetics of the constructed waste dump. The long distance perspective of the shape and colour of the dump in relation to the surrounding landscape needs to be assessed from the main access ways and viewing points of the site. At closer range the view of the dump area should provide the viewer with an impression that the area has been rehabilitated to both blend with the natural land form and support a stable vegétative cover similar to the surrounding area.

These factors should be established as long term objectives and planned from the beginning of the operation.

The site selection process for tailings disposal areas requires special consideration and a detailed disccusion will be given in a later section of this bulletin, however, it is appropriate to present the basic environmental objectives in this section. Tailings Dams are required to be;

- non-polluting while in operation and following de-commisssioning

- the tailings disposal structure must have long term stability from both an engineering and an erosion view point, and should be maintenance free

- The final landform produced should be compatible with the surrounding landscape

There are many ways for these objectives to be met, however it is essential that appropriate design, construction and management of the tailings facilities are carried out. These factors are further stressed in a later section of this bulletin.

The location of the other mine facilities such as the plant, work shops, offices and in some cases the living accommodation all need to be considered. It is stressed that the site conditions and the local environmental factors which will be detailed in the site inventory should provide assistance in locating these facilities.

A useful method of locating the facilities after the site conditions are well understood is the use of an enlarged aerial photograph. An overlay sheet should be used on which the details of the various units and special features should be depicted. Tenement boundaries will also be very important.

Prior to conceptually locating the various facilities, a clear understanding of the required dimension of each facility is essential. All the facilities and infrastructure which needs to be developed should then be arranged on a trial and error basis to evaluate the advantages of each . In this way a final conceptual plan can be developed. Figure 3.1 shows a typical site plant.

Within this process it is necessary to consider the possibility of preserving buffer strips of vegetation. The buffer strips can be used for separating activity zones and can provide improved aesthetic quality to the site.

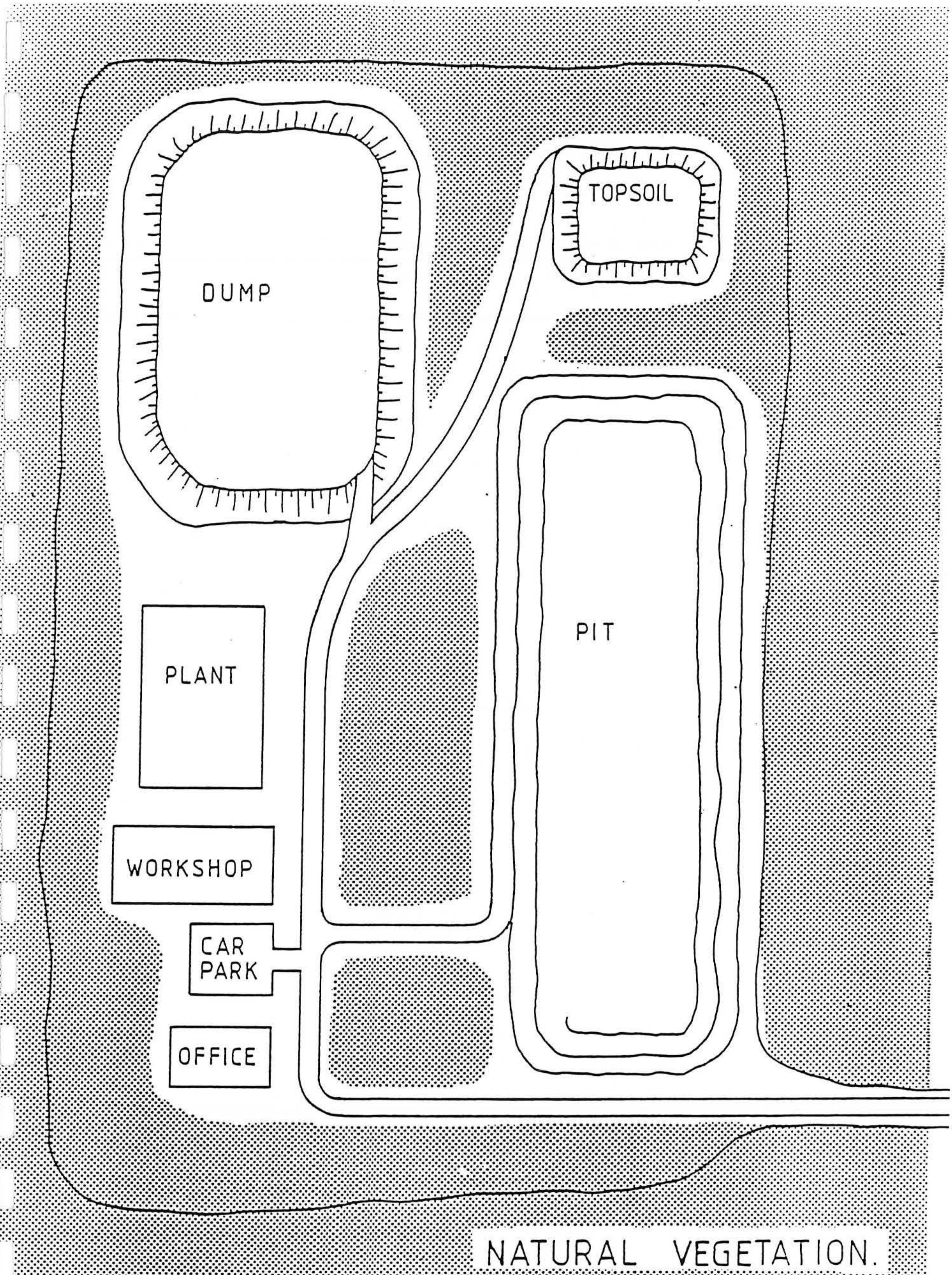
Once the site plan has been refined and finalised it is essential to clearly establish the amount of recoverable top soil to be pre-stripped from development areas. This figure needs to be compared to total area of disturbed land which will need rehabilitation during the life of the mine. A minimum stripping depth of 200 mm is recommended and where possible this depth should be increased. Separate stock piles of pre-stripped vegetation and top soil should be made. The pre-stripped vegetation is useful in providing a source of organic matter for later re spreading over topsoil on rehabilitated surfaces.

Where the site contains markedly different soil types these should be stock piled separately. The location of stock pile sites also needs to be considered to ensure they are not disturbed or covered by the mining operation and that they are conveniently located for re-spreading operations. In the planning stages it is essential to develop strategies which will enable top soil to be utilised early in the life of the mine.

Techniques for rehabilitation will be addressed in greater detail in a latter section of this bulletin, however it is essential and cost effective to integrate environmental and rehabilitation aspects of the operation with daily mine operations. Do not wait until mine closure is imminent to consider rehabilitation as the costs will be greater and the options will be fewer. Only the obligations will remain the same.

Many other site planning considerations need to be addressed including water supply, waste water disposal, and rubbish disposal. One particularly important consideration is how the project will effect neighbours and other users of the area, for example, pastoralists. Agreements with pastoralists and Shires regarding road access, fencing, public health matters and many other factors may need to be established.

In summary proper evaluation of environmental factors in the planning phase of a mining operation can achieve considerable benefits to both the operation and its final decommissioning.



3.1 TYPICAL SITE PLAN .

4. REHABILITATION

It is expected that all areas disturbed by the operations will be rehabilitated. This will include the removal of all plant, facilities, rubbish and the restoration of the land surface to allow vegetation to re-establish.

The development of a successful rehabilitation programme to meet the objectives will require the allocation of people and resources to the task. The sooner that a clear programme of actions is implemented the cheaper and more effective the result will be.

Mining operators should assess their environmental management requirements according to the number and type of projects involved, and allocate their resources to suit. It may be possible to utilize the skills already present in an organization. Often, however, specialized input will be required. This can be achieved by utilizing consulting firms or acquiring in-house skills by appointing an appropriate specialist. A list of consulting firms who have had previous experience in this field is provided in Appendix 1. For more information the regional office of the Department of Mines should be contacted. No matter which course is taken in obtaining environmental advice, it should be noted that environmental management of mining projects has become a specialized field where study and experience in a wide range of sciences are utilized. Different situations will require different expertise which should be sought accordingly.

Operators will also need to allocate financial resources to achieve effective environmental management. Expenditure for these purposes should be integrated with, and treated the same as, all other components of the operating budget. In many cases the use of provision accounts or trust funds will be useful. What is required is the cost of rehabilitation to be expressed as part of the production costs and allocated as such.

The most satisfactory and economical approach to rehabilitation planning is to integrate rehabilitation requirements with the day-to-day mining operations. Planning of the final land form should be considered as important as planning the mine pit because the condition in which the site is left is a measure of the environmental performance of the company. The future of a company's operations and for that matter the industries development is to some extent dependent on how environmentally responsible operators are. Further, determining final land forms prior to commencing operations is the only way in which the lowest overall operating costs will be achieved along with the rehabilitation objectives.

Planning for rehabilitation will need to consider four major components. These are:-

- Rehabilitation objectives, including post mining land use,
- Topsoil,
- Earthworks and erosion control,
- Revegetation

4.1 Rehabilitation Objectives

Establishing rehabilitation objectives from the outset of an operation is crucial for effectiveness and efficiency. Usually final land form and land use objectives need to be discussed with the land owner or government department responsible for the area. The Mines Department has set objectives for various types of operations. Many aspects of mining rehabilitation are being reviewed by the Work Party on Conservation and Rehabilitation in the Mining Industry who are evaluating various segments of the industry. To date two reports have been prepared, they are:

- Report on Conservation and Rehabilitation in the Gold Mining Industry

- Report on Conservation and Rehabilitation in the Sand Mining Industry.

These reports have identified areas which need improvement and recognise the fact that the industry, as a whole, needs to raise its standards and develop environmental management practices which are acceptable to the entire community.

When formulating the rehabilitation objective for the site it is important to consider the present land use of the site and how the operation will effect that activity. Some operations such as some sand mining in agricultural areas have the clearly defined objective of returning the land to viable agricultural purposes. In forested areas the aim may be to re-establish a self supporting forest community.

For mines in the semi-arid or arid environments the most realistic short term rehabilitation goal is to establish a ground cover resistant to erosion. The long term goal should be to establish a community of plants which is as stable, diverse and resilient as the pre-mining vegetation and which is compatible with the surrounding environment and land uses. Therefore, the aim in pastoral country should be to rehabilitate land to enable normal grazing practices to be re-instated.

More detailed objectives for the rehabilitation of mine waste dumps have been listed on page 8.

The most important feature of the rehabilitated land will be an ability to withstand long term erosion.

It is stressed that the earlier in the life of the operation that rehabilitation requirements are considered and an individual who is in a position to influence how operations are undertaken, is assigned the responsibility for the rehabilitation programme, the cheaper and more effective the programme will be.

The following information on rehabilitation techniques provide a brief outline of some of the aspects which need to be considered and should only be considered as an introduction to establishing a programme.

4.2 Topsoil

In the planning section of this bulletin it has been stressed that an assessment of the quantity and quality of topsoil should be made. Equally important is the fact that the earlier the top soil is re-used the more effective the topsoil will be. This is because the biological value of stored topsoil decreases with time. The depth of top soil recovered will depend on the site, however, 200 - 300 mm should be recovered if possible. Even soil profiles which appear to be stoney and unfriable should be recovered as this material will be much better for rehabilitation purposes than the over burden which will need to be rehabilitated.

It is suggested that soil should not be recovered when wet as this can lead to undesirable compaction either in the stock pile or in re-spread material.

Vegetation and overburden material should be stockpiled separately, however, incorporation of some vegetation matter and litter reserves will be useful in the re-vegetation process, particularly if the topsoil can be used immediately.

Instant re-use of topsoil gives the best results, however, it can normally be assumed that some storage of material will be required. Even short storage will result in deaths of short lived seeds (Maireana species; Atriplex species). Of more concern however will be the inevitable and quite quick decline in the soil microbiota, principally the vesicular-arbuscular micorhizas (fungi) which have been recognised as having significance for arid land plants in taking up water and nutrients. The loss of these agents from stockpiled topsoil will need to be compensated for when the topsoil is eventually re-spread. Other factors that will influence the final value of the stored topsoil are: the degree of compaction during storage; the amount of water stored in the pile and the seasonal conditions at the time of recovery. The influence of these factors is not well understood except to suggest the unnecessary compaction will result in a decline in soil structure.

The top soil stockpile is the most important resource for any rehabilitation programme and at no time should this resource be used for any other purpose. If the salvaged topsoil can not be used elsewhere immediately then it should be stockpiled in an area where it will not be disturbed. Every effort should be made to minimise the need for relocating top soil stockpiles.

4.3 Earth Works and Erosion Control

The approximate volume of material required to be disposed of in waste dumps should have already been calculated and sufficient land area should have already been allocated. Design criteria, for the final shape of the dump should be decided upon prior to commencement. The objectives already discussed provide the basis for the design criteria remembering that in most cases the aim is to blend the waste dumps as much as possible into the surrounding landscape and to produce stable, non erodible, surfaces in the long term.

A number of factors need to be considered in final waste dump design, for instance, when considering final slope angles it is informative to view the natural slopes occurring in the particular area as they have evolved as a result of natural erosional process. Natural slope angles are depicted in Figure 4.1. The final angle and shape should blend with the natural landscape.

Control of erosion is dependant primarily on two factors, slope angle and slope length. Figure 4.2 shows the influence of slope angles on erosion and revegetation success. Long unbroken slopes allow surface runoff to accelerate and produce rill and gully erosion. For these reasons the Department of Mines recommends slopes of no greater than 20^{o}, with benches every 10 metres of vertical height as basic criteria for waste dump rehabilitation. Figure 4.3 shows the basic slope profile for most dumps.

Erosion is also influenced by soil characteristics, rainfall run-off charactistics and the extent of vegetation. Therefore rehabilitation of disturbed surfaces needs consideration of all of these factors.

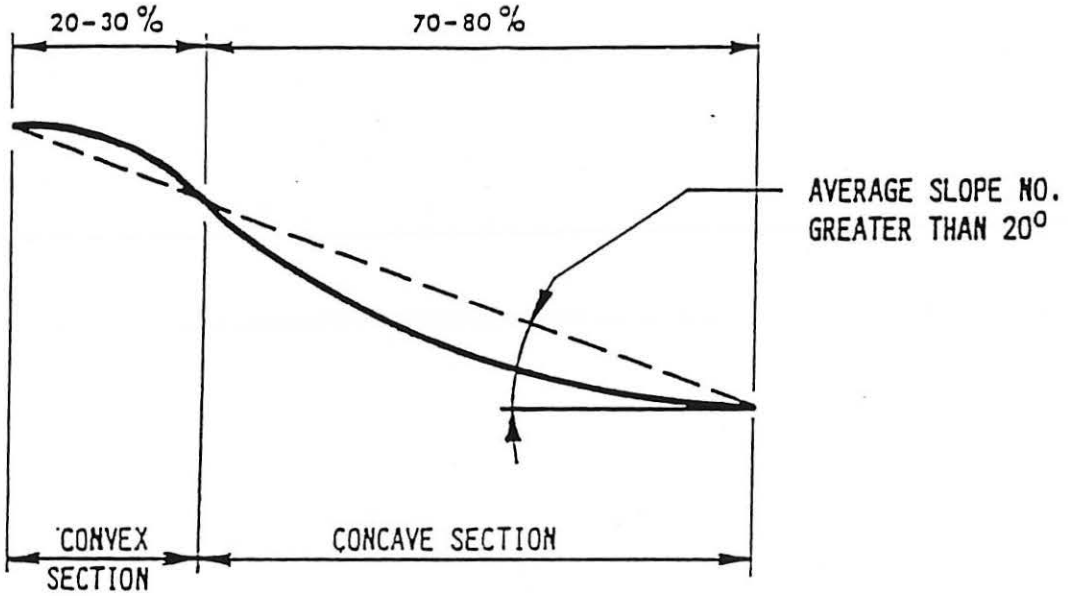


FIGURE 4.1. TYPICAL NATURAL SLOPE PROFILE, IDEAL PROFILE FOR WASTE DUMP.

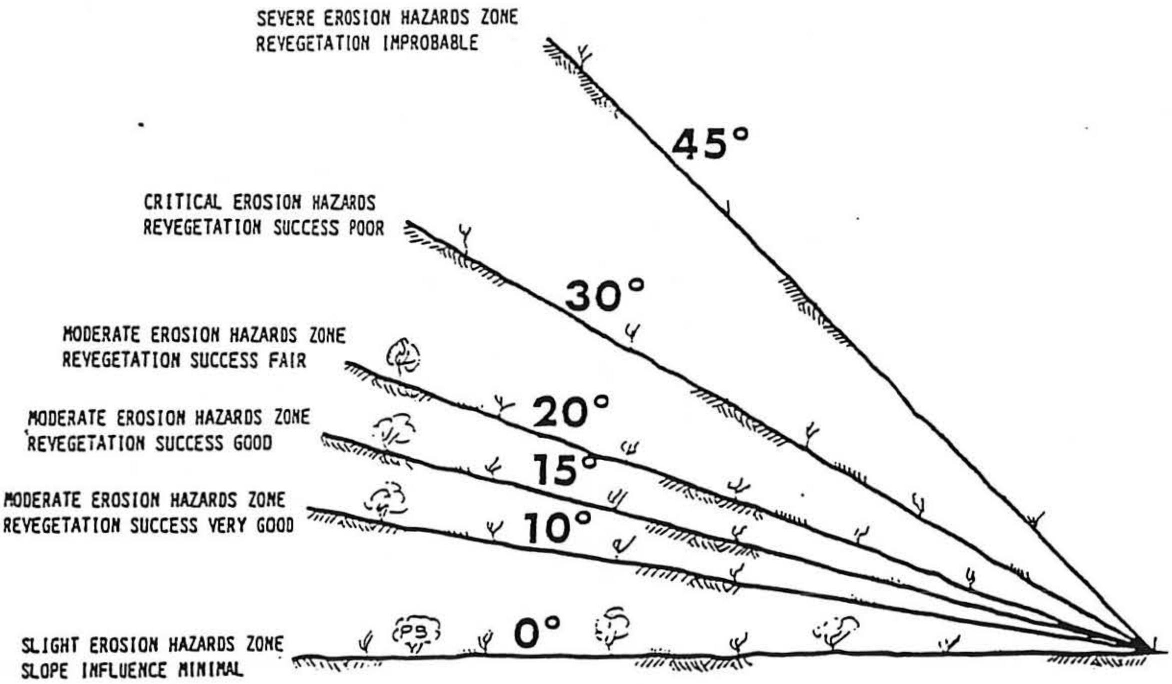


FIGURE 4.2. INFLUENCE OF ANGLE OF SLOPE ON REVEGETATION AND EROSION.

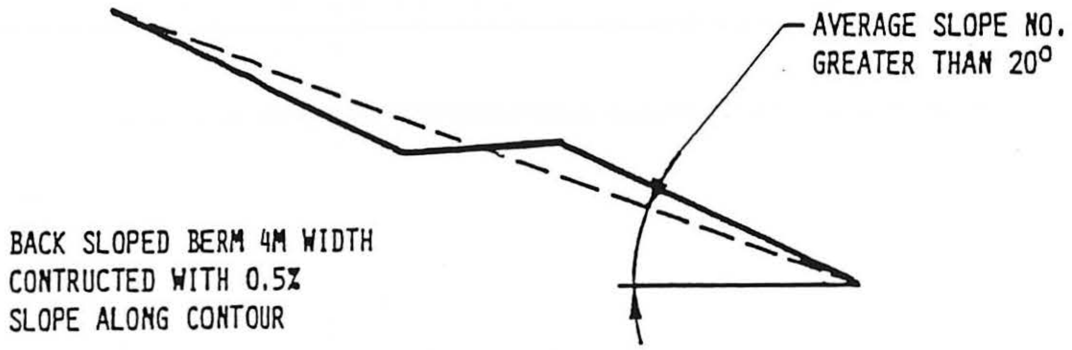


FIGURE 4.3. BASIC SLOPE PROFILE FOR MOST WASTE DUMPS.

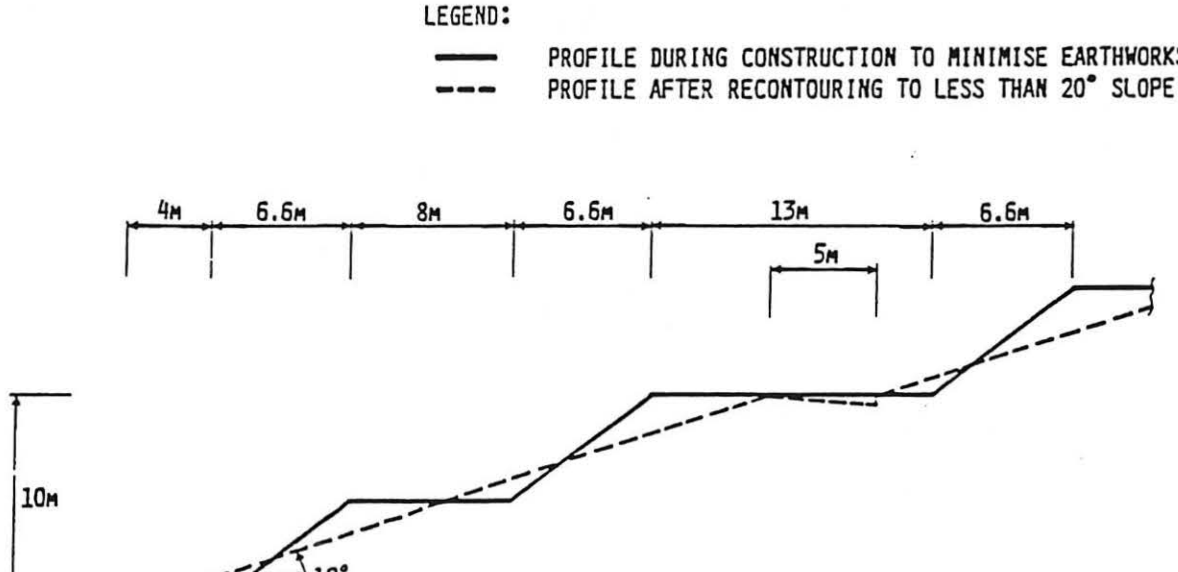


FIG. 4.4. EXAMPLES OF WASTÈ DUMP CONSTRUCTION TECHNIQUE.

At present many operators prefer to leave any major earthworks for rehabilitation until the waste dump is nearing completion. This however can be a very expensive exercise. Construction of the final land form as the dump develops is far cheaper than many hours of dozer time at the end of the mine life to batter slopes and construct berms. Figure 4.4 illustrates a waste dump construction technique which aims to minimise earth works.

For example to re-contour a 380 000 cubic metre waste dump which has 37° slopes to the recommended 20° or less slopes, approximately 80 000 cubic metres of material will need to be shifted. The amount of land required to achieve these lower slopes will mean that approximately twice as much surface area will be required. It is thus of paramount importance to design waste dumps in the planning phase of the operation and ensure that sufficient land is available.

One technigue highly recommended is to construct the out facing batters of the waste dump first. Development of the outside faces of the dump can be achieved by initially dumping material around one to two thirds of the boundary. The remaining open area can be used to expand into if the need arises.

The completed outside faces can then be rehabilitated early in the operation when the viability of the topsoil is highest. Figure 4.5 illustrates the concept of construction of outside faces first.

The out sloping faces should have a maximum angle of 20° as previously mentioned, however, shallower angles allow machinery to work with greater safety. Shallower angles are also far more stable and, where space is available shallower angles are encouraged.

Outside faces of the dumps should be built progressively, and berms of at least 4 metres width should be established every 10 metres of vertical height. The berms allow access for machinery to dump topsoil prior to spreading. These berms act as catchment drains and should be sloped back into the dump. The berms require a 0.5% slope along their length to lead the runoff to rock lined vertical drains. The old haulroad can also be used as drain. The vertical drains should be linked with energy dissipating sediment straps.

The number of vertical drains required is dependant on final slope angles. On steeper slopes the catchment area for the vertical drains needs to become smaller to ensure that runoff water does not exceed the design capacity of the drainage systems. Individual catchment areas should not exceed 2 hectares on fourteen degree slopes, 1.25 hectares on eighteen degree slopes and 1 hectare on twenty degree slopes.

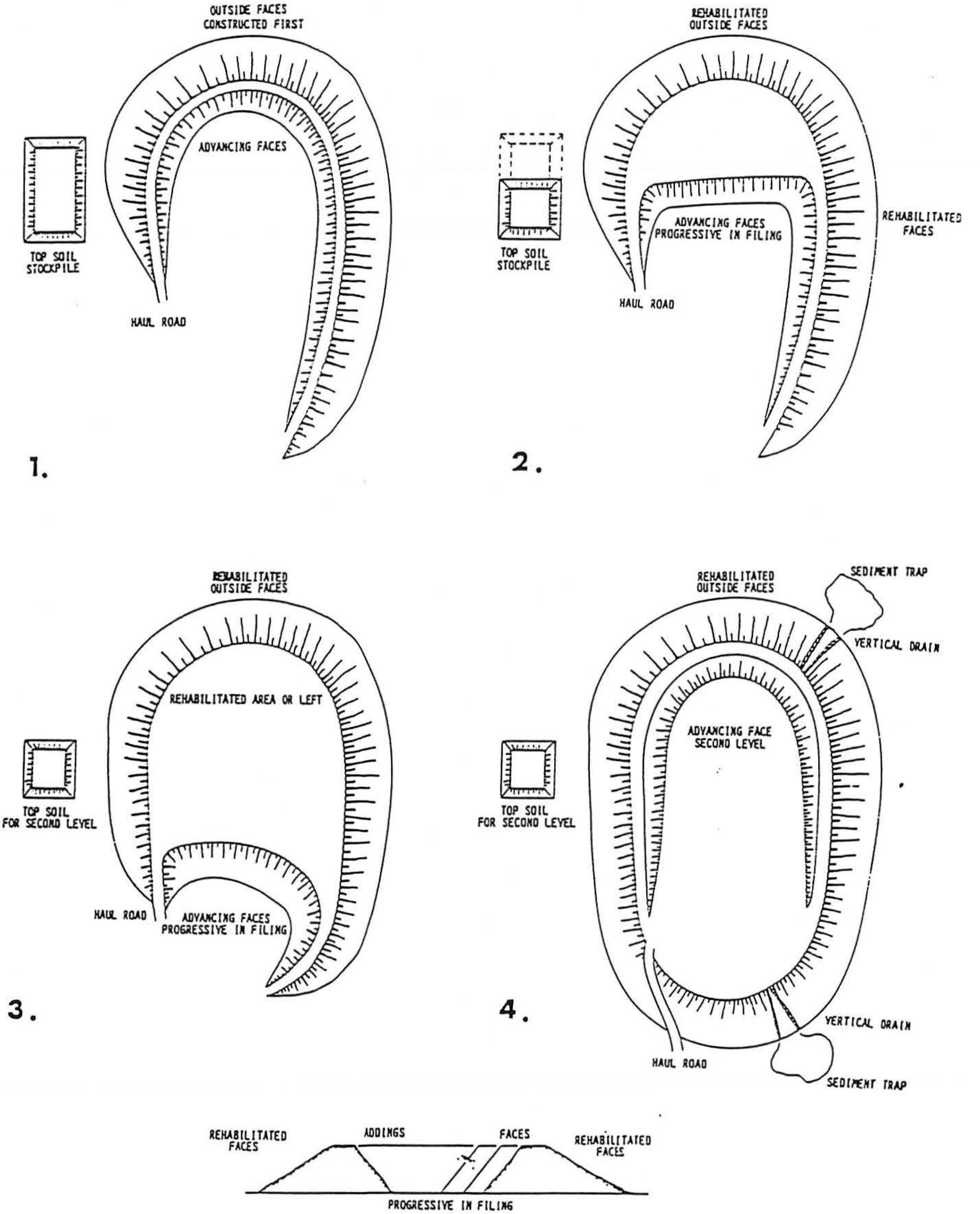


FIG 4·5 DUMP CONSTRUCTION AT ALLOW FOR PROGRESSIVE REHABILITATION.

It needs to be emphasized that these drainage structures should be maintenance free and designed to last for decades to ensure that no failures occur before vegetation is well and truly established. Waterways need to be lined with rock and not just hard clay chunks. Alternatives may include meshing secured in place, old conveyor belting or half round pipe.

The lateral bank or berm drainage system is widely used as it can be largely constructed during the building of the dump and requires little re-contouring. It can also produce a land surface which appears similar to the original surface and capable of supporting some future use for the land. Properly constructed and re-vegetated, the final surface should be self sustaining and able to resist the natural forces of erosion.

A vegetative cover is the best long term strategy for stabilization and erosion control. To begin this process the top soil should be replaced to a similar depth as that removed from the site originally (i.e. 200-300 mm). If topsoil is in short supply it may be necessary to place the topsoil in strips. This at least provides areas of improved surface for regeneration.

To increase the success of vegetation establishment, rehabilitation techniques in arid areas should aim to increase rainfall infiltration. The term used for this approach is "water harvesting", and many specific techniques have been developed for various applications. The most basic of these techniques is to leave the surface of the dump as rough as possible by deep ripping along the contour after the top soil has been spread. The roughness and ripping allows for water penetration and provides places for seeds to lodge. Replacing pre-stripped vegetation also helps this process and reduces wind erosion. Creating a surface which enhances water harvesting will also help to leach soil salts out of the surface profile and aid the revegetation programme.

In areas where salt content of the overburden is high it is recommended that the dumps be screened with overburden of the lowest possible salt content. This is usually from material closer to the surface. This selective handling of overburden may be considered expensive, however, such treatments will be required to provide a suitable environment for plant growth, as it will take many years for the salts to leach out of the surface layers. The screening material needs to be covered by topsoil.

In all cases the surface and faces of waste dumps will need to be ripped to break compaction and allow water penetration. This ripping will usually be carried out by a dozer after the top soil and old vegetation material is spread. It is stressed that water harvesting and erosion control are the key issues in establishing the final surface for the rehabilitation programme.

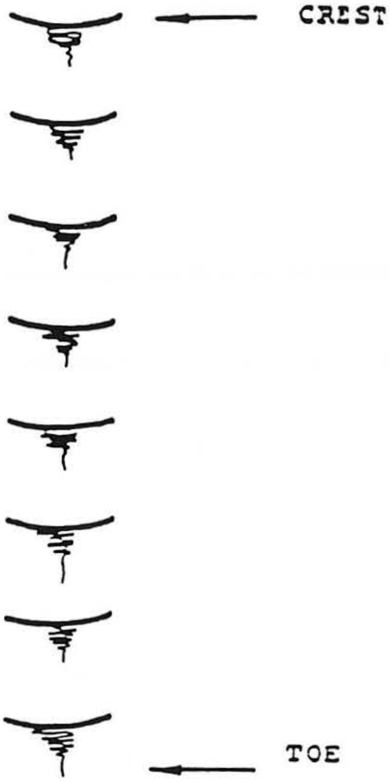
A number of other techniques have been developed to stabilise the eroding surfaces of waste dumps. These include techniques such as "Moonscaping" and using "Blocking Material". i.e. rock armouring.

Moonscaping refers to the development of interlocking banks or craters approximately eight metres apart by one and half metres deep (a Caterpillar D9 Bulldozer length and blade height, refer diagram). This techniques has been developed by Mt Newman Mining in the Pilbara region to stabilise waste dumps in arid, low rainfall environments. The technique provides an alternative way to stabilise steeper slopes were cross ripping is not possible. It also reduces water and wind erosion and allows small micro catchments to be created which provide suitable places for vegetation to establish.

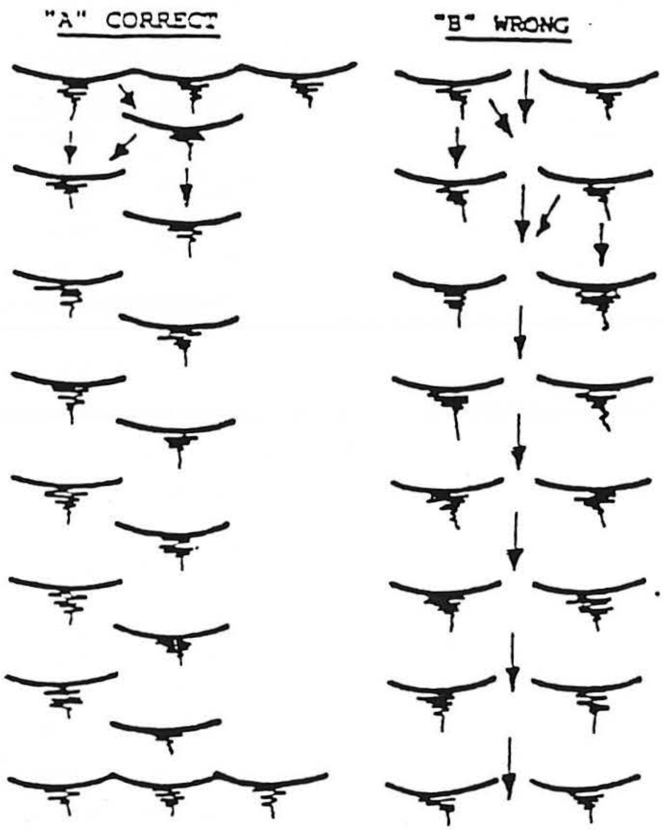
Effectively a dozer is required to push up a blade height of material before backing up the slope and repeating the process. The development of the craters beginning at the toe of the slope and working up and towards the crest. It is important to ensure that subsequent runs up the slope should be worked very close to the previous run to ensure that runoff can only occur between adjacent craters and not down the slope. On long slopes continuous contour banks may be required to guard against erosion of the entire face (refer Figure 4.6).

"Moonscaping" can be carried out with or without topsoil; and has the advantages of providing micro catchments for vegetation establishment. The final surface does appear somewhat "alien", (hence the name) but any stable surface is better than no surface at all. It should be pointed out that this technique is expensive in terms of machine time as only approximately 1.5 ha of moonscaping can be created in a normal working day.

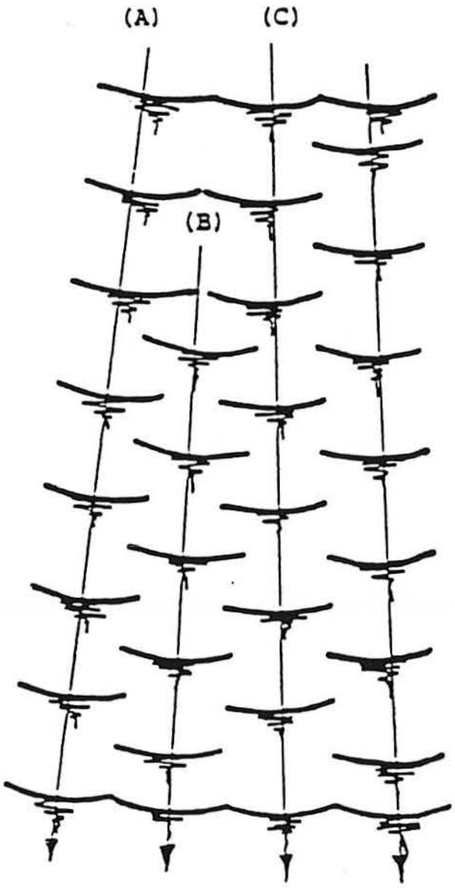
The use of "Blocking Material" in the stabilization process provides analternative option in specific situations. "Blocking Material" refers to the use 150mm and larger rocky material to screen or rock armour the dump. The technique is derived from observations of the natural surface profiles of slopes in many arid regions. In many cases natural slopes are covered with a mantel of rocky and blocking material, effectively resisting the forces of erosion as the lighter material has washed away. In many cases the top soil recovered will be made up of this type of material which has the benefit of reducing erosion and providing niches for seed lodgement and vegetation development. Blocking material can also be derived from stock piling of most suitable waste material. Blocking material should be component rock and preferably of a colour which blends with natural surroundings. Use of blocking material also has the advantage of providing a dust free environment. With suitable seed application



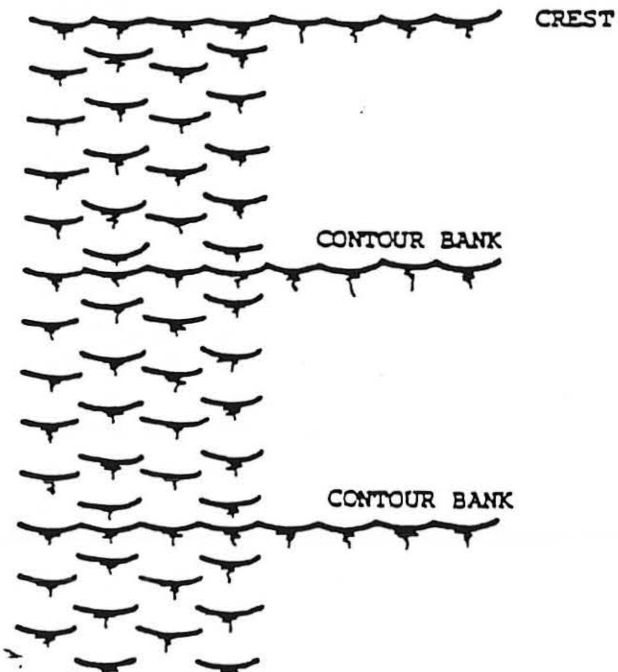
MOUNDS APPROX. 8 METRES APART AND 1.5 METRES DEEP (D9 DOZER LENGTH AND BLADE HEIGHT)



"A" CORRECT. EROSION INTO INTERLOCKING CRATERS WITH CONTINUOUS WINDROW ALONG TOE.
"B" WRONG. EROSION RESULTS BETWEEN CRATERS OVER ENTIRE SLOPE.



CURVED SLOPE. SHORT RUN "B" TO "TIE-IN" MOONSCAPING



MOONSCAPING ON LONG SLOPE SHOWING CONTOUR BANKS FOR ADDITIONAL CONTROL.

FIG 4.6 MOONSCAPING

this treatment can provide a stable vegetated slope if adequate erosion control berms are incorporated into the final land form.

Additional stabilization techniques include use of spray seeding equipment such as hydro or straw mulching. These techniques are effective for applying seed and fertilizer to steep batters. These methods generally only provide short term stabilization and rely on plant growth to provide longer term protection.

Erosion control on steep batters can also be achieved by using meshes made of jute or plastic fibre. The mesh provides a temporary stabilizing surface until vegetation becomes established. Unvegetated dumps provide a source of dust and sediment and whilst vegetation is establishing it may be necessary to chemically seal the surface for dust control. Construction of a sediment dam to protect downstream water rights in sensitive locations may also be necessary.

4.4 Revegetating the Site

Establishment of a vegetation cover on the disturbed site is usually one of the main objectives of the rehabilitation programme as vegetation cover is the best long term method of stabilising the site. When the major earthwork components of the rehabilitation programme have been completed, the process of establishing a stable vegetation community begins. If top soiling of the areas and adequate erosion control has been achieved, then this phase may simply require undertaking a seeding and fertilising programme and monitoring the performance of revegetation.

There are a number of factors which need to be considered in the revegetation process Developing an understanding of how plant communities re-establish themselves through a colonization process on suitably prepared sites will assist with the overall management of the rehabilitation programme. Again it is recommended that responsibility for the rehabilitation programme is assigned to a person who is in a position to establish a suitable programme, and if possible, has some experience in rehabilitation or vegetation establishment, or use a consultant to supervise the work.

Management of soil nutrient levels is an important consideration. Soil nutrient levels should have been obtained during the resource inventory and the need for, and value of, additional nutrient applications is best determined by trial data. In areas currently being mined, phosphorous is likely to be the dominant limiting nutrient. In areas with poorer soils, all nutrient levels will be low, however, the native vegetation has evolved to a handle low nutrient regime. Care must be taken that any additional nutrients applied as fertiliser do not produce toxicity for native plants with low tolerance or assist weed species. Additional nutrients are likely to be useful in three situations;

- where the nutrient level of spread topsoil is lower than than material in situ.
- where it is intended to grow plants with a higher nutrient requirement than those occurring naturally.
- where it is desirable to get a quick growth response from the native flora during those times when moisture is not limiting.

One or more of the above situations often apply, and good responses have been achieved on natural soils with the use of fertilisers containing phosphorus. Fertilizer applications are cheap ($50-$100 per hectare) and a single application at the time of rehabilitation will suffice in all areas except those prone to artificially high soil leaching (ie: tailings material).

The role of soil microbiota, and the loss of this material when topsoil is stockpiled has already been discussed. Recovering these micorrhiza (fungi) is less easy and part of the value of some fertilizer application may be in making up for the loss of the nutrients normally harnessed by soil fungi. The infective pores are not readily windblown, but they can be moved by animals. At present it seems that the most practical method of infecting a new area would be to raise seedlings in infective material, and then transplant these seedings into the sterile soil. This would be a simple procedure involving watering at the time of transplanting.

If the above procedures have been adhered to, the rehabilitated site should have soil characteristics similar to that occurring naturally. If the spread topsoil was subject to only short stockpile, time in fairly dry conditions, then growth of plants from stored seed should readily occur. Initially these will be from the annual and biennial flora and it will be important to determine if the durable perennial shrubs and trees are growing in the area. If this does not occur, or if the soil has been stockpiled for a long time, then some addition of seed will be required. Experience suggests that establishing a natural vegetation from seed, on a well prepared fertile and preferably non-saline site, is feasible, and involves procedures such as those listed here.

- Use locally collected seed where possible, as it will have come from plants that have thrived in that environment.
- Annual and biennial grasses, herbs and sub-shrubs can be introduced by gathering bush litter (which will contain seeds) in areas where these plants grow. The litter also could have a desirable mulching effect.

- Acacia species seed can either be collected from the trees themselves, or in the case of some species, (tan wattle, Acacia hemiteles) can be collected on the ground beneath the tree. These seeds will benefit from a pre-seeding treatment (immersion in boiling water) to soften them for early germination.

- Seed from the saltbushes (Atriplex species) is easy to collect in bulk when the bushes are seeding (usually spring-summer) and stores well for at least one to two years. Saltbushes are the logical plant to establish in any area where the salinity has been raised by the mining activity.

- Bluebush (Miareana species) seed is short lived and should be dried carefully and used within six to twelve months of collection.

- Other seeds generally worthy of collection are Cassia spp and Ptilotus spp. These are collected from those types of plants that grow in the same environment as the rehabilitated one.

Establishment of tree species can be achieved by direct seeding methods, or by transplanting seedlings with adequate site preparation. Tree seedlings should be planted only where the environment can support them, in arid areas direct seeding methods are more appropriate. Again local species are best suited to the environmental conditions of the site. It should be pointed out that seed collection requires licences from the Department of Conservation and Land Management (CALM). CALM regional officers can also provide information on suitable species for particular sites.

A great deal of information about how to develop various techniques for revegetation and what plants are most suitable will be gained from the following three sources.

Firstly, information will come from interaction with other people in the mining industry who have had experience in these activities. Appendix I contains a list of people who are actively involved in this field.

Secondly, formally conducted research programmes will provide useful information. These may be major research projects or simply trials established to verify a specific technique's usefulness at a particular location.

Thirdly, information gained by carefully observing the natural vegetation and conditions at the site. One very useful way to learn about how your particular area responds to disturbance will be to review any previously disturbed areas. The success or failure of these areas to revegetate will provide important information about how to provide a suitable surface for revegation, and what types of vegetationare suitable for these areas.

Monitoring of rehabilitation work at all of the stages is vital. There will need to be detailed monitoring of soil fertility and salinity for some time after the work is finished, and the erosion status of the surface may need documenting. Monitoring the performance of vegetation establishment and growth is essential. Some record of the return of the native fauna may also be required; this could include both vertebrate and invertebrate fauna. At a simpler level, a photographic record of all of the work done, and of the growth of the resultant vegetation, will be valuable both to those doing the work and to those who arrive after the events. It can be a source of satisfaction to both groups as it will provide a necessary documentation of progress and development.

4.5 Summary

In summary, the earlier a rehabilitation programme is begun in a mine's life the more cost effective the programme will be. Allocation of personnel and resources to the programme is essential. Clearly defined rehabilitation objectives should be established including final land form and vegetation types. Top soil recovery is an essential component of the rehabilitation programme, and the sooner it is reused the better the results will be. It has been recommended that the final out slopes of dumps should be created during the construction of the dump, rather than undertaking a major earth works programme at completion or during the close down phase of the operation, when funds may be in short supply. Stability and erosion control are the key factors which need to be achieved. Vegetation provides the best long term stabilizing treatment. In arid environments the key to success of all rehabilitation involves developing water harvesting techniques; these techniques maximise penetration of rainfall infiltration on the site, or allow limited run off to occur in micro catchments providing adequate water for plant development.

Erosion control earthworks will be required to minimise the erosion potential of the site and a number of techniques including berms, "moonscaping' and use of "Blocking Material" have been discussed. The revegetation component of the programme requires an understanding of plant communities, their nutritional requirements, and how best to establish a vegetation community which will become stable and self supporting in the long term. The major consideration throughout the rehabilitation programme will be the establishment of a land form which blends, as much as possible, with the surrounding environment.

5. TAILINGS DAMS

Concern has been expressed about current tailings dam practice and as a result, the Department of Mines along with other Government agencies is now paying far more attention to ensure that tailings disposal is carried out in an acceptable manner. All new tailings dams are now required to be specifically assessed and approved by the State Mining Engineer, and often also require "Works Approval" under Part V of the Environmental Protection Act.

To gain the necessary approvals details of the design, construction, operations and de-commissioning of dams are required to be submitted, in the "Notice of Intent", to the Mines Department. The following section outlines the philosophy used by the Department when assessing tailings disposal systems, and details a number of design and operational faults and problems that have been encountered with gold tailings systems in Western Australia. Guidelines for the preparation of a "Notice of Intent for New Tailings" proposal are available from the Department of Mines.

5.1 Objectives

The basic environmental objectives in any tailings disposal system are quite simple:

- The method of disposal should be non-polluting, while the system is operational and following de-commissioning.

- The tailings disposal structure must have long term stability from both an engineering and an erosion view point, and should be maintenance free.

- The final landform produced should be compatible with the surrounding landscape.

There are many ways in which these objectives can be achieved. The vast majority, however, require conscious decisions to be made at all stages from initial site selection through design, construction and operation. There are far too many cases of tailings disposal systems being established without adequate consideration of the long term objectives, resulting in very costly rehabilitation exercises at or after the close of operations.

5.2 Site Selection

Site selection is one of the most important aspects of successful tailings disposal planning. Many environmental factors must be taken into consideration and the way in which they will interact with the design process will depend upon the major climatic factors affecting the site. In W.A. we are dealing predominantly with arid environments which, typically, have large excesses of evaporation over rainfall. However, rainfall events in these environments can be of considerable intensity and therefore, must be taken into consideration in the site selection process.

The designer is often faced with a decision on whether to place the tailings disposal structure in a valley or on the interfluve. While valley sites have been traditionally used for tailings disposal and often have a number of attractions (ie: being low in the landscape and requiring minimal civil works to contain a large tailings volume), there are also a number of disadvantages which must be considered. These include adverse geotechnical conditions resulting from alluvial valley deposits and problems caused by the catchment area of the valley system upstream from the disposal site. In the goldfields of W.A. much of the potable water supplies are associated with alluvials in the typically broad, flat valley systems. The valleys also contain better quality and quantity of vegetation and include the more productive soil types.

In contrast, the interfluve sites are usually closer to bedrock, have no upstream catchments and potable water resources are usually absent. The sites are, however, usually very visible and it is often difficult to adequately blend the structure into the surrounding landscape.

Geotechnical assessment of potential sites should always be carried out. Special attention needs to be paid to the existence of permeable substrates and fracture systems over the total impoundment site, not just the dam wall. In the goldfields problems have occurred as a result of calcrete deposits, which often occur within the soil profile and display very high lateral permeabilities while remaining impermeable vertically. The presence of old mine workings is another cause for concern and may require special assessment. The alluvial deposits referred to above have also resulted in a number of leakage problems. Like the calcrete, they also show high lateral permeabilities.

The vegetation and soils on potential sites should also be given consideration. Where possible, areas of better quality vegetation and soils should be avoided. Stands of trees and larger vegetation can often be used to screen the tailings site from critical view angles. Arid land vegetation is very dependent on water balance, thus special attention should be given to the effect that a tailings structure will have on both the upstream and downstream water flow. Both ponding and lack of run off can adversely affect existing vegetation, particularly where sheet, rather than channel run off, exists.

Landscape aspects should also be considered when selecting a site. Such practices as siting the structure below the skyline, altering the shape or orientation, or blending into a dominant landscape feature can all be used to lower the visual impact. Another possible alternative is to site the tailings disposal area such that it can be progressively covered with waste rock from the mining operation, and thereby incorporated into the final waste dump structure.

A common fault in the goldmining industry is the selection of a short-term site that does not have adequate area to cope with the total project output. This often leads to excessive rates of disposal, which in turn, cause stability problems.

5.3 Design

By far the most important objective of any tailings design should be to achieve the maximum possible final tailings density. Tailings dams are expensive and should be used for solid tailings not for water storage. Poor design can result in very low densities with water contents as high as 40 or 50%, (i.e. up to half the capacity of the dam is used to hold water). In the gold industry, this water almost always contains gold values so that its recovery is not only environmentally desirable, but also makes good economic sense. (There is some credibility in the statement that the tailings dam is the circuit's leach tank with the longest contact time.)

Low tailings density also leads to poor structural properties in the tailings mass and excessive hydraulic pressure on the floor and walls of the dam. Although it is not the intention of this bulletin to examine in detail, techniques of producing high density tailings, discussion of some successful techniques is warrented. The first is the somewhat unconventional technique of deliberately designing a leaky dam. This has been achieved in a number of cases by utilising a permeable layer in the soil profile that would have normally been removed in conventional designs. Sandy soils and laterite layers have both been successfully used as drainage blankets beneath the tailings emplacement. All that is required is a suitable cut off and collection system that will enable seepage to be collected and returned to the mill circuit.

Where natural under drainage cannot be adequately achieved or controlled it is of course possible to install a suitably engineered system. Such systems usually pay for their installation cost very quickly due to water and gold recovery alone. Well designed decant systems also greatly improve water recovery and lead to higher tailings densities, as can the use of segmented dams that allow adequate draining to take place between each emplacement cycle.

There are also alternative techniques such as the thickened tailings discharge system developed by Robinski, and belt filters that can produce high density tailings. These techniques have a number of other environmental advantages, however, such systems are yet to be used in the gold industry in W.A.

Again, it must be stressed that the most common failure to achieve adequate tailings density results from tailings impoundments that are too small to cope with the quantity of tailings. Frequently plants are established with tailings dams designed to just cope with the rated capacity. Within the first year of operation, the plant is fine tuned or upgraded resulting in much greater throughput, however, the tailings dam area remains constant, being difficult to extend, and overloading occurs. It is usually not until major problems such as instability or leakage occur that consideration is given to increasing the capacity (i.e. the area) available for tailings disposal. Even the best designed dam cannot be expected to cope with significant increases in the deposition rate without problems occurring.

The next most important aspect of the design is the containment structure. While it is possible to construct tailings dumps directly out of tailings that remain stable in an engineering sense throughout the life of a project it is not possible, in the vast majority of cases, to produce a structure using that technique which has long term stability. Tailings are almost always highly erodable to both wind and water and some form of surface stabilisation is inevitably required.

There are essentially two ways to achieve long term stability, these being an engineering approach and a vegetative approach. Where tailings are suitable for use in the construction of the containment walls, it is possible to simply coat the outer surface with a sufficiently thick layer of rock armouring that will protect the structure from wind and water erosion. While it is often possible to achieve quite steep angles of repose in such structures, there are often considerable cost disadvantages when it comes to placing the rock armouring and maintaining it. More conservative slope angles are often not only more aesthetically pleasing but also more cost effective.

Vegetative surface stabilisation has a number of advantages over the fully engineered approach. Vegetation, if carefully selected, will greatly assist in blending the structure into the existing landscape. It is also self regenerating so that maintenance is not a major problem. Even in cases where exceptional events occur, such as abnormal rainfall, vegetation has the ability to recolonise disturbed areas. At this stage our knowledge of arid land species suitable for revegetation on tailings structures is poor. The work of the Goldfields Dust Abatement Committee at Kalgoorlie has, however, clearly demonstrated that suitably selected vegetation can provide a cost effective long term surface stabilising cover, and that vegetation can even be established directly onto saline tailing with the use of selected surface preparation techniques.

In most mining operations, there are large quantities of waste rock or overburden available and this usually provides a much more amenable medium for plant growth. The material is also far better than tailings from a construction viewpoint, as it usually provides a far better containment structure for the tailings. Again, conservative slope angles in the order of 1:4 usually provide far more cost effective outer surfaces than the steeper angles that are achievable with normal engineering practice.

Outer slopes at 1:4 can be accessed by normal earthmoving and agricultural equipment, in turn leading to major cost savings in final rehabilitation. Drainage works on these flatter slopes are both more effective, and require less maintenance, than on steeper slopes.

Drainage design is often overlooked in arid land tailings structures, but it is the most common cause of failure and erosion problems. The top and outer surfaces of the structure must have a positive drainage system that can cope with the highest expected long term rain event. Again there is little practical experience in this aspect of tailings design. To date contour banks, grade banks and moonscaping have been successfully used on waste dumps and appear to also offer the best options for the outer slopes of tailings structures.

Special attention should be given to the design of the final top surface of the dump. Most tailings dams have a concave upper surface during their operational life and this is not desirable in the final configuration. A convex upper surface capable of shedding water is far more desirable. The Robinski system produces a highly desirable convex upper surface and has been used in a number of cases overseas to cover previous concave, conventional dams.

5.4 Construction

In any civil construction work, the final product is dependent upon the adequate supervision of those contractors and employees undertaking the work. Failure to remove top soil and vegetation from the dam floor prior to commencement of construction is the most common fault. The top soil and vegetation represent a very important resource that must be saved if adequate rehabilitation is to be achieved. Soil left behind can cause problems of leakage, or hide other geotechnical problems with the site. Vegetation can result in gold values being removed from the return water through absorption into woody material.

There have been a number of dams in which the decant pipe leading from the decant tower under the wall has been damaged by construction activities resulting in an ineffective decant system, or expensive post operational repair. Adequate re-assessment of the geotechnical conditions should be carried out during the construction phase to ensure that problems do not occur due to the unpredicted presence of permeable materials.

Considerable rehabilitation work can be undertaken as part of the construction activities. Top soil removed prior to construction can be replaced onto the initial lift of the dam walls. This can result in a effective vegetation cover being developed on the outer slopes that will protect them from erosion and provide visual screening.

5.5 Operation

It is important that the tailings system is adequately monitored in the operational stage to ensure that the design objectives are achieved. Checks on the water balance and tailings density will quickly identify potential problems. Where dams are constructed in areas where there is potential for pollution of water resources, a system of monitoring bores should be established and regularly sampled, with the sampling programme ideally commencing before tailings emplacement starts.

The most common operational problems result from attempts to place tailings at greater than the design rate, failure to establish correct beach angles for efficient decant operation and overflows from the decant collection pond going un-noticed by operators or because of system malfunctions.

While wall failure or over topping should never occur there are, unfortunately, a number of such events that have resulted in damage to surrounding vegetation and added rehabilitation costs to the operations.

The health of vegetation in the immediate vicinity of the tailings dam often provides the first indication of seepage problems, so cases of vegetation death or excessive growth should always be followed up.

Leakage from the tailings dam into the ground water is a potentially serious problem in the gold industry because of the use of cyanide. The chemistry and breakdown of cyanide and its metal complexes is usually reasonably understood in the mill circuit, but a is leakage of this water from the dam occurs and mixes with chemically different ground water, a number of problems can occur. Saline water can also quickly damage vegetation.

Most ground waters are reducing rather than oxidising and this, combined with the absence of UV light, mean that there is little breakdown of the cyanide. Changes in pH can also lead to the freeing of previously complexed cyanide. There are several cases where it has been necessary for operators to undertake recovery exercises to remove contaminated ground water. This can be both an expensive and time consuming activity, yet with proper monitoring such potential problems can be identified at an early stage and dealt with at their source.

5.4 Decommissioning

Provided the tailings system has been adequately designed and correctly operated, decommissioning should not present any major problems. Rehabilitation of the outer slopes should have been progressing as each lift was established so all that remains to be done is the top surface treatment. In the majority of cases the physical nature or chemical composition of the tailings is such that some form of inert capping will be required on the top. Waste rock is usually available for such purposes. Where topsoil is available it can then be spread over the waste capping.

The aim of the decommissioning must be to isolate the tailings from the environment. As described earlier this will require an adequate drainage system and a stable non-erodible outer surface. In the goldfields many of the tailings dams will contain very large quantities of salt resulting from the hypersaline water used in the treatment process. As an example, a dam planned for a tailings retreatment exercise at Kalgoorlie will hold some 30,000,000 tonnes of tailings and over 5,000,000 tonnes of salt. Such huge quantities of salt could cause enormous environmental damage if it were to leach out of the dam into surface water flows.

6. MINE CLOSURE

Detailed planning, lengthy metallurgical testing, economic feasibility studies and environmental approvals normally proceed the development of mining projects. Until recently, however, little or no forethought has been given to the environmentally sound closure of these facilities. In fact it was common for an operator to simply "close the gate" and abandon the site when the mine could no longer operate profitably.

Previous sections of this bulletin have highlighted the need to establish a environmental programme from the beginning of the operation. From an expenditure point of view adequate financial provision should be made for the cost of the close down phase of the operation when no further moneys are likely to be earned from the project. It is therefore appropriate to adequately plan the mine closure phase of the operation to fulfil the commitments made in the environmental approval phase of the operation, to abide by any conditions of the lease and to adequately meet the environmental standards of the day.

Closure should be viewed as all those activities, including rehabilitation, revegetation and activity designed to restore the land surface a productive use agreed land use; construction and maintenance of diversions or other safeguards to prevent the risk to people or live stock; measures to control release of pollutants; monitoring to assure that no unforeseen environmental problems arise in future. These activities should be viewed as those necessary to comply with legal requirements and industry standards, as well as aim to minimise any future liability arising from impacts on human health or further environmental damage.

Mine closure standards should be discussed with the Mines Department to establish any site specific requirements, and meet those commitments already agreed to.

From a safety point of view the final pit should be surrounded by a substantial bund or windrow, water should not be able to drain into the pit and final upper bench batter angles should be such that normal weathering process will maintain the bund or windrow.

All plant, machinery and buildings should be removed from site and a final rehabilitation programme should be undertaken to return the site to an area suitable for vegetation colonization. This means that all unnecessary access should be blocked off and rehabilitated. The rehabilitation programme for the waste dump area and tailings dam should be well advanced, however, final works may be required. The requirements for these facilities have been discussed in other sections. Some commitment may be required to continue monitoring the performance of the rehabilitation until a satisfactory vegetation community is established. Where ground water pollution from tailings dam leakages is a concern, a clear indication of how these problems are going to be overcome is required.

Heap leach operations need to be treated in a similar way as tailings dam and measure must be taken to cover these facilities and to establish rehabilitated stable surfaces.

In some cases it may be necessary to undertake post-closure measure such as follow up vegetation and groundwater monitoring, repair of eroded surfaces and undertake any activities which reduce the liability of the operator from both an environmental and safety view point.

Final closure requirements should be discussed with, and agreed to by the Mines Department and meet the industry standards of the day. It is difficult to predict all the environmental requirements in the initial approval phase of the project. Many projects change during the life of the operation, therefore final requirements may need modification to suit the changes which have taken place throughout the operation.

7. SUMMARY

The mining industry is an extremely important industry in the economy of Western Australia. There are many and varied types of operations. This bulletin has provided some guidelines to assist the development of a higher standard of environmental and rehabilitation management for mining in Western Australia.

The subjects covered in this bulletin included the requirements of project approval, which outlined the process of preparing a development proposal or Notice of Intent. In the section on site planning it was stressed that during this phase of the operation many useful modification to the project can be made to minimise the environmental effects of the project. It is during this phase of the operation that important information about the site is obtained and the long term objective of the rehabilitation programme should be established.

A comprehensive section on rehabilitation discussed some of the basic objectives which the Mines Department has set for typical operation, and provided important information concerning topsoil, earthworks and erosion control, and revegetation The next section discussed the Mines Department philosophy on tailings dams, and provided some useful suggestions regarding modern approaches to these facilities.

The final section has described some of the important points of mine closure including the need to discuss the final requirements with the Mines Department, as well as satisfying the conditions of the tenement and ensuring that modern industry standards are met.

It is intended that the information provided in this bulletin is presented as a guideline for environmental and rehabilitation management. It is anticipated that many operators will develop techniques to meet their environmental objectives in different ways to those described in this bulletin. It is also envisaged that, as new techniques become available, these guidelines will be revised and updated.

GUIDELINES FOR ENVIRONMENTAL MANAGEMENT OF MINING IN ARID AREAS

INSERTION

ENVIRONMENTAL CONSULTANTS

Australian Groundwater
Consultants Pty Ltd
300 Albany Highway
VICTORIA PARK WA 6100
(09) 3624322 - Peter Dúndon

Australian Revegetation &
Environmental Consultants Pty Ltd
51 King Edward Road
OSBORNE PARK WA 6017
(09) 4464277 - Stephen Hill

Dames and Moore
26 Lyall Street
SOUTH PERTH WA 6151
(09) 3678055 - Barry Muir

Kinhill Engineers Pty Ltd
47 Dugan Street
KALGOORLIE WA 6430
(09) 213777 - Andrew Abercromby

Martinick and Associates
114 Churchill Avenue
SUBIACO WA 6008
(09) 3882123 - Wolf Martinick

McArthur and Associates
PO Box 522
SOUTH PERTH WA 6151
(09) 4741906 -
Geoffrey M McArthur

Landmarch
Collaborative Design Consultancy
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SOUTH PERTH WA 6151
(09) 368-2281 - Steven Davies

Merz Australia Pty Ltd
Brecon, 47 Colin Street
Private Bag 8, West Perth WA 6005
(09) 3222433 - Rob Pannell

Purchase & Associates
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FREMANTLE WA 6160
(09) 4305838 - T Purchas

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& Pty Ltd
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Whelans-Survey & Mapping Group
Pty Limited
PO Box 99
MT HAWTHORN WA 6016
(09) 4431511 - David Wilcox

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& Environmental Scientists
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Soil & Rock Engineering Pty Ltd
Centrepoint Tower
123 Colin Street
WEST PERTH WA 6005
(09) 3215666 - Chris Land

Gutteridge Haskings & Davey
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WEST PERTH WA 6005
(09) 322 3899 - Jim Davies

Wood & Grieve
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(09) 321 9925 - David Harrington

K H Morgan and Associates
34 Geddes Street
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(09) 361 6554 - Kevin Morgan

Sinclair Knight & Partners
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SOUTH PERTH WA 6151
(09) 367 8588 - Gordon Smith

Hart, Simpson & Associates Pty Ltd
21 Rankin Road
SHENTON PARK WA 6008
(09) 3822086 - Dr Ray Hart

Quilty Environmental Consultin
10 Turner Street
WARNBRO WA 6169
(09) 593 1417 - John Quilty

D C Blandford & Associates
Pty Limited
PO Box 467
KALAMUNDA WA 6076
(09) 291 6593 - Doug Blandford

Ecologia Ecological Consultant
120 McKenzie Street
WEMBLEY WA 6014
(09) 3802227 - Garry Connell

REVEGETATION CONTRACTORS

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