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Mine Rehabilitation Handbook

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Every effort has been made to contact the copyright holders of material used in this book. However, where an omission has occurred, the publisher will gladly include acknowledgement in any future editions.
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The Handbook will continue to be revised from time to time. If you wish to provide comment please forward it to the:

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Rehabilitation is the process by which the unavoidable impacts of mining on the environment are repaired. It is an essential part of developing mineral resources in accordance with the principles of sustainable development. The purpose of this handbook is to give field personnel in the mining industry some of the information needed to rehabilitate areas disturbed by mining in a sensible, scientifically based way. While it is impossible to give specific rehabilitation procedures suitable for all sites, the handbook attempts to outline the broad principles and practices that should be used as the basis for rehabilitation.

1.1 Statutory Requirements

There is a range of legislation concerned wholly or in part with environmental matters that may affect mining. Key acts relevant to rehabilitation of mine states are listed in Appendix 1, together with the government body responsible for administering each act, and other government agencies where technical advice on matters relating to land rehabilitation can be obtained.

Legislation, and administrative arrangements between government agencies, differs from state to state and changes from time to time. Information on current legislative requirements can be obtained from relevant Mines and Environment departments.
2  AUSTRALIAN MINERALS INDUSTRY CODE FOR ENVIRONMENTAL MANAGEMENT

In 1996 in recognition of the need to achieve environmental excellence and to be open and accountable to the community, Australia’s minerals industry developed a Code for Environmental Management. The Code is the centrepiece of a new commitment to respond to community concerns through consultation, demonstrated environmental performance, continual improvement and public reporting. Adoption of the Code is voluntary and open to all companies.

The Code provides a basis for improving environmental performance through progressive implementation of the Code’s nine principles, which include rehabilitation and decommissioning (refer Appendix 2).

2.1 Systems and Processes

The systems and processes relevant to the rehabilitation and decommission principle of the Australian minerals industry Code for Environmental Management are:

Ensuring decommissioned sites are rehabilitated and left in a safe and stable condition, after taking into account beneficial uses of the site and surrounding land.

1. Incorporate rehabilitation and decommissioning options in the conceptual design of operations at the feasibility stage.
2. Develop clearly-defined rehabilitation plans, monitor and review rehabilitation performance and progressively refine such plans.
3. Determine and account for rehabilitation and decommission costs and periodically review their adequacy during the life of the operation.
4. Establish a program of progressive rehabilitation commensurate with the nature of the operation and the rate of disturbance.
5. Periodically review the rehabilitation and decommissioning strategies over the life of the operation to incorporate changing legislative requirements, public expectations and environmental and cultural heritage information.
6. Address issues and programs related to long-term responsibility for land management in the final decommissioning plan.

3  PLANNING

Planning and commitment are the keys to successful rehabilitation. Good planning prior to the commencement of mining can prevent or significantly reduce the environmental impacts of mining operations. A detailed proposal for the rehabilitation of the site must be contained within the mine plan. There are three main elements that should always be included in the rehabilitation plan, which are:

- rehabilitation objectives;
- a description of the site; and
- a detailed plan of the site.

3.1 Rehabilitation Objective

Mining is a temporary land-use that usually only affects small areas when considered in a regional context. A clear rehabilitation objective, which is consistent with the projected future land-use of the area, must be defined. Different components of a mine such as pits, waste rock dumps, tailings dams etc. may have different post-mining land-uses. These land-uses should take into account the land capability of the rehabilitated areas and the level of management that will be required to maintain the land-uses. Rehabilitation objectives should be established in consultation with relevant government departments, local councils, landowners etc.

The long-term rehabilitation objectives may vary considerably at different sites. In all cases, the first objective will be to protect the safety and health of people living in areas surrounding the site. The rehabilitation program may involve the following:

- Restoration of the area by attempting to replicate the pre-mining conditions. This term generally applies to the restoration of native ecosystems.

- Reclamation of the area so that the pre-mining land-use and ecological values can be re-established in similar conditions. Reclamation can refer to returning a low maintenance native vegetation or re-establishing a land-use such as agriculture or forestry. Establishing a forest or wooded habitat on formerly marginal or degraded farmland could also be considered as reclamation.
• Developing the area so that it is returned to a use substantially different to that which existed prior to mining. This type of rehabilitation aims to achieve new land-forms and land-uses which bring about a greater overall community benefit than would occur if the former land-use was restored. For example mined land could be developed for wetlands, recreational areas, urban development, forestry, industry, agriculture or numerous other uses.

• Converting low conservation value areas in regions with intrinsically low productivity to a safe, stable and non-erodible condition.

Whatever the final rehabilitation objective, rehabilitation plans should be drawn up as early as possible and be an integral part of the mining plan. The person responsible for rehabilitation should be in a position to influence how the mine develops and operates. Rehabilitation should be undertaken progressively during the life of the mine if possible. Progressive rehabilitation may achieve significant efficiencies in equipment use, earth moving costs and topsoil management.

Sufficient personnel and resources must be allocated during mining to enable progressive rehabilitation without impeding production. Funding for final rehabilitation should be considered during mine planning and money budgeted while the mine is operating, as there may be insufficient income at the end of the mine’s life to cover final costs. If the mine has been operating for many years it may be a more efficient use of capital and machinery to integrate rehabilitation with the final years of production.

In South Australia, the Department of Mines & Energy administers the “Extractive Areas Rehabilitation Fund”. The Fund is financed by a levy on production and eligible operations are able to access money for rehabilitation works. In other states, authorities may require a bond or similar financial guarantee to ensure funds are available for final rehabilitation of disturbed areas.

3.2 Description of site

A survey of the site is essential to provide a baseline standard for later rehabilitation. A site survey will normally need to include information on:

• landform;
• geology;
• soil types;
• surface and ground water;
• flora and fauna components;
• land-use;
• cultural and heritage;
• areas or sites that may be of particular significance to Aboriginal or Torres Strait Islanders in accordance with their tradition; and
• other specific conservation values.

The significance of various factors will vary between sites. However, climate conditions (particularly the amount and distribution of rainfall), landform and soil characteristics are invariably of direct significance to site rehabilitation procedures.

Early planning can identify environmental issues that need to be managed. For example: characterisation of overburden and waste is important if selective placement is required. Unless difficult material is identified at an early stage elective placement may be impossible or costly.

Typical environmental issues during and after mining include:

• landform stability;
• soil conservation, erosion, sedimentation and subsidence;
• management of soil salinity;
• surface and groundwater flow and quality;
• control of pollution of surface or groundwater by toxic materials;
• avoiding impaired drainage and consequent water logging;
• conservation of flora and fauna;
• conservation of biodiversity;
• the control of weeds or plant pathogens;
• levels of noise, dust and vibration;
• solid and liquid waste management;
• visual quality; and
• the management of natural, historical and archaeological sites of significance.

Management of larger sites can be simplified by classifying the area into land units, which have different environmental characteristics and sensitivities and must be managed accordingly.

Examples of land units are:
• gibber plains;
• sand dunes;
• frontal dunes;
• drainage lines;
• salt lakes;
• sand plains; and
• alluvial flood plains, etc.

3.3 Site Plan
Many of the potential adverse impacts of mining operations can be avoided or reduced by careful siting of the proposed operation. The physical elements of the site discussed in 3.2 are fixed, as is the location of the ore body itself. Preparation of a site plan, preferably in the form of a number of themes within a Geographic Information System (GIS), or a series of overlays from an air photo or detailed topographic map, enables the clear identification of the important physical elements of the site including environmentally sensitive locations. Positioning of site infrastructure and mining procedures can then be determined to:
• protect access to the ore body and any possible extensions;
• optimise haul distances for ore and overburden;
• avoid impacts on environmentally sensitive locations or land units;
• minimise disturbance beyond the mine excavation and avoid steep cuts and fills or other extensive earthworks;
• minimise the noise and visual impacts (including lights) on adjacent land users;
• develop a site drainage plan; and
• optimise the configuration of the mined areas to accommodate the proposed post-mining land-use.

In areas where the potential for visual and noise impacts is large, provision to reduce impacts and remedial works can be incorporated into the site plan. Some examples of site planning are illustrated in Figure 3.1 below.

A. Location of Access Roads - DIAGRAMS

![Diagram of Location of Access Roads](image)
4 PRINCIPLES OF REHABILITATION

Ensuring decommissioned sites are rehabilitated and left in a safe and stable condition, after taking into account beneficial uses of the site and surrounding land.

Good planning and operations procedures will minimise the adverse impacts of mining operations. Rehabilitation refers to the operations whereby the unavoidable impacts on the environment are repaired. Rehabilitation should be concurrent with mining when possible.

Rehabilitation normally comprises two stages:
- landform design and the reconstruction of a stable land surface, which behaves and evolves in a predictable way; and
- the establishment of sustainable vegetation or the development of a sustainable alternative land-use on the reconstructed landform.

The following is a list of the basic principles of rehabilitation that should always be followed:
- Develop clearly-defined rehabilitation plans prior to the commencement of mining.
- Ensure the site is made safe.
- Always remove and retain topsoil for subsequent rehabilitation, except where it contains an unacceptably high number of seeds of undesirable species. Where possible, retain cleared vegetation for resspreading on disturbed areas.
- If the topsoil must be stockpiled seed the stockpiles with desirable post-mining species to discourage weeds and maintain soil microbial populations.
- Be aware of any statutory requirements and ensure these are met in the plan and the rehabilitation program.
- Where feasible, reinstate natural drainage patterns where they have been altered or impaired.
- Remove or control residual toxic materials. Identify potentially toxic overburden or exposed strata and screen with suitable material to prevent mobilisation of contaminants.

Figure 3.1
• Ensure the re-shaped land is formed so as to be inherently stable, adequately drained and suitable for the desired long-term land-use.

• Minimise any long-term visual impact by creating landforms which are compatible with the adjacent landscape.

• Minimise erosion by wind and water both during and following the process of rehabilitation.

• When mining is complete, remove all facilities and equipment from the site unless approval has been obtained from the regulatory authorities and/or affected landholders to do otherwise. There may be occasions when post mining uses such as tourism or heritage values require consideration.

• Compacted surfaces should be deep ripped to relieve compaction unless subsurface conditions dictate otherwise.

• Provided it is consistent with post mining land-use, re-vegetate the area with plant species that will control erosion, provide vegetative diversity and will, in time, contribute to a stable and compatible ecosystem.

• Prevent the introduction of noxious weeds and pests.

• Monitor and manage rehabilitated areas until they are self-sustaining or an end-point is reached which is satisfactory to the landowner, or the government instrumentality responsible for the land.

5 STANDARD REHABILITATION

The Australian minerals industry includes major open-cut and strip mines, underground long wall and hard rock ore mines, sand and gravel extraction, dredging operations and gemstone mining. Each mine will have particular characteristics that will influence the procedures adopted in the rehabilitation program. These characteristics may be obvious but critical differences are often only identified by careful investigation. The proposed post mining land-use will also influence the procedure and the plant species used for rehabilitation.

This section outlines the basic rehabilitation practices which, with appropriate modification, will apply to most disturbed areas. Section 6 discusses additional rehabilitation procedures for particular categories of problem sites.

5.1 Making Safe

After planning, the first step in rehabilitation is to clean up and make the area to be rehabilitated, safe. This involves the following:

• Removal of infrastructure and unused or unwanted equipment. No facilities or equipment should remain on site unless with the written approval of the land owner or relevant authority.

• Removal of rubbish for disposal at approved sites. Particular care is required with residual toxic or hazardous materials including contaminated packaging and containers (refer 6.6).

• Removal of all services.

• Removal or burial of concrete slabs, footings, etc.

• Backfilling or securely and permanently covering any shafts, pits or similar excavations (refer 6.10).

• Restricting or preventing public access by removal or closure of access roads and tracks.

Be aware of the potential to create safety hazards as a consequence of rehabilitation. In particular, re-vegetation may create a fire hazard. Observe statutory regulations and liaise with local fire control authorities. Prepare a fire management plan for the site.
5.2 Landform Design

The re-shaping and grading of a site is an essential aspect of rehabilitation. Unless slopes are stable, the effectiveness of subsequent topsoiling and re-vegetation is greatly reduced and maintenance may be prolonged. When planning the final landform the whole of the mine and associated infrastructure needs to be considered. The final landform should be hydrologically and, if possible, visually compatible with the surrounding area. The following factors should be considered in the planning stage:

- **Will the final landform be stable?** The erosion potential of the material on the site needs to be assessed. A geo-technical engineer’s report may be required. Important factors are elevation, slope and drainage density. Steep and long slopes allow surface run-off to accelerate, resulting in erosion. Shallow (gentle) slopes are less erosive and vegetation is more easily established. Slope angles, lengths and shapes within the range of natural slopes in the area are more likely to be visually compatible with the surrounding area and are potentially stable under local rainfall patterns and erosion processes. However, it should be recognised that post-mining landforms consist of unconsolidated materials. Individual particles in such materials are generally uncemented which make them more prone to soil erosion than natural occurring soils.

- **The drainage patterns for the overall site must be planned as part of the overall landscaping.** Drainage density (length of natural watercourses / unit area) of adjacent land areas will provide a guide to site requirements. However, the density will often need to be higher on the post mining landform. Changes in land-use and vegetation may also increase the drainage density requirement.

- **Open-cut mines with large volumes of overburden will normally require a drainage density higher than existed prior to mining to compensate for the increase in the gradient of slopes and drainage channels.** As a guide, where runoff is being concentrated into drains or diversion channels individual catchment areas of 1-2 hectares are appropriate.

- **Slopes should be designed so as to reduce the velocity of runoff as the catchment of the slope increases (refer figure 5.1).** Avoid long straight ridges and sharp angles, as these will look unnatural. Slope angles should be less than 20 degrees, except for slopes constructed of non-erosive rock.

---

**Figure 5.1**

- Where site limitations prevent the formation of a stable slope profile, contour benches or similar erosion control methods may be required. Slopes with an overall convex profile should always be avoided.

- Benches are best located in the middle of the slope. Where long slopes cannot be avoided, several benches may be required and their spacing will need to consider slope and run-off characteristics. Benches need to be “surveyed in” to ensure accurate construction. Table 1 provides a guide for spacing of benches along the slope. Benches will need to be spaced closer in areas with high rainfall intensities and/or very erodible soils.

<table>
<thead>
<tr>
<th>Slope (degrees)</th>
<th>Suggested Maximum Spacing between Benches (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>520</td>
</tr>
<tr>
<td>6</td>
<td>220</td>
</tr>
<tr>
<td>7 - 9</td>
<td>100</td>
</tr>
<tr>
<td>9 - 11</td>
<td>80</td>
</tr>
<tr>
<td>11 - 13</td>
<td>50</td>
</tr>
<tr>
<td>13 - 17</td>
<td>30</td>
</tr>
</tbody>
</table>

**Table 1**
• Drainage can be directed to the surrounding area or directed internally to a final void. Low quality water should not normally be directed to a void.

• Final discharge points for water leaving the new landform are dependent on the location of suitable watercourses in the surrounding land. The volume and velocity of the discharged water must be controlled (refer section 5.3.2).

• Ideally, the area of catchment of the watercourse receiving the discharge should not be significantly increased. Where mining results in an increased catchment area for an existing watercourse leading away from the site, additional downstream erosion control structures (e.g. graded banks, rock-lined waterways) may be required or existing structures may need upgrading. Consult the State government department responsible for water resources.

• In flat or low-lying areas control of surface elevation is critical for drainage. Slight changes in elevation can result in very different soil moisture conditions and hence the type of vegetation that can be established.

• Settlement of backfilled areas may require re-shaping some years after the initial landform is constructed. Critical areas are those where backfilled areas and undisturbed areas meet.

As a guide to operating equipment on slopes, consider the following:

- Contour ripping is possible on slopes up to 27 degrees.
- Normal agricultural machinery can be used on slopes up to 19 degrees.
- Large bulldozers can usually only efficiently push fill material up a slope of up to 22 degrees.
- Topsoil will generally not adhere to slopes steeper than 27 degrees. The maximum slope for mechanically spreading topsoil is approximately 19 degrees.
- The maximum slopes considered suitable for the following land-uses are:
  - hill grazing  28 degrees
  - improved pasture  15 degrees
  - some buildings & roads 12 degrees
  - rotation cropping     5 degrees
- Depending on geology, soils and other site-specific variables, gentler slopes may be necessary.

5.3 Erosion Control
Control of erosion is important, both during mining and rehabilitation. The effects of erosion may require remedial works on sites where soil loss has occurred as well as where the material is deposited as drift, dust or river sediment. Inadequate control of erosion can lead to a reduction in water quality downstream. A major objective of most rehabilitation programs is to establish an adequate cover of vegetation so as to stabilise the site and prevent or control erosion to natural levels. Until a vegetation cover has been established, provision to protect against wind and water erosion will be required.

5.3.1 Wind Erosion
The areas most susceptible to wind erosion are coastal dune systems and semi-arid or arid regions; however, much wider areas are potentially at risk. The major impact of wind erosion is to reduce the productivity of the soil and create a dust nuisance. Although wind eroded material can be moved large distances, the majority is usually deposited locally in drifts across roads and against fences and buildings.

A vegetation cover is the best long-term means of protecting against wind erosion. While a vegetation cover is being established, there are three basic methods of controlling wind erosion on disturbed soils. All aim to reduce the wind velocity near the soil surface. They are:

- Protection of the soil surface by natural or manufactured materials or mulch.

In most cases, the use of these materials may form an integral part of the revegetation program, the aim of which is to establish a permanent protective cover. Suitable mulch materials are discussed in section 5.5.1. Selection of the mulch will need to consider the following:

- availability of material, particular attention should be paid to using wastes or by-products which require disposal and which might be available at low cost;
- proposed method seeding or planting which may be integrated with the application of mulch (hydromulching etc);
- future trafficking of the area - rock mulch or similar resistant material may be necessary if total exclusion of traffic is not possible; and
- Effects of mulch colour on soil temperature - dark coloured mulches can significantly raise soil temperatures and light coloured can reduce them.

**Maintenance of the soil surface in an erosion resistant condition.**

This usually means leaving the surface in a coarse (cloddy) condition. This is particularly difficult in sandy soil because aggregation of soil particles is not strong enough to resist abrasion. Keeping the soil surface damp using sprays or water tankers will increase the aggregation of particles and their resistance to wind erosion.

In arid areas with sandy soil, creating a dimpled effect, similar to the surface of a golf ball has been shown to assist natural revegetation. Using trucks rather than scrapers to place topsoil in contiguous mounds creates the dimples. The method is best suited to the tops of waste dumps or on slopes of 12 degrees or less (refer figure 5.2).

- Reduction of wind velocity across the disturbed areas by establishing windbreaks.

Windbreaks may be rows of trees or shrubs retained or planted at right angles to the direction of the erosive winds. Trees or shrubs should be fast growing and hardy but be cautious not to introduce unwanted weeds or exotic species. Artificial windbreaks, in the form of various kinds of fencing, are also available. Selection and placement of windbreaks should consider the following:

  - The direction of critical winds - windbreaks need to be placed at right angles to the direction of wind, but care is required to determine which daily or seasonal winds are initiating soil loss.
  
  - Height and spacing - on level ground protection will extend a distance approximately 20 times the height of the windbreak.
  
  - Permeability - specialty windbreak materials will have a permeability of some 40%. Constructed or vegetative windbreaks should aim at a similar permeability, otherwise turbulence will reduce effectiveness (refer figure 5.3).

- Length and continuity - avoid gaps and ensure windbreaks extend sufficiently to protect the disturbed area, since turbulence and increased wind speeds will occur at the end or at gaps in the windbreak. Where gaps are required, avoid tunneling wind by protecting the gap (refer figure 5.4).
5.3.2 Water Erosion

Erosion by water is caused mostly by raindrop splash and surface runoff from intense rainfall events. Even in arid and semi-arid areas, high intensity low frequency rainfall events can cause rapid runoff and extensive soil erosion. The important factors influencing runoff characteristics are rainfall, area of disturbance, catchment area, slope and profiles of channels (angle, length and cross section etc), soil characteristics and land-use. Properly planned, the rehabilitation of a mine site can, to some extent, manage all of these variables excepting rainfall.

- **Minimising Area of Disturbance.**
  
  Clearing of vegetation should be limited to that absolutely necessary for the safe operation of the mine (including fire management). Minimising the area cleared will reduce costs both for clearing and site rehabilitation. Provisions that will assist in minimising the area cleared include:
  - preparing detailed site and mine development plans (refer 3.3);
  - restricting progressive clearing ahead of the pit to that required for no more than 6 months production;
  - clearly identifying, on the ground, areas designated for clearing;
  - training mobile equipment operators on the need to identify the exact limit of area to be cleared prior to commencement;
  - close supervision of mobile equipment during clearing operations; and
  - including penalty clauses for employees and contractors for damage to areas not designated for clearing.

- **Restricting Entry of Runoff to the Site.**
  
  Construction of diversion channels or holding structures such as banks, drains or dams will effectively limit the entry of water on to the site. This will reduce the potential for soil erosion on the site, but may, by concentrating runoff, create off-site problems at discharge points. When planning diversion structures, consider the following:
  - Are the structures permanent or temporary? All structures will need to be designed to accommodate anticipated peak flows. Consider the consequences of structure failure, from operational, safety and environmental viewpoints. Always seek help when designing permanent or major temporary structures.
  - Information needed to properly design major erosion control structures will include rainfall frequency and duration curves, catchment size and runoff coefficient. Where field data is lacking, statistical approximates can be derived - seek advice.
  - A critical storm return period will need to be nominated as part of design criteria. Design parameters will depend on the purpose of the structure and its anticipated life.
- Where dams are constructed for water storage and/or as a measure to limit entry of water to site, ensure the dam is adequately sized and provision is made for safe discharge.

- Contour or graded banks are suitable for diverting or retaining runoff on moderate to gentle slopes.

- Channels and waterways constructed to divert runoff or accept flows from the site should be designed to avoid erosion within the channel.

- Avoid convex profiles.

- Triangular or trapezoidal channel/drain/waterway cross sections, which can be constructed using a small bulldozer or grader, are preferred. Avoid rectangular or v shaped cross-sections (refer figure 5.5).

A. Line Channels to Protect Against Erosion

![Diagram of Channel Protection](https://example.com/diagram1.png)

Not Recommended

Recommended

**Figure 5.4**

- Diversion channels (slopes and cross-section) must be designed with adequate capacity to ensure that flow velocities will not scour the channel. Contact the state/territory government department responsible for soil conservation for advice.

- Where flow velocities cannot be reduced to a safe level, it will be necessary to protect the channel with erosion resistant lining materials (refer figure 5.6). These techniques can also be applied to discharge from retention dams etc.

- Lining materials should be selected to match the expected life of the diversion bank of channel. Specialist advice regarding lining materials should be obtained from the state/territory government department responsible for soil conservation.

- Care is required to ensure lining materials and structures are positioned so as to avoid undermining or scouring (refer figure 5.6).
C. When using jute mesh

- **Encouraging Infiltration**
  
  This is often, but not always, most effectively achieved by ripping the disturbed area parallel to the contours. In addition to increasing infiltration, ripping relieves soil compaction, “keys” topsoil to subsoil, increases the volume of soil readily available to plant roots and provides places for seeds to lodge. Important considerations when ripping include:
  - always rip precisely along the contour - this will normally require a surveyed line;
  - rip the area following development of the post mining land form;
  - ripping should normally be as deep as possible 0.8 - 1.8m depending on the material, available equipment and subsurface conditions;
  - spacing of rip-lines should be approximately equal to ripping depth;
  - do not rip when soil conditions are too wet to allow the soil to shatter;
  - a “winged” ripping line may be more effective in moist soil conditions;
  - take care when ripping sodic materials, as they are prone to tunnel erosion (piping); and
  - avoid drawing large rocks to the surface whilst ripping.

- **Managing Water Leaving the Site**

  Water, which is discharged from the site, or is diverted away from the site, will generally have been controlled and the flow concentrated. Diversion of established drainage lines or watercourses would normally require specific approval from the State/Territory water authority. Similarly, diversion or discharge of runoff may have legal implications and necessary approval or permits should be obtained. Unless the water can be utilised by the mining operation, it must be managed to avoid pollution due to erosion and sediment deposition, either at the point of discharge or further downstream. As a guide:
  - Sediment dams are most commonly used to control and retain sediment laden runoff prior to discharge.
  - Most sediment will be carried by the infrequent high intensity rainfall events. Dams and spillways must be designed to accommodate these events or they will not function at the most critical times. Seek advice from appropriate authorities or detailed references for design techniques (refer Appendices 1 & 3).
  - Ensure that construction materials are suitable. Leakage from the dam may in itself not be critical but consequent instability of the dam wall due to tunnel erosion (piping) may result in failure.
  - Locate dams so that runoff from undisturbed catchments can be diverted to natural waterways. Ensure that channel gradients are not excessive and the need for protective measures within the channel is minimised.
  - In many dams, sediment levels greater than half of the total dam capacity will significantly reduce sediment removal rated. In these circumstances, sediment should be removed (refer figure 5.7).
  - In saline areas, be aware that the head (pressure) of a dam on a slope may cause salt scalding downslope of the dam.
- Design of spillways, outlet pipes, etc is an integral part of the dam design and function. Clarified water will need to be discharged from the settlement dam in readiness for subsequent storms. Figure 5.8 illustrates some possible options.

A. SELF-SIPHONING PIPE

B. PIPE THROUGH DAM WALL

Figure 5.8

- Discharge of water from small or temporary retention ponds can be controlled using methods illustrated in figure 5.6.

- Always ensure flow rates at the discharge points are reduced to safe levels. Consider the need for installation of some means of dissipating energy e.g. suitable body of water, concrete structure, rocks etc.

- Sediment leaving small and/or temporary areas of disturbance can be controlled by methods illustrated in figure 5.9.

A. RETAIN VEGETATED BUFFER STRIPS

B. HAYBALES ETC FOR TEMPORARY CONTROL (6-12 MONTHS)

Figure 5.9

5.4 Topsoil Management

Although re-vegetation has been achieved on various substrates, topsoil is almost always an essential factor in successful rehabilitation programs, particularly during the period of initial plant growth. Subsoil conditions become of more importance in the longer term. Topsoil (or weathered surface material) provides a good microenvironment for seed germination and generally contains seeds, nutrients and microorganisms that are necessary for plant growth. If these are lost then the system will generally take a longer time to re-establish.
The numbers and diversity of seeds in the topsoil from areas of good quality native vegetation cannot be duplicated economically by collecting and sowing seed. During the planning stages for rehabilitation the following questions should be considered:

- How much topsoil should be saved? In general, the term “topsoil” refers to the “A” horizon of the soil, which is usually darker than the underlying soil, because of an accumulation of organic matter. Whether it is darker than the underlying soil or not, the top 100mm-300mm of soil should be recovered. It may be best to double-strip the topsoil i.e. remove and separately place the top 50mm of soil. This is especially beneficial when the soil contains large numbers of seeds of desirable species. Seed stores are concentrated in the surface layers of soil and removing and replacing a thin layer of soil ensures that the majority of seeds remain near the surface from where they can successfully germinate and establish.

- Is direct replacement of recovered topsoil on an area awaiting rehabilitation possible? Direct replacement of topsoil will give the best results because it prevents or reduces the deterioration of the biological components in the soil during storage. This technique also offers material handling (cost saving) advantages.

- Has the value of the topsoil for rehabilitation been reduced by past land-use, content of weed seeds or exposure to degrading processes such as salinisation?

- The desirable attributes of topsoil deteriorate during storage but if stockpiling the topsoil cannot be avoided then:
  - plan to re-use the topsoil as soon as possible;
  - do not store in large heaps - low mounds no more than 1-2m high are recommended;
  - re-vegetate the stockpile to protect the soil from erosion, discourage weeds and maintain active populations of beneficial soil microbes;
  - locate the stockpiles where they will not be disturbed by future mining; and
  - consider how the topsoil will be re-spread.

- Soils should be stripped at an appropriate moisture content to avoid compaction and loss of structure;

- Is enough topsoil available for rehabilitation? The appropriate depth of topsoil will depend on the site. Approximately 200-300mm of replacement soil is desirable where over-burden material is not toxic to plant growth. If adverse conditions exist, topsoil may need to be increased and other measures to isolate toxic material considered (refer section 6.0).

- Where there are only limited supplies of topsoil then sensible compromises may need to be made by:
  - Identifying priority areas. These are likely to be:
    * those areas most prone to erosion (lower end of slopes, embankments, etc); or
    * locations where the physical and/or chemical characteristics of the overburden are adverse to plant growth (e.g. saline, alkaline or acid spoils etc); or
    * arid areas; or
    * those areas that accumulate water (e.g. contour benches and berms).
  - Topsoiling (and re-vegetating) in strips.
  - “Borrow” topsoil. Stripping adjacent areas not scheduled for mining can, in some cases, be justified (e.g. to sheet toxic material), but it is generally not recommended since rehabilitation of the borrow area must be considered.
  - Import topsoil from other mining sites. This is generally not economical but may be possible in some circumstances. Care is required to ensure weed species are not introduced.
  - Trial plant species and surface treatments for direct re-vegetation of overburden material. Less rapid re-vegetation may be an acceptable trade-off on non-priority areas so as to achieve rapid re-vegetation of critical areas by using all available topsoil.
  - Can the topsoil be augmented with other material? An “underlay” of subsoil with reasonable properties for plant growth will produce better results than a thin layer (0.1m) of topsoil alone. Although not always possible, as a general guide avoid placing subsoil or overburden material near the surface if it:
    * is excessively sandy; or
    * is excessively clayey (especially if mottled in appearance, indicating poor drainage); or
* has dispersive properties; or
* has a pH of below 5.0 or above 8.5; or
* has a chloride >0.12% (1:5 soil:water extract); or
* has an EC (electrical conductivity) >150 milliSiemens/per metre (EC of a 1:5 soil:water suspension). Where species with some salt tolerance are going to be grown then material with an EC of up to 300-400 milliSiemens/per metre may be acceptable.

• Seek assistance and advice on taking soil samples and the selection of a suitable laboratory.
• There are standard procedures for many soil tests and soil conservation or agriculture departments are often able to routinely carry out soil tests. If using a private laboratory always ensure the method of analysis is given. Section 5.5 discusses plant nutrients, appendices 3 & 4 list common soil tests and the effect of pH on nutrient availability.

5.5 Soil Properties for Plant Growth

Maintaining or improving the ability of the soil (or other plant growth media) to supply nutrients, to store and supply water and support root growth should be a major consideration during rehabilitation. Improving water infiltration, relieving compaction and increasing the volume of soil accessible to plant roots are major aims of the deep ripping normally carried out as part of the erosion control measures during rehabilitation of disturbed areas (section 5.3.2). Successful rehabilitation requires a sufficient depth of soil with chemical and physical properties that allow the post-mining species to access the water and nutrients they require for normal growth. One or two metres or more of soil may be needed in some cases, especially for tree species.

The soil factors most likely to affect the success of rehabilitation are:
- compaction or the presence of hard layers that restrict root penetration;
- surface crushing or hard-setting;
- acidity, alkalinity, salinity or sodicity;
- presence of excess Manganese, Aluminum or heavy metals;
- low availability of nutrients (especially nitrogen and phosphorous but can also include other major and minor plant nutrients); and
- water repellence.

It is almost always more effective to select plant species which are suited to local conditions than to undertake major amendments of the plant growth medium characteristics. This may not be possible at difficult sites or tailing areas (refer section 6). An assessment of soil conditions will identify any serious physical or chemical deficiencies and can indicate appropriate remedial actions and fertiliser applications. Appendix 4 lists soil tests that are often important but the soil analysis required will vary from site to site. Sampling should ensure the variation within any one site is assessed. Soils or other plant growth media should always be tested before attempting major amendment or fertiliser treatments. Interpretation of data from tests of the physical and chemical properties of growth media is an expert task and professional guidance should be sought. Soil amendments and fertilisers are discussed below.

5.5.1 Soil Amendments

• Unless the site is small or problematical (refer section 6) widespread use of soil amendments other than gypsum, lime and some mulches are not usually feasible.
• Gypsum is used to condition heavy clay soils and reduce surface crusting on hard-setting soils. The application of gypsum replaces sodium ions with calcium ions, which can improve soil structure, increase water infiltration, improve aeration, reduce crusting and reduce salinity by leaching (refer section 6.4).
• Although gypsum is soluble it requires incorporation into the soil. Where clay material is being treated, deep rip to allow gypsum to penetrate. If surface crusting is being treated, incorporate only into the surface layers.
• Application of gypsum at the rate of 5 tonnes/hectare is normally sufficient to treat surface crusting. Rates of 10 tonnes/hectare or more may be required for clayey material, which is more difficult to treat effectively.
• Lime is used primarily to adjust pH but may also assist in improving soil structure. Adjusting pH can significantly alter the availability of plant nutrients and other elements including heavy metals (refer Appendix 5).
• Lime is mostly applied as ground limestone, dolomite or agricultural lime. Hydrated (slaked) lime is less commonly used. Agricultural or
coarsely crushed limestone and dolomite is slower acting than slaked lime but is likely to have a more sustained effect on pH. Hydrated lime will reduce the effect of nitrogenous fertilisers if applied at the same time. Always apply separately.

- The extent of pH adjustment required and the rate of application will depend on the extent of acidity, the soil type and the source of the limestone. As a guide, application of agricultural lime at the rate of 2.5-3.5 tonnes/hectare will increase pH by approximately 0.5 unit provided the pH is not less than 5.0.

- Mulches are materials applied to the surface to enhance soil conditions for seed germination and initial plant growth. Short-lived cover crops are also used as mulches. The use of mulches to control erosion is discussed in section 5.4.2. Other benefits of mulching include retention of soil moisture, protection of seedlings and modification of surface temperature.

- Application of most mulches is normally limited to locations requiring rapid revegetation, special protection (embankments, etc.) or where significant amelioration of the soil or root medium is required (e.g. tailings dams etc - refer section 6.2).

- Hay and straw are commonly used for mulching broadscale areas but are not available in many parts of Australia. Application rates vary between approximately 2.5 to 5.0 tonnes per hectare. A wide range of other organic materials and agricultural wastes are suitable for mulching; their use is dependent on availability and cost. Materials or wastes successfully used include: stripped vegetation; sawmill and wood-processing wastes (chips and sawdust); sugar mill wastes (bagasse); brushwood, and peanut and macadamia nut shells. Additional nitrogen may be required to compensate for the nitrogen demand created when fresh mulch materials break down.

- Mechanical application of mulching materials can be by conventional agricultural equipment (manure spreaders etc) or by specialised equipment. Specialised mulching equipment can be used to apply mulching material (usually hay or straw) mixed with seed. The material is broadcast either in dry form or as a slurry with water of bitumen or specially formulated soil binding agents.

- Hydromulching or similar techniques have the advantage of applying mulches to relatively large but inaccessible areas, however the necessary equipment is costly and is normally carried only by contractors.

- Cereal crops (cereal, rye, oats, sorghum, millet etc) can be grown to provide an in-situ mulch while permanent vegetation is being established. Care needs to be taken to ensure these crops do not out-compete and restrict the establishment of the desired species.

## 5.5.2 Fertilisers

- Fertiliser requirements will vary widely according to site conditions and intended post mining land-use.

- For agricultural uses, fertiliser application will need to meet the special requirements of the proposed pasture or crop. Precise soil/plant growth medium testing, multiple fertiliser application and subsequent intensive maintenance may be required.

- Although native species are adapted to the low nutrient levels common in Australian soils, improved growth and establishment has been achieved following fertiliser application in a number of areas in Australia where the objective is to restore the native vegetation.

- Species vary in their capacity to respond. Members of the Proteaceae family, particularly Banksia, Grevillea and Hakea are reportedly sensitive to increases in levels of phosphorus and may be adversely affected. Any adverse affects are likely to be seen principally on sandy soils and are less likely to occur on finer soils with a greater capacity to absorb phosphorus.

- Relatively high rates of phosphorus and low rates of nitrogen fertiliser will favour the growth of legumes.

- Organic fertilisers (sewage sludge, manure, blood & bone etc) are generally beneficial but often costly and difficult to apply. Unlike most inorganic fertilisers they are beneficial both as fertilisers and as soil amendments.

- Application rates of inorganic fertilisers should be assessed according to soil analysis. Where vegetation is with native species, relatively low application rates (250-400 kg/hectare) of compound fertilisers have resulted in increased plant vigour.

- Commercial inorganic fertilisers always contain one or more of the macronutrients (i.e. nitrogen, phosphorus and potassium). They may also contain sulfur, calcium, magnesium and micronutrients.

- Common “single element” and “compound” fertilisers are listed in Appendix 6.
• The level of available trace elements (boron, copper, cobalt, iron, manganese, molybdenum, zinc etc) will vary with pH (refer Appendix 5).

• If plant deficiencies or toxicities are suspected, seek advice before attempting to correct the level of trace elements.

• Be aware of the potential for excessive application of fertiliser to cause water pollution problems, particularly in areas with sandy soils.

• Fertilisers, particularly nitrogen fertilisers, may stimulate the growth of weed species. These weeds can jeopardise the success of rehabilitation by out-competing the more desirable species or by becoming a fire hazard.

• Slow release fertilisers in the form of granules or tablets can be placed 100-150mm below or adjacent to individual tree seedlings at the time of planting. Always avoid direct contact between fertiliser and seeding roots (refer figure 5.12).

5.6 Revegetation

Revegetating an area disturbed by mining, after the final landform has been constructed and a suitable growing medium provided, involves a number of steps which are described below. The best time to establish vegetation is determined by the seasonal distribution and reliability of rainfall. All the preparatory works must be completed before the time when seeds are most likely to experience the conditions they need to germinate and establish (i.e. reliable rainfall and suitable temperature) or the optimum time for planting seedlings.

5.6.1 Species Selection

The species selected for establishment will depend on the future land-use of the area, soil conditions and climate. Many minesite rehabilitation programs are directed towards the re-establishment of native species. If the objective is to restore the pre-mining ecosystem, then the species are pre-determined. However, a decision must be made whether to use only local provenances of the native species or to use a wider range of provenances. This decision needs to be made on a site by site basis, often depending primarily on the degree of similarity between the pre- and post-mining environmental conditions.

Where the aim is the re-establishment of a diverse and permanent cover of local species but not restoration of the complete pre-mining flora then the following methods of determining suitable species for the post-mining conditions should be followed:

• Observe plant species growing naturally on any old disturbed areas near the rehabilitation site so that the effective colonising species can be identified.

• Observe the soil and drainage conditions to which the different local species are adapted and match them with the conditions on the mine site.

• Identify plant species that produce sufficient viable seed to harvest economically.

• Consider habitat requirements where return of wildlife to the area is a significant element of post-mining land-use.

• Consider planting local legume species as they are often good colonisers and will improve soil fertility.

Some indigenous species may not thrive in areas where soil conditions are substantially different after mining. If this is the case, and the objective is to re-establish vegetation, which fulfills the function of the original native vegetation, then some species from outside the mining area, may have to be introduced. Care must be taken to avoid introducing a species, which could become an unacceptable fire hazard, invade surrounding areas of native vegetation or become agricultural weeds.

Where agriculture is the planned land-use then the species planted should be those commonly used for pasture or crops known to be successful on soils of similar texture, drainage status, pH and fertility. Suitable legumes should always be considered for their ability to improve soil fertility.

There is a rapidly growing depth of knowledge of the suitability of native species for mine rehabilitation. Seek advice from the local community, Minerals Council/Chamber, Department of Mines or other agencies listed in Appendix 1, who can assist in the process of selecting suitable plant species for a particular location.
5.6.2 Planting

Some options available for re-establishing native vegetation are outlined below. Significant numbers of species can become established from seed stored in the topsoil if appropriate soil handling methods (section 5.4) are used. The planting method or methods selected will depend on size and nature of the site and the species being established.

Cover crops can be considered where a quick cover for erosion control is required. When establishing native plants with a cover crop a compromise must be reached between the density of the cover crop needed to provide rapid erosion control and the tendency of the cover crop to suppress or smother the native species. Dense cover crops may also pose a fire hazard. Hybrids such as sudax can be useful cover crops, as they don’t set viable seed and so won’t persist on the site.

**Direct Seeding**

- Potentially a very economical and reliable method for establishing species which produce sufficient numbers of easily collected, viable seed with high germination and seedling survival rates.
- Advantages include low costs, random distribution of plants and no check on growth rates through planting-out.
- Disadvantages include higher risk of failure through adverse climate conditions, competition from weeds, loss of seed by insect predation and low seed germination and survival rates.
- Failure can result in loss of seed stocks and seasonal opportunity for field work.
- Seed can be broadcast by hand, conventional or modified agricultural equipment, by air and by hydromulching etc.
- Select the seeding method most appropriate for the site - specialised direct seeding equipment is now being manufactured but simple easily manufactured tools can assist e.g. the “Leggate Spear” (refer figure 5.10). In many cases, broadcasting by hand is still the best option. Mechanically sowing native seeds is difficult because of the large range in seed size, which make an even coverage of seed hard to obtain. In addition, many native seeds have awns or other appendages that can create problems for mechanical seeding.
- Broadcast seed can be buried after spreading by harrowing etc. or left on the soil surface. Care must be taken not to bury the seed too deep for successful establishment.

- Seeding rates will depend on species, site conditions, desired density of vegetation and viability of seed; seed should be tested to establish approximate viability percentage.
- Numbers of seeds per unit weight is highly variable (e.g. Eucalyptus species may vary between 3500/2,500,000 seeds/kg).
- Field establishment rates from direct sowing are typically 1-5% for fine seed species and 5-10% for coarse seed species. An estimate of the required sowing rates can be calculated from the number of seeds per unit weight, estimated field establishment rates and the desired density of plants.
- Bulking of fine seed with sand, sawdust, etc will assist in even distribution. Pelleting larger native seed to assist in sowing and reduce wind blow has been successfully achieved.

**Bradysporous Species**

In some Australian ecosystems, many species retain their seeds on the plant in woody capsules that open after fire (Bradysporous species). Where species with bradysporous seeds are an important part of the ecosystem, the vegetation can often be harvested using a forage harvester before clearing and spread on areas being rehabilitated.
**Planting Seedlings**

- A reliable supplier of seedlings or the establishment of an onsite nursery is necessary.

- Advantages include efficient use of available seed, control over species mix and placement and less limitation on the species included in the revegetation program.

- Seedlings of species which produce limited amounts of viable seed may be able to be propagated vegetatively (by tissue culture or cuttings) increasing the numbers of species which can be reestablished after mining.

- Disadvantages include higher costs for planting and/or nursery operation or purchase of seedlings, check in growth rate at planting, need to pre-order or sow several months prior to anticipated use, longer planting time required and seedlings may deteriorate if planting is delayed.

- For sites requiring a large and/or sustained supply of seedlings, establishing and on-site nursery can significantly reduce costs. Specific skills or guidance are required to ensure appropriate nursery procedures that will provide a reliable seedling supply.

- Plant seedlings along rip lines or on graded mounds if location is poorly drained.

- Unless irrigation can be provided, plant seedlings when soil is moist and prior to reliable rainfall, or in cold and wet areas, when water logging is least likely to occur.

- Handle seedlings with care. Where seedlings are not in tubes or similar containers, ensure roots remain moist (see figure 5.11).

- Where seedlings are planted into an existing vegetation cover (cover crop or “weed” invasion etc) clear the area adjacent to the seedling to reduce competition. This is particularly important if fertilisers are applied/

- Planting by hand remains a widely recommended and reliable method (see figure 5.12). Avoid using post-hole diggers, which compact the sides of the hole (particularly in clay materials) and may cause rootbinding. Devices to increase planting rates include auger attachments for tractors etc. Planting sticks are suitable for sites with friable soils (refer figure 5.13). Several tractor mounted or similar mechanical seedling planting devices are now being manufactured in Australia.

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**Figure 5.11**

**Figure 5.12**
Transplanting
- Transplanting of mature trees, shrubs, sub-shrubs and ground-covers is possible for specific sites or amenity planting.
- Advantages include immediate effect and introduction of species not amenable to other means of propagation.
- Disadvantage is high risk of costly failures.
- Transplanting is generally best carried out in cool, wet conditions.
- Where individual mature trees are required for the rehabilitation program, transplanting should be completed while suitable earthmoving and lifting equipment is on site.

Aftercare
- Success rate of all methods of planting will be reduced unless adequate aftercare is provided.
- Staking and protection of individual trees is desirable but seldom practical on a broad scale.
- Perimeter fencing will provide protection from browsing stock, vehicle and pedestrian trafficking. Temporary fences are unlikely to provide adequate protection for the required period.
- Perimeter fencing which incorporates wind break materials will increase success of revegetation programs in most circumstances.
- Avoid irrigating seeded areas unless irrigation can be maintained until reliable rains occur.
- Irrigation of seedlings should be progressively and slowly reduced to prevent over dependence on surface roots.
- Follow-up application of fertilisers, additional seeding or planting may be required.
- Damage and loss by insects and vermin are common, particularly where revegetation programs provide herbage in otherwise sparse environments.
- Seeding and planting should provide for some losses, as application of insecticides and vermin control programs quickly become costly.
5.6.3 Seed Collection and Purchase

A consistent supply of quality seed is essential for the success of revegetation. Before collecting seed, always check with relevant authorities to establish what permits/licenses are required. It is unlikely the mine site will be uniform in terms of aspect, drainage, soil types etc. Seed may need to be collected from several areas in order to match site conditions. There are many difficulties inherent in collecting native seeds. In many years seed set may be poor due to climatic conditions, insect pests, grazing or fire.

Points to consider when collecting seed include:
- Locate collection areas and desired species before seed matures.
- Avoid seed cases or fruit that show any signs of insect attack or fungal infestation.
- Consider establishing a seed orchard of species which are rare, produce limited seed or have seed which is difficult to collect.
- Collect seed only when it is mature. Differential ripening within one species or even a single plant may necessitate several visits.
- Woody seed cases or cones (e.g. Hakeas, Banksias, Casuarinas, Eucalypts etc) are ripe when they have changed colour (normally green to brown) and are hard and woody.
- Fleshy “fruits” (e.g. quandong, Ficus species etc) become softer and change in colour when ripe.
- Winged cases (hop bushes, blue bushes etc) become softer and change in colour when ripe.
- Pods (e.g. Acacia and other legumes) change colour from green to brown, become brittle on the winged portion of the seed-case, often accompanied by changes in colour at maturity.
- Where a plant has seed cases of varying ripeness, the oldest are those furthest from the growing tip. Check to ensure that cones or cases have not opened and seed already discharged.
- Avoid placing seed or seed cases in plastic bags - use cloth or paper bags.
- Collection of some seed can be speeded up by mechanical means, including modified vacuum cleaners and scoops fitted to the bull bars.
- When operating in forest areas seed can often be collected from trees that have been felled for saw milling.
- Where air-drying is sufficient to open seed cases, heat extraction may be required. Oven temperature of 60°C are suitable for Eucalypts, Casuarinas and Hakeas. Banksias required stimulated fire conditions and temperatures of 120°C will cause release of seed.

Appendix 7 lists some commercial suppliers who deal in seed of native species. When purchasing seed:
- Purchase seed from reputable seed merchants. This should avoid problems of wrong identification of species, contamination with weed species and non-viable seed.
- Consider setting up long-term contracts with seed merchants for particular species. With the security of contracts, merchants can concentrate on improving their knowledge of the seed biology, the location of the species, and build up inventories knowing that the seed will be purchased.
- Ask for information as to the area from which the seed was collected and the date.
- Ideally the germination rate of the seed should be provided.
- Seed of agricultural species should be certified by the State Department of Agriculture or Primary Industry.

5.6.4 Seed Pretreatment

Seed of some species requires pre-sowing treatments. Germination of most native legumes and a number of other species is enhanced by heat treatment. These species are commonly immersed in boiling water for 30 seconds to five minutes before sowing.

There is evidence that the germination of some species that normally have low germination rates is enhanced by treatment with smoke from burning plant litter. These species can either be treated directly with smoke or with water that contains the soluble components of smoke. Commercial preparations of “smoke water” are now available but are only useful for seed of smoke-responsive species.

Other seed treatments that may improve the germination of seed of native species include scarification and the use of plant growth regulators such as gibberillic acid.
In arid areas it may be appropriate to only treat 30-50% of the seed so that a bank of ungerminated seed remains if follow-up rains (after the initial germination event) are not forthcoming and there is a high mortality of seedlings.

Agricultural legume seed should be inoculated with the appropriate strain of rhizobium bacterium. This is usually done in conjunction with lime pelleting, which is a simple procedure easily carried out on-site. Rhizobia inoculum and details of the pelleting procedure are readily available from seed merchants.

Rhizobia, which form associations with native legumes, seem to be tolerant of soil disturbance and storage and will often readily infect native species after rehabilitation. However inoculation may be necessary if infection doesn’t readily occur after rehabilitation or when establishing native legumes in overburden, tailings or sub-soil. This will involve isolating native rhizobia, growing them on suitable media and attaching them to the seeds. While this is a relatively simple procedure, specialist guidance will probably be needed.

### 5.6.5 Seed Storage

- Clean seed to remove as much debris as possible before storage, failure to do so may result in fungal infection.
- Label seed clearly including species, date collected, location, etc.
- Store seed in dry insect and vermin proof containers and dust with fungicide and insecticide powder.
- Loss of seed viability during storage is common. Most seed will keep for several years but some species cannot be stored beyond 1 or 2 months. For most species, storage at 1-4 degrees C in airtight containers at less than 10% humidity will maintain seed viability.
- Tropical species may be killed at temperatures below 10°C.
- Dormancy in many Australian plant species is affected by changes in light or temperature conditions and moisture content.

### 5.6.6 Seedbed Preparation

Methods used for the preparation of the seedbed will depend on topography of the site, the proposed landuse, the extent of soil amelioration and fertiliser use, and the sowing or planting technique proposed. The objective in creating a seedbed is to place the seed in a suitable place for germination. Points to consider include:

- Prevent compaction, crusting and subsequent erosion by avoiding disturbance to soils when wet and sticky or dry and powdery.
- Application of most fertiliser can be carried out during tillage of the seedbed. Nitrogenous fertilisers tend to dissipate to the atmosphere and planting should follow immediately after application.
- Timing of seedbed preparation (and sowing) is often critical for successful establishment of vegetation. In most cases preparation and sowing should occur prior to the onset of “reliable” rainfall.
- Where the topsoil contains significant quantities of seed of desirable species, care must be taken not to disturb the soil after these seeds have started to germinate, as this will cause a substantial reduction in plant establishment.
- In southern or alpine areas, soil temperatures also need to be considered. Local agricultural practices may provide a guide to the optimum period.
- A variety of heavy-duty conventional agricultural equipment can be used for seedbed preparation. Disk harrows and chisel ploughs are both able to operate in stony soil conditions.
- Avoid “over preparing” the seedbed. A rough “cloddy” surface reduces runoff and provides better lodgement and protection for seeds and seedlings.
- When hand planting of seeds or seedlings is proposed, site preparation may best be limited to deep ripping or minimal tillage.
There are many rehabilitation situations where specialised procedures are required in addition to the standard rehabilitation techniques described in Section 5. This section describes a number of cases where specialised rehabilitation is likely to be required; however, these procedures should be integrated with the basic techniques described in section 5.

6.1 Waste Dumps

Large volumes of waste rock are a common factor in many open-cut and strip mining operations. The siting and rehabilitation of waste dumps needs to be planned as early as possible. The ideal situation is to be able to return waste material to previously excavated areas, however, this is often impossible and the waste must be placed in a dump. Where out-of-pit dumps are necessary, consider the following:

- The siting of dumps - the shape and location of dumps should be determined as early as possible and included in the mine plans (refer section 3.3). It is easy to underestimate the area required for properly constructed dumps.
- It is not sufficient to just select sites for out-of-pit dumps. An estimate of total volume of waste material to be placed is required and plans need to include slope profile, runoff control and (if necessary) selective handling procedures for difficult material.
- Maximum slope angles may be included in lease conditions. Slope angles will vary according to the material being dumped, the local topography and the rainfall pattern. Slope angles should be typical of those found in the surrounding landscape. As a guide, slope angles of between 5 degrees and 15 degrees (not greater than 20 degrees) are suitable.
- Slope lengths should generally be less than 50 metres.
- Dumps should not be higher than the surrounding hills.
- The tops of waste dumps may be left either convex or concave. Concave surfaces increase water infiltration and reduce runoff. However they are not suitable if the dumps contain materials such as sulfides which could lead to the production of polluting leachates. There may be an increased risk of tunnel erosion if the dump includes sodic materials. Convex surfaces reduce infiltration, thereby decreasing the risk of pollutant production, increasing runoff and consequently the erosion risk.

Figure 6.1

- Waste material can be effectively used to screen mining operations from critical viewpoints; it can also cause major visual impact. Figure 6.1 illustrates a procedure which enables early revegetation of the outside faces of the dump.
• Drainage control structures will be required wherever water concentrates (refer section 5.3.2). Revegetation is likely to be the best long-term method for stabilising the surface of the dump but without some form of temporary erosion control and drainage structures, the dump will be inherently unstable.

• In arid and semi-arid areas a number of techniques have been developed to provide increased protection against erosion, to increase the capture and infiltration of rainfall and to create protected micro-climates. These methods include “dimpling” (refer 5.3.1), “moonscaping”, basin listing (using reciprocating tines) and the use of rock cladding to provide a protective armour.

• “Moonscaping”, illustrated in figure 6.2, provides an alternative way to stabilise steeper slopes and improve conditions for revegetation.

For “moonscaping” to be effective, it is essential that each run of craters and mounds is interlocking to avoid channeling runoff. On long slopes, a contour bank or bench may be required.

• Rock cladding can frequently be obtained from selected “slabby” or “blocky” overburden material 150mm or greater in diameter. The resistance of selected materials to weathering must be confirmed in advance. Rock-cladding is used as a very coarse mulch to provide an erosion resistant surface similar to scree slopes commonly found in arid areas.

• Care is required to ensure material selected for rock cladding does not produce an acid environment after weathering and is suitable colour to blend with the existing environment.

• The coarse irregular surface created by rock cladding provides protected crevices that act as traps for wind-blown dust and seed. Hydroseeding and similar techniques can be used to encourage the more rapid establishment of vegetation (refer section 5.5).

6.2 Tailings Storage areas

Tailings vary greatly in their physical, mineralogical and chemical properties but are usually difficult to stabilise and vegetate.

Tailings storage structures fall into three main categories: dumps, impoundment dams and storage in existing mine pits. Specialised geotechnical and engineering assistance should always be sought when planning the design and siting of tailings areas. Tailing storage areas should be:

• non-polluting while they are operating and after de-commissioning (dust, surface water or groundwater pollution);
• structurally stable (including under earthquake loading);
• resistant to erosion;
• visually compatible with the surrounding landscape; and
• have adequate capacity to cope with the output of tailings.

The siting, design and operation of the storage area will affect how quickly, after de-commissioning, equipment can be used to assist in the rehabilitation process.

In most circumstances, it is important to avoid designing and operating a tailings impoundment as a water storage facility. Tailings should be discharged so as to maximise density within the storage area. By doing so, the storage area will accommodate a greater volume of tailings, the hydraulic pressure on the floor of the storage area will be reduced and rehabilitation will be more readily achieved.
Options for increasing the density of tailings include:

- mechanical thickening and filtering prior to discharge;
- multi-point discharges;
- discharge onto a sloping "beach" within the storage area to allow drainage; and
- collection of liquor by under-drainage, decant structures or filter walls.

Design of the tailings storage area and tailings discharge system to provide for a permanent cover of water may be a viable alternative, particularly in areas of high and reliable rainfall and where tailings have a potential to be acid forming when oxidised. It is essential that the tailings disposal option be designed to the specific site conditions.

Other important considerations in the disposal of tailings include:

- The location of storage areas to prevent or minimise external catchment - this may require a location outside of valley sites or the construction of permanent diversion structures.
- Ensuring geotechnical conditions are suitable or can be amended to prevent undesirable seepage. Always seek professional advice.
- Where seepage of leachate has occurred, measures to recover seepage and/or prevent infiltration and the formation of leachate will be required. Recovery measures will need to continue to operate for as long as seepage occurs.
- Constructing external slopes that will be stable and can be revegetated or clad to resist erosion. Maximum slopes of storage area walls may form part of the lease conditions. As a guide, they should not exceed 3:1.
- Rotate discharge points to avoid areas of very fine tailings that are difficult to traverse and revegetate.
- Where possible, treat tailings prior to discharge to remove or reduce levels of toxicity.
- Examine pre-treatment processes for possible cost savings either by recovery of fugitive materials in the waste or cost effective methods for co-disposal e.g. neutralising acidic streams.
- Provide for the control of runoff from the tailings storage area and external walls to protect them against erosion.

### 6.2.1 Tailings Characterisation

The physical and chemical properties of tailings materials will determine the extent to which vegetation of the tailings is practical and what other options may need to be considered. Characteristics of tailings that inhibit plant growth include:

- high concentration of heavy metals and salts;
- extremes of pH;
- lack of essential plant nutrients;
- lack of microbiological organisms;
- textural and structural characteristics which limit aeration and infiltration;
- high levels of reflective light or heat absorption in light or dark tailings causing physiological stress to vegetation; and
- physical damage by sand blast.

The extent to which these problems exist for any single tailings area will need to be determined. Essential information required includes:

- particle size distribution;
- existing pH and likely changes in pH values over time;
- chemical demand (and likely cost) to achieve pH neutrality;
- level of heavy metals or other plant toxins;
- changes in toxicity levels likely with pH adjustment;
- in-situ water infiltration characteristics; and
- changes in physical and chemical properties with depth (at least in likely root zone).

### 6.2.2 Treatment Options

#### Permanent Water Cover

Where tailings have high sulfide levels and have potential to be acid-forming or are slow to settle, the tailings disposal system may be designed to provide for a permanent water cover. This approach prevents the oxidation of the tailings and eliminates the need for consolidation. It is essential that the disposal system be designed to ensure that there is a permanent water cover but, at the same time, avoiding seepage, overtopping etc. This technique has limited application in Australia because of the generally high evaporation rates.
Where tailings are exposed, several options exist to stabilise the exposed surfaces. These include:

- **Cladding.**
  - Rock cladding or similar protective permanent armour to protect against wind erosion on sites where plant growth and amelioration of tailings is impractical. Rock cladding may, in some circumstances, assist in the establishment of some vegetation.

- **Capping.**
  - Isolating tailings by capping prior to revegetation, in order to prevent the generation of toxic leachate that cannot be effectively contained or recovered.
  - Inhibiting infiltration so that leachate is not generated. This may require reshaping the storage area to provide controlled drainage away from the surface in the first instance. The tailings can then be capped with a layer of compacted clay or similar impermeable substance, over which a layer of free draining material is placed. Topsoil is then used to re-surface the area prior to revegetation (refer figure 6.3).

- **Amelioration & Vegetation.**
  - A self-sustaining vegetation cover is generally the most satisfactory method for long-term stabilisation.

- Because of the inherent characteristics of most tailings, they will require some change to their physical and/or chemical properties in order to support satisfactory plant growth.

- Methods used to assist plant growth include:
  a) **Incorporation of Organic Materials and Mulches**
     e.g. sewage sludge, organic mulches, fly-ash etc
     * Texture and structural characteristics are improved, aeration and moisture infiltration and retention are increased.
     * Micro-organisms are introduced to the growth medium.
     * Organic materials tend to react with heavy metal ions and can reduce toxicity.
     * Woodchips, bark and similar materials when used fresh may absorb available nitrogen and release phenols adversely affecting plant growth. Where possible, stockpile prior to use.
     * Fly-ash and similar material have been effectively used to amend tailings material, but check levels of potential leachate contaminants prior to use.
  b) **Correction of pH**
     * Acidic conditions are common; the oxidation of pyrite is most frequently the source of acidity.
     * Plant growth is very limited at pH 4.5 or less. Correction of pH to 4.5 or above will substantially alter the availability of existing or introduced plant nutrients (refer appendix 5).
     * Various forms of lime are the most effective method of pH correction. Lime demand may be excessive (in some cases 30 tonnes calcium carbonate equivalent (cce)/hectare). Correction is generally impractical when required dosage rates exceed about 15 tonnes cce/hectare.
     * The acid-base status of the tailings material will determine the lime demand, however, the following application rates can be used as a guide for treating weak or moderately acid tailings (or spoils etc):

<table>
<thead>
<tr>
<th>pH</th>
<th>Application Rate (tonnes/hectare calcium carbonate equivalent)</th>
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<tr>
<td>6.0 - 5.5</td>
<td>2 - 5</td>
</tr>
<tr>
<td>5.4 - 4.6</td>
<td>6 - 9</td>
</tr>
<tr>
<td>4.5 - 4.0</td>
<td>10 - 13</td>
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* Hydrated lime (slaked lime) is quicker acting and has 50% to 100% greater neutralising capacity than agricultural lime and some crushed limestones.
* Smelter slag is a slow acting pH neutralising material which if readily available can be used to bulk quantities for pH correction.
* Raising pH to above 4.5 may reduce the activity of acid producing thiobacilli and help reduce the production of leachate.
* The pH of very alkaline tailings can be reduced by amendment with soluble calcium salts (calcium chloride or gypsum) or by acids or acid forming amendments (sulfur, sulfuric acid or iron sulfate). Alkaline tailings should be treated in the same way as naturally occurring alkaline soils (section 6.4).

c) Irrigation
* Leaching of salts, metal toxins and acidic material can be achieved by irrigation prior to, and in some cases after, establishing a vegetative cover. An adequate supply of water of suitable quality is required.
* Where water is limited, drip irrigation has a similar leaching effect, but only in the immediate root zone.
* In acid tailings, pH neutral or alkaline conditions at depth can neutralise the acid leachate and capture heavy metals.

d) Application of Fertilisers
* Fertiliser treatments should not be considered unless the physical conditions and levels of plant toxins including salinity are such that plant growth can occur.
* Assessment of fertiliser treatments should be made after pH correction.
* Macro plant nutrients (i.e. nitrogen, phosphorous and potassium etc) are likely to be low and large fertiliser applications may be required. The availability of micronutrients will be heavily dependent on the chemistry of the tailings (refer Appendix 5).

e) Capillary Intervention
* Transportation of salts and toxins to the surface of the tailings storage area by capillary rise, and their concentration in the surface soil by evaporation, can occur in many parts of Australia. This may prevent the establishment of a sustainable vegetation cover.

* A layer of crushed waste rock over the tailings prior to the placement of topsoil can reduce or eliminate this effect. Crush rock to minus 10-20mm diameter and make the capillary intervention layer at least 300mm thick.

f) Surface Manipulation
* In arid areas, the surface of a tailings storage area may crust in a similar way to salt pans. Ridge ploughing or the creation of pond areas causes removal of salts from the root zone (section 6.4.2).

g) Protection from Sand-blast
* Physical damage to vegetation by sand-blast can be a major limiting factor for vegetation establishment.
* Irrigation, rock cladding etc may reduce or prevent sandblast, but where direct revegetation of tailings material is being attempted, wind-breaks may be required. (section 5.3.1).

h) Use of Topsoil
* Covering tailings with a layer of topsoil is often the most effective method of establishing a vegetation cover. This is most effective after a layer of material has been used to limit capillary rise (see (e) above).
* Even a thin layer of topsoil can introduce essential micro-flora into the growing medium.

6.3 Acid Drainage
Acid drainage (formerly referred to as AMD or ARD) is the term used to describe leachate that has become acid due to the oxidation of sulfur minerals exposed to air and water. Acid drainage may be recognised by orange/yellow ferric hydroxide precipitate in streambeds and/or a sulfurous smell, but this does not always occur. Acid soils may be an indication of a potential acid drainage problem.

The most effective and economical method of controlling acid drainage is to prevent its formation. Once established, acid drainage is often difficult and costly to treat. Because most metal ions are increasingly soluble with decreasing pH, acid drainage frequently results in a heavy metals problem. Management by prevention requires characterisation of overburden or waste material and knowledge of the hydrology of the site so that the likely occurrence of acid drainage can be predicted and potentially acid-producing material selectively handled and isolated.
Where the potential for acid drainage exists, provision in the planning stage to prevent acid drainage is essential.

6.3.1 Prediction

- Factors affecting the formation of acid drainage include: host rock and ore mineralogy, topography, climate, rainfall regime, the nature of the groundwater, mining method, surface area of waste exposed and extent of biological activity.
- The identification, quantification and sampling of major rock types and geological environments on the site is essential for accurate prediction.
- Characterisation of overburden is required to identify both potentially acid producing materials and non-acid or calcareous materials (an “acid-base analysis”).
- Calculation of the acid-base status requires determination of total sulfur (or pyritic sulfur) and material with neutralising potential. Leaching tests in humidity cells or columns are also required to simulate oxidation and bacterial activity etc since acid-base accounting assumes all measured sulfur is acid forming and all calcareous materials are available to react.
- Where significant potential for acid drainage exists, professional assistance should be sought.

6.3.2 Prevention

Oxygen and water are necessary to initiate acid formation and prevention methods aim to exclude either reactant from the pyritic material. This involves controlled placement of acid forming materials and appropriate water management strategies.

Prevention is dependent on identifying the pyritic material before mining in order to:
- Adopt mining procedures that are able to selectively handle acid-forming materials for placement within the waste dump. If calcareous strata or other alkaline material, which can neutralise and acidity generated, are available mining methods and dump construction should enable blending of material within the dump.
- Control the hydrology of the site to prevent water from contacting pyritic material by diverting surface water away from pyritic material and preventing ponding and subsequent infiltration.
- Isolate the pyritic material from water by placing it above the water table and capping with clay or other impermeable materials. The cap can then be covered with soil and vegetation established (see section 6.2.20). This technique reduces infiltration and leaching. In practice it is very difficult to completely isolate pyritic spoils from water contact. Unlike tailings storage areas, waste dumps are unlikely to have an impermeable or semi-impermeable base or sides. The task of reshaping and encapsulation is consequently greater and more costly.
- Submerge the acid-forming material; this can be an effective strategy where sufficient water is available (see section 6.2.2). It has been suggested that a water cover sufficient to maintain the partial pressure of oxygen below 1% is necessary to inhibit pyrite oxidation.

6.3.3 Treatment

Treatment procedures for dealing with acid leachates will vary according to site conditions. Treatment methods previously adopted or under trial include the following:
- Incorporation of lime (or other neutralising materials) into the surface of waste dumps. Neutralising capacity of the available material and the “lime demand” of the dump should be tested to determine feasibility (refer 5.5.1 and 6.2.2).
- Channeling run-off from the dump to selected recharge areas i.e. ditches filled with alkaline material or areas of the dump where selected material with high neutralising capacity has been placed.
- Injection of neutralising fluids e.g. sodium carbonate, anhydrous ammonia or caustic soda into mine dumps to intercept flow paths of acid drainage.
- Collection of acid drainage downstream for chemical treatment or in-line aeration.
- Directing acid drainage to artificial wetlands where biological production of bicarbonate neutralises the acidic drainage. Metals are removed through hydrolysis and biological formation of insoluble sulfides and carbonates.
- In areas where evaporation consistently exceeds precipitation, disposal by evaporation may be feasible. Safe disposal of sludge with elevated levels of heavy metals and salts is then required.
- Controlling the bacteria Thiobacillus ferrooxidans in situations where it plays a significant role in accelerating acid formation.
6.4 Alkaline and Saline Soils

Alkalinity and salinity commonly occur together in Australian soils. Highly saline strata are often encountered at mining sites. As a general rule, overburden closest to the surface will be less saline. It should be selectively handled and used to sheet dumps prior to topsoiling. Where local soils are saline or salt pans and scalds are common, upper levels of overburden may also be saline. Highly saline material should be treated in a similar way to acid forming overburden, to avoid adverse effects on plant growth and downstream water quality.

6.4.1 Determining Alkalinity and Salinity of Soils

- As a guide, soils can be considered moderately saline when they have an EC (1:5 soil:water suspension) of 100-300 mS/m and chloride levels exceeding 0.15% and highly saline when the EC is greater than 300 mS/m and chloride levels exceed 0.45%.
- Soils can be considered alkaline when they exceed pH 8.0 and strongly alkaline at pH 9.5 or above.
- Sodic soils are soils where sodium ions constitute a significant proportion of the exchangeable cations in a soil. Sodic soils often have poor structure and may become strongly alkaline. Soils are classified as sodic when they have an exchangeable sodium percentage (ESP) of 6 and strongly sodic at ESP 15.
- Soils affected by salinity and sodicity commonly occur in arid and semi-arid areas but have been extended by agricultural practice, particularly irrigation.
- These soils may be recognised by salt crusting, sparse and salt-tolerant vegetation or “scalds” of bare and cracking earth with highly dispersive soils.

6.4.2 Treatment

- Saline soils that are not strongly alkaline can, in theory, be reclaimed by leaching the salts from the rooting zone.
- Sodic soils can be reclaimed by exchanging some of the exchangeable sodium with calcium. Gypsum is the most effective ameliorant for sodic soils. Application rates for mildly affected soils are 2.5-5.0 tonnes/hectare. Application rates of 20 tonnes/hectare may be required in severe conditions.
- Prolonged irrigation will leach out sodium and other deleterious salts from saline and sodic soils but is only practical when the soil remains permeable, the water table is well below the root zone and an adequate supply of suitable water is available.
- Forming water impoundments 300-400mm high to induce infiltration and leaching of salts is widely used in agriculture. Several seasons are required to achieve sufficient leaching in arid areas.
- Ridge-ploughing to form ridges 200-300mm high spaced at 1-2 metres apart enables a more rapidly leached root zone to be formed for direct seeding and planting.

6.5 Heavy Metals and Toxic Mines Waste

- Heavy metals occurring naturally on the site may be mobilised and cause a potential health or environmental problem in overburden, soils and water. Acid conditions and acid drainage indicate a possible heavy metals problem.
- Arsenic, cadmium, mercury, lead, nickel, manganese and molybdenum are cations that are potentially harmful to human life because they bio-accumulate and/or require relatively small dosage to affect health.
- Elevated levels of radioactivity may be associated with some mine wastes. Identification and appropriate disposal of these wastes is essential to avoid impact through: - direct exposure, offsite contamination, or animals browsing on vegetation that has accumulated radioactive elements.
- Copper is the principal concern for aquatic systems; however, other heavy metals may accumulate in sediments.
- Aluminum, manganese, copper, zinc and lead may become available in acid soils and be toxic to plant growth.
- Sub-grade ore, waste rock etc, which has the potential to generate acidity and mobilise metals, should be selectively placed within waste dumps (refer section 6.3).
- Neutralise the upper 200mm of waste material with lime or similar material (refer 6.3) to provide a buffer against possible mobilisation by acid drainage.
6.6 Toxic Chemicals

- A wide range of chemicals may have been used for mineral processing or ancillary activities on-site. An inventory of all the chemical substances used on-site and their relevant Material Safety Data Sheets should be kept on-site. A method for safe disposal of residue materials and their containers should be determined.

- Acid and caustic solutions are commonly used for mineral processing, other potentially hazardous materials include resins, paints, flocculants, reagents etc.

- If any doubt exists on how to dispose of materials safely, contact relevant authorities (refer appendix 1).

- Cyanide is used in large quantities at most gold mines. It is very reactive and highly toxic.

- Cyanide is essentially unstable and oxidizes rapidly to more stable products, which are generally non-toxic; however, some cyanide complexes may be toxic to aquatic life. Both “free” and “total” cyanide levels should be considered prior to discharge.

- Residual cyanide and other hazardous materials should be returned to suppliers or disposed of at an approved site.

- Never bury cyanide tablets or powder - they may remain a potential hazard for many years if soil conditions remain dry and alkaline.

- Ensure containers used to hold hazardous materials are detoxified prior to disposal.

- Check discarded equipment especially electrical transformers for PCB contaminated oil. Refer to the ANZECC PCB Management Plan and the appropriate state government department for details of PCB regulations.

6.7 Noxious Weeds

- Controlling the introduction and spread of weeds is an important consideration in rehabilitation. Weed infestations on rehabilitated areas can be very difficult to control and the emphasis should be on prevention rather than cure.

- Weeds are often vigorous, persistent and good colonisers. Consequently, they may rapidly invade sites being rehabilitated.

- Each State and Territory has legislation relating to weed control and lists of declared weeds – a list of declared weeds should be obtained from the relevant State/Territory department (An indicative list of species declared in some, not all, States is at Appendix 8). The legislation enables governments to compel landholders and occupiers to control certain weeds and to prevent their movement and spread. Failure to control or eliminate these weeds is an offence under the relevant State/Territory act. Most of the declared weeds are agricultural weeds. Many other species, including grasses and legumes used in agriculture, can be considered environmental weeds.

- Weeds in areas adjacent to those disturbed by mining should be controlled to reduce the potential seed load. Be sure the mine site does not become a source of weeds for possible infestation of adjacent properties.

- Care must be taken to ensure that weeds are not introduced to the area in topsoil, hay, mulch or manure or as contaminants in seed of the desirable species. There are many examples of plant species that have become weeds after being knowingly or unwittingly introduced into Australia and this possibility should always be considered when introducing exotic species in a rehabilitation program.

- Clean equipment coming on to site from other areas to remove seed or plant pathogens.

- Fertilisers and manures should always be used carefully as they can stimulate weed growth, seed set and spread. A vigorous cover of the desirable plant species is often an effective impediment to invasion by weed species.

- Early detection of weeds before they are well established can simplify their control.

- Cultivation, hand weeding, burning and herbicides can all be used in attempts to control weed infestations. However, control can be difficult where desirable plants are growing amongst the weeds. Hand weeding is expensive, but can be effective for smaller areas.

- Selective grass herbicides can be used for grass weeds in areas revegetated with non-grass species. Herbicides can be applied selectively using wick applicators in some cases, for example, when the weeds are much taller than the desirable species.
6.8 Roads and Tracks
Planning, design and construction of roads and tracks is important to their subsequent rehabilitation.

6.8.1 Planning
- Roads and tracks should be incorporated into the site plan (refer to section 3.3). Those required after the completion of mining should be identified.
- Plan for safe operations, but avoid unnecessary parallel tracks, turning circles, bypass points etc.
- In arid areas, or areas where vegetation is sparse, plan to deviate the road or track to avoid vegetation or landscape features which assist in reducing the line of sight impact.
- Where possible, plan roads and tracks to conform with the topography in order to minimise earthworks. Roads and tracks that avoid water courses, steep side slopes and permanently wet or boggy areas etc will require less earthworks and be more readily rehabilitated (refer 6.4).

6.8.2 Design and Construction
- Avoid “over-designing” tracks; consider the likely extent of their use and the type of traffic.
- For temporary tracks, avoid using large equipment and, wherever possible, leave topsoil and rootstock undisturbed.
- In timbered areas, remove and salvage usable timber or allow others to do so.
- Balance cut and fill if possible.
- Retain topsoil, stockpile or use for revegetating batters etc.
- Formed roads and tracks readily concentrate runoff - design and construction must allow for frequent and safe discharge from the road/track alignment. Provision of properly designed structures is necessary to dissipate or control runoff and prevent soil erosion (refer to 5.3.2).
- In flat areas (including arid areas), where transfer of overland flow across the road/track alignment is important, provide for passage of runoff onto and from roads and tracks (refer to figure 6.5).

Figure 6.5

• On slopes, divert up-slope drainage and control discharge. Dissipate drainage from the surface of the track or road by outsloping the camber, or provide side drains or table drains with protection at discharge points (refer figure 6.6).

Figure 6.6
• Where batters or culverts are required, protect slopes and discharge points.

6.8.3 Rehabilitation

• Consult landholders to determine whether they require the retention of roads and tracks for future access.

• Install gates or barriers to prevent unlawful access.

• Properly designed roads and tracks will remain stable. Re-spreading topsoil and ripping will relieve compaction prior to seeding. It will also discourage unauthorised access and facilitate revegetation (see figure 6.7.)

• Remove temporary culverts, spoon drains etc and re-instate natural flow lines.

• Where construction of cut or fill batters has resulted in unstable slopes, return fill material from the road or track formation to create a stable slope prior to attempting revegetation.

• Program closure and rehabilitation work so that access for rehabilitation equipment (hydroseeders etc) is maintained to those specific locations requiring treatment.

6.9 Power Lines and Telecommunication Installations

• During installation, minimise excavation and clearing of vegetation. Only limited access is required and leaving rootstock undisturbed will promote rapid revegetation of the access way.

• Consider helicopters for installation and access for maintenance and removal at isolated or difficult sites.

• Remove cables and guys etc when towers are dismantled. Bury or remove concrete slabs and footings.

• Prevent access and rehabilitate access ways after de-commissioning.

6.10 Final Voids

When open cut mining techniques are employed it is common for an open pit to remain at the end of mining. The extent of this final void may be minimised in some cases by progressive direct emplacement of overburden in the mined out sections of the pit. It is essential that final voids be left in a safe condition where backfilling is not reasonably feasible. The location and nature of the pit mainly determine available options for post mining land-use.

Void options include:

• Water Storage Area.

  Depending on the intended use of the stored water, the quality of water in the pit (both on entry and after storage) will be a determining factor. Sufficient catchment area should be provided to fill the pit within a reasonable time and flush the pit storage periodically to prevent the stored water becoming saline.

• Wetland/Wildlife Habitat.

  Depth will be a critical factor. Deep, steep sided voids are generally not suited. Consideration of the natural movement in the level of ground water and the consequent effect on any remodeled landscapes and habitats requires careful investigation.

• Waste Disposal.

  The void must be located sufficiently close to the source of waste for this option to be economical. The type and amount of waste available is important. Wastes which may be suitable include domestic waste, industrial wastes, tailings, coal wash rejects and flyash. Investigation of the ground water regime and the risk of contamination by leachate from the disposed material will also require investigation.
6.11 Abandoned Adits and Shafts

As with final voids, shafts and adits must be left in a safe condition and will need to comply with the mine safety regulations. Potential problems and hazards include subsidence, illegal access, fires, gas emissions, pollution of surface or groundwater and a tendency to become illegal rubbish dumps.

- Before closing off a shaft or adit, consideration should be given to the possible need for future underground access, particularly when no other workings exist in the area.
- Whenever possible, obtain information on the extent and design of the workings and the geological conditions. Where there is a high possibility of mine gas, seismic activity etc, ensure all structures intended to seal the shaft are adequately designed. Seek advice.
- Check quality of mine water, it may be a useful water supply or a potential pollution hazard.
- Remove all disused equipment and identify any waste ore or a potential pollution hazard.
- Dispose of toxic wastes safely (not as fill in abandoned shafts) and rehabilitate the area in accordance with relevant sections of these guidelines.

6.11.1 Sealing and Closing

Selection of closure and sealing method will depend on site conditions. Possible options include:

- **Enclosure with safety fence or wall etc.**
  - encompass sufficient area to allow for subsidence;
  - extend fence along line of adit excavation until rock cover is sufficient to ensure protection;
  - maintain enclosure while the adit or shaft remains unsafe; and
  - do not rely on enclosure alone; cover the entrance to the shaft or adit.

- **Surface covers and caps.**
  - covers will help prevent accidental access, illegal dumping etc when used in conjunction with enclosures but will not protect against subsidence or support heavy loads;
  - use concrete, steel plates etc to raise cover above the ground level to avoid accidental loading;
  - make sure covers are sufficiently large to prevent burrowing around the side by vandals etc;
  - concrete caps (for shafts) should be made of reinforced concrete supported around the periphery of the shaft by solid bedrock; and
  - shaft caps should be sufficiently thick to prevent subsidence and support normal loads, including suction or pressure from collapsing fill or mine gas.

- **Shaft plugs constructed at depth in order to retain access to the upper levels.**
  - Plugs should be watertight and designed to accommodate permeability, elasticity and compressive forces adjoining strata or accumulated water. Seek specialised assistance.

- **Backfilling with selected material.**
  - do not use abandoned shafts as disposal sites for rubbish, chemical residues etc;
  - where mine gas is present, avoid tipping quartzite, concrete rubble with metal reinforcing or other material liable to cause sparking;
  - the base of shafts should be stabilised with clean, hard, free draining rock fill to a depth at least five times the diameter of the shaft; and
  - general fill suitable for filling a shaft (other than at critical points) should be stable and able to fill voids and support the shaft linings e.g. broken stone, brick and concrete rubble etc.
It is essential that monitoring be carried out to verify the success or otherwise of the rehabilitation program. Reworking may be necessary in areas where rehabilitation is not performing adequately. Sufficient funds must be allowed for monitoring, maintenance and reworking.

In Australia, there are no recognised criteria for determining when rehabilitation is complete. Handing back responsibility for the management of rehabilitated land to the relevant landowner or government, instrumentally will often be when an end point satisfactory to all parties has been reached.

The parameters that may need to be monitored after rehabilitation include the following:

- the continued safety of the site;
- the establishment and growth of plants including the return of non-sown desirable species and weeds, percentage of ground cover and species composition;
- the return of native fauna including insects, birds, amphibians, reptiles and mammals;
- soil fertility, pH and salinity;
- evidence of erosion or land degradation;
- surface and groundwater quality; and
- condition of adjoining lands.

Maintenance that may be required in addition to rehabilitating any failed areas includes:

- watering planted seedlings;
- fencing to stop excessive grazing of rehabilitated areas;
- fertilisation;
- pest and weed control; and
- liming to control pH or heavy metals.

Rehabilitated ecosystems must be sustainable in the long-term. Rehabilitation can be considered successful when the site can be managed for its designated land-use without any greater management inputs than for other land in the area being used for a similar purpose. Restored native ecosystems may be different in structure to the surrounding native ecosystems, but the land managers should be confident that they will change with time along with or towards the make up of the surrounding area. The rehabilitated land should be capable of withstanding normal disturbances such as fire or flood.

While the criteria for assessing whether an ecosystem developing on a rehabilitated site is sustainable in the long-term have not been fully developed, the issue continues to be a key subject of industry research. A large number of ‘vital ecosystem attributes’ that may serve as indicators of ecosystem structure and function have been suggested. Components of the success criteria could include:

- physical (stability, resistance to erosion, re-establishment of drainage);
- biological (species richness, plant density, canopy cover, seed production, fauna return, weed control, biomass productivity, establishment of nutrient cycles);
- water quality standards for drainage water; and
- public safety issues.

Ecosystem Function Analysis (EFA), a methodology developed by researchers from the CSIRO to provide indicators of rehabilitation progress, has been tested on a number of different types of mine around Australia. EFA may be used widely in the future.
## 8.1 Appendix 1 – Statutory Requirements & Advisory Government Agencies

### 8.1.1 Statutory Requirements

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<td>Department of Mineral Resources</td>
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<td>National Parks and Wildlife Service</td>
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| **Tasmania** | |
| Mineral Resources Development Act 1995 | Department of Resources & Energy |
| Environmental Management and Pollution Control Act 1994 | Department of Environment & Land Management |
| Land Use Planning and Approvals Act 1993 | Department of Environment & Land Management |

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<td><strong>Victoria</strong></td>
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</tr>
<tr>
<td>Mineral Resources Development Act 1990</td>
<td>Department of Natural Resources and Environment</td>
</tr>
<tr>
<td>Planning and Environment Act 1988</td>
<td>Department of Infrastructure Development</td>
</tr>
<tr>
<td>Environmental Effects Act 1978</td>
<td>Department of Infrastructure Development</td>
</tr>
<tr>
<td>Environment Protection Act 1970</td>
<td>Environment Protection Authority</td>
</tr>
</tbody>
</table>

| **Queensland** | |
| Mineral Resources Act 1989 | Department of Mines & Energy |
| Environmental Protection Act 1994 | Department of Environment & Heritage |
| Water Resources Act 1989 | Department of Natural Resources |

| **South Australia** | |
| Mining Act 1971 | Department of Primary Industries, Natural Resources and Regional Development |
| Mines and Works Inspection Act 1920 | Department of Primary Industries, Natural Resources and Regional Development |
| Development Act 1993 | Department of Transport and Urban Planning |
| Clean Air Act 1984 | Department of Environment, Heritage and Aboriginal Affairs |
| Water Resources Act 1997 | Department of Environment, Heritage and Aboriginal Affairs |
| Environmental Protection Act 1993 | Department of Environment, Heritage and Aboriginal Affairs |
| Local government Act 1934 | Local councils |

| **Western Australia** | |
| Mining Act 1978 | Department of Minerals and Energy |
| Environmental Protection Act 1986 | Department of Environmental Protection/Environmental Protection Authority |
ACT
Conservation and Land Management Act 1984
Wildlife Conservation Act 1950
Rights in Water and Irrigation Act 1945
Waterways Conservation Act 1976
Waterways Conservation Regulations 1981
Soil and Land Conservation Act 1945
Various State Agreement Acts
Aboriginal Heritage Act

Northern Territory
Mining Act
Uranium Mining (Environment Control) Act
Mine Management Act
Environmental Assessment Act
Water Act
Environmental Penalties & Offences Act
Waste Management and pollution Control Act
Heritage Conservation Act
Pastoral Land Act
Noxious Weeds Act
Soils Conservation & Land Utilisation Act
Bushfires Act
Territory Parks and Wildlife Conservation Act

ADMINISTERING BODY
Department of Conservation and Land Management
Water and Rivers Commission
State Mining Engineer/Commissioner of Soil and Land Conservation
Department of Resources Development
Aboriginal Affairs Department
Department of Mines and Energy
Department of Mines and Energy
Department of Mines and Energy
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Department of Lands Planning & Environment
Environment Protection Authority

Commonwealth
Environmental Protection (Impact of Proposals) Act 1974*
Australian Heritage Commission Act 1974
Endangered Species Protection Act 1993*
Corporations Law Amendment Bill (Sec 299(1)(f))
* Currently being reviewed

8.1.2 Advisory Government Agencies
The Department of Mines or equivalent body in each State has primary statutory responsibility for all aspects of mining including environmental protection and pollution control. However, in NSW, the Department of Mineral Resources has primary responsibilities only in relation to mining methods, safety and rehabilitation (including derelict mines). All other aspects are the primary responsibility of other agencies, such as pollution control by EPA.

Relevant expertise has been developed to administer and advise on environmental issues in accordance with statutory requirements. There are, however, other government agencies whose principal functions are related to agricultural, environmental protection and management of natural resources etc. Specific expertise held by these agencies may be of assistance in the rehabilitation of disturbed land. Liaison should be in accordance with the administrative procedures adopted by each State. State Minerals Councils/Chambers may be of assistance both with technical data and additional sources of information. Agencies in each state that may have relevant expertise include those listed below:

DEPARTMENT
New South Wales
Department of Land and Water Conservation
Environment Protection Authority

AREAS OF EXPERTISE
soil conservation techniques
soil and water sampling and analysis
contract rehabilitation
plant species selection and establishment
water allocation and licensing.
toxic/hazardous chemicals control
air, noise and water pollution control
and licensing
waste management
contaminated land
<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>AREAS OF EXPERTISE</th>
<th>DEPARTMENT</th>
<th>AREAS OF EXPERTISE</th>
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<tbody>
<tr>
<td>State Forests of NSW</td>
<td>tree species selection, establishment and supply, seed technology</td>
<td>Department of Natural Resources and Environment</td>
<td>fire management</td>
</tr>
<tr>
<td>Department of Urban Affairs and Planning</td>
<td>State/regional planning and amenity project assessments for major developments European Heritage</td>
<td>and Environment continued</td>
<td>fertiliser and soil amendments forests</td>
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<tr>
<td>NSW Agriculture</td>
<td>noxious weeds and their control fertiliser and soil amendments</td>
<td>Department of Infrastructure</td>
<td>pasture and land management</td>
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<tr>
<td>National Parks and Wildlife Service</td>
<td>protected flora and fauna archaeological assessment and management Aboriginal heritage</td>
<td>Environmental Protection Authority</td>
<td>planning and amenity environmental impact assessment</td>
</tr>
<tr>
<td>Tasmania</td>
<td>planning plant species selection and establishment water and air pollution management of toxic materials environmental monitoring protected flora and fauna</td>
<td>Queensland</td>
<td>water and air pollution hazardous chemicals noise emissions</td>
</tr>
<tr>
<td>Department of Environment and Land Management</td>
<td></td>
<td>Department of Natural Resources &amp; Department of Primary Industries</td>
<td>plant species selection soil conservation techniques tree seed supply</td>
</tr>
<tr>
<td>Department of Primary Industry and Fisheries</td>
<td>plant species selection and establishment seed technology soil conservation techniques noxious plants and control fertiliser and soil amendments</td>
<td>Environmental Protection Authority</td>
<td>air and water pollution toxic chemical and wastes protected flora and fauna</td>
</tr>
<tr>
<td>Forestry Tasmania</td>
<td>plant species selection and establishment soil conservation techniques drainage techniques track rehabilitation tree seed supply</td>
<td>Rural Land Protection Board</td>
<td>noxious plant and animals and their control</td>
</tr>
<tr>
<td>Victoria</td>
<td>plant identification plant species selection, supply and establishment soil conservation techniques noxious weeds protected flora and fauna</td>
<td>South Australia</td>
<td>database of plant communities and locations plant species selection and establishment seed technology</td>
</tr>
<tr>
<td>Department of Natural Resources and Environment</td>
<td></td>
<td>Department of Environment, Heritage and Aboriginal Affairs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>plant species selection, supply and establishment contract planting and direct seeding plant selection and establishment soil conservation techniques fertiliser and soil amendment dedicated rehabilitation officer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>planning and amenity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>identification of plant species</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
## DEPARTMENT AREAS OF EXPERTISE

### Western Australia

**Environmental Protection Authority**
- pollution control
- environmental policy
- impact assessment of development proposals

**Department of Environmental Protection**
- environmental impact assessment
- planning and amenity policy
- conservation policy
- pollution licensing and waste management

**Department of Conservation and Land Management**
- plant species selection and establishment
- seed supply and technology
- flora and fauna amenity
- fire management

**Water and Rivers Commission**
- groundwater and surface water management
- catchment management
- water abstraction licensing

**Agriculture Western Australia**
- soil conservation, tree species selection
- management of saline soils

**State Mining Engineer/Soil and Land Conservation Council**
- vegetation clearing

**Department of Resources Development**
- “one-stop-shop” for State Agreement Act companies

**Aboriginal Affairs Department**
- Aboriginal Heritage

### Northern Territory

**Department of Lands, Planning & Environment**
- plant and tree species selection and establishment
- noxious weeds and plants
- soil conservation techniques
- coastal management
- air and water pollution
- tree seed supply
- protected flora and fauna

### DEPARTMENT AREAS OF EXPERTISE

**Department of Primary Industries & Fisheries**
- noxious plants
- feral animals
- fertiliser and soil amendments

**Parks & Wildlife Commission**
- Territory parks operations
- bushfire management and control

**Aboriginal Areas Protection Authority**
- identification, management and protection of Aboriginal sacred sites

### National & Academic Institutions

**Academic Institutions**
- Refer to relevant departments of local Universities, Colleges of Advanced Education, Cooperative Research Centres

**CSIRO**
- Division of Wildlife & Ecology (Canberra, ACT)
- Centre for Environmental Mechanics (Canberra, ACT)
- Centre for Mediterranean Agriculture Research (Perth, WA)
- Division of Entomology (Canberra, ACT)
- Division of Forestry & Forest Products (Canberra, ACT)
- Division of Land and Water (Canberra, ACT)
- Division of Plant Industry (Canberra, ACT)
- Division of Tropical Agriculture (Brisbane, QLD)
- Division of Exploration and Mining (Perth, WA)

### Cooperative Research Centres

There are over 60 CRCs throughout Australia. For full details of all CRCs, check their website: www.dist.gov.au/crc/html/centres.html or www.dist.gov.au/crc/contacts.html (for location).
8.2 Appendix 2 – Australian Minerals Industry Code for Environmental Management

More than in any other way, the community judges the minerals industry by its environmental performance. Recognising the need to achieve environmental excellence and to be open and accountable to the community. Australia’s minerals industry has developed a Code for Environmental Management. The Code has been strengthened by contributions from government and non-government organisations.

The Code is the centrepiece of a new commitment to respond to community concerns through consultation, demonstrated environmental performance, continual improvement and public reporting.

Adoption of the Code is voluntary and open to all minerals companies. Signatories will be required to demonstrate their commitment to environmental excellence and provide leadership in the minerals industry for the broad adoption of the Code. Irrespective of whether a company becomes a signatory, the Code provides a basis for improving environmental performance through progressive implementation of the Code’s principles.

Effective environmental management within the minerals industry must take into account the physical, environmental, statutory, economic and social parameters relevant to each operation. Therefore, the Code provides a comprehensive framework for the development of effective systems and processes for each operation. It does not prescribe specific practices, standards or any particular local requirements as they cannot provide effective environmental management across diverse operations.

The Code does not set entry standards but requires signatories’ commitment to continual improvement and public reporting of Code implementation and environmental performance. Signatories will progressively implement the Code’s principles by putting in place systems and processes to achieve full implementation over time.

Signatories will apply the Code wherever they operate. The principles will guide signatories through each phase of mineral development, from exploration, through design and construction to mining, minerals processing, rehabilitation and decommissioning.
Signatories to the Code will:

- observe the policies, and respect the aspirations of State, Territory and sovereign governments relevant to mineral developments;
- facilitate community partnerships on environmental matters;
- report publicly on environmental performance and implementation of the Code.

The industry recognises that community, government and industry needs and expectations will change over time. The Code will continue to evolve with ongoing input from all stakeholders.

**STATEMENT OF PRINCIPLES**

Signatories to the Code are committed to excellence in environmental management through:

**Sustainable Development**
Managing activities in a manner consistent with the principles of sustainable development such that economic, environmental and social considerations are integrated into decision making and management.

**Environmentally Responsible Culture**
Developing and environmentally responsible culture by demonstrating management commitment, implementing management systems, and providing the time and resources to educate and train employees and contractors.

**Community Partnership**
Consulting the community on its concerns, aspirations and values regarding development and operational aspects of mineral projects, recognising that there are links between environmental, economic, social and cultural issues.

**Risk Management**
Applying risk management techniques on a site-specific basis to achieve desirable environmental outcomes.

**Integrated Environmental Management**
Recognising environmental management as a corporate priority and integrating environmental management into all operations from exploration, through design and construction to mining, minerals processing, rehabilitation and decommissioning.

**Performance Targets**
Setting environmental performance targets not necessarily limited to legislation, licence and permit requirements.

**Continual Improvement**
Implementing management strategies to meet current and anticipated performance standards and regularly reviewing objectives in the light of changing needs and expectations.

**Rehabilitation and Decommissioning**
Ensuring decommissioned sites are rehabilitated and left in a safe and stable condition, after taking into account beneficial uses of the site and surrounding land.

**Reporting**
Demonstrating commitment to the Code's principles by reporting the company's implementation of the Code and environmental performance to governments, the community and within the company.

**SYSTEMS AND PROCESSES**
The systems and processes relevant to each Principle are:

**Sustainable Development**
1. Support activities to improve knowledge of the short- and long-term availability and use of mineral resources.
2. Promote reuse and recycling of mineral products and by-products to maximise their utility to current and future generations.
3. Pursue cleaner production through research, technological innovation, operational efficiencies and waste minimisation.
4. Recognise the maintenance of ecological and cultural heritage values as an important consideration in sustainable development.

**Environmentally Responsible Culture**
Development of environmental management systems and processes within organisations.
1. Develop, implement and communicate an environmental policy consistent with the Code.

2. Demonstrate management commitment through application of environmental management practices consistent with the Code.

3. Implement effective environmental education and training programs for all employees and contractors.

4. Ensure that employees and contractors are provided with necessary company policies, goals, procedures, guidelines and practices for environmental and heritage protection.

5. Require employees and site contractors to comply with company practices and procedures.

6. Facilitate community education about the minerals industry and its environmental management.

**Community Partnership**

Consulting the community on its concerns, aspirations and values regarding development and operational aspects of mineral projects, recognising that there are links between environmental, economic, social and cultural issues.

1. Identify directly and indirectly affected stakeholders, and their concerns.

2. Foster openness and dialogue with employees and the community, promote cross-cultural awareness, and specifically address concerns about environmental and social impacts.

3. Provide to the community technical information about potential effects of operations, products, waste and rehabilitation practices.

4. Establish community consultation relevant to each stage of operations.

**Risk Management**

Applying risk management techniques on a site-specific basis to achieve desirable environmental outcomes.

1. Utilise environmental baseline studies as the basis for risk management.

2. Evaluate the risks of alternative project concepts, weighing the positive and negative concepts of the outcomes and provide opportunities for stakeholder participation.

3. Implement management strategies to mitigate environmental impacts of the preferred development option.

4. Adopt a proactive and cautious approach to reasonably foreseeable environmental risks.

5. Develop and implement contingency plans to address incidents and abnormal operating and environmental conditions.

**Integrated Environmental Management**

Recognising environmental management as a corporate priority and integrating environmental management into all operations from exploration, through design and construction to mining, minerals processing, rehabilitation and decommissioning.

1. Establish a management system which allocates management and employee responsibilities relevant to the organisation’s activities and applicable legal requirements.

2. Address within an environmental management system:
   - applicable legal and regulatory requirements;
   - requirements under this Code and any other codes to which the company is a signatory;
   - company environmental policies, objectives and targets;
   - environmental management plans and procedures;
   - environmental monitoring procedures;
   - setting and testing of contingency and emergency response plans;
   - regular auditing of the environmental management system and environmental performance;
   - reporting procedures.

3. Periodically review the environmental management system to ensure that it remains effective and relevant to the company’s evolving needs and changing community values and expectations.

**Performance Targets**

Setting environmental performance targets not necessarily limited to legislation, licence and permit requirements.

1. Identify legal and other requirements applicable to the environmental aspects of the organisation’s activities, products or services.

2. Set internal performance targets and periodically assess achievements to reinforce policy commitments and to enable demonstration of continual improvement.

3. Ensure that legal requirements and internal performance targets are effectively communicated to the employees who are accountable for the relevant activities.
Continual Improvement

Implementing management strategies to meet current and anticipated performance standards and regularly reviewing objectives in the light of changing needs and expectations.

1. Regularly review and update corporate policies, programs, and environmental performance to correct any deficiencies.
2. Assess and rank environmental issues in order to concentrate efforts in priority areas and where maximum gains are achievable.
3. Undertake, participate in, or support research on priority issues and facilitate transfer of information on technical developments, scientific understanding, consumer needs and community expectations.

Rehabilitation and Decommissioning

Ensuring decommissioned sites are rehabilitated and left in a safe and stable condition, after taking into account beneficial uses of the site and surrounding land.

1. Incorporate rehabilitation and decommissioning options in the conceptual design of operations at the feasibility stage.
2. Develop clearly-defined rehabilitation plans, monitor and review rehabilitation performance and progressively refine such plans.
3. Determine and account for rehabilitation and decommissioning costs and periodically review their adequacy during the life of the operation.
4. Establish a program of progressive rehabilitation commensurate with the nature of the operation and the rate of disturbance.
5. Periodically review the rehabilitation and decommissioning strategies over the life of the operation to incorporate changing legislative requirements, public expectations and environmental and cultural heritage information.
6. Address issues and programs related to long-term responsibility for land management in the final decommissioning plan.

Reporting

Demonstrating commitment to the Code’s principles by reporting the company’s implementation of the Code and environmental performance to governments, the community and within the company.

1. Implement regular reporting of environmental performance to all stakeholders, including the Board of Directors, shareholders, employees, authorities and the community.
2. Provide an annual public environmental report.
3. Reports should describe the company’s processes for:
   - communicating environmental policy;
   - communicating environmental performance;
   - community consultation and responding to concerns;
   - Code implementation.
4. Reports should also include, but not be limited to:
   - organisation profile, environmental policies and objectives;
   - environmental management processes;
   - establishment of benchmarks against which continual improvement can be measured;
   - opportunities/progress in improvements;
   - prosecutions and associated significant environmental incidents;
   - performance in relation to regulatory requirements and internal targets;
   - environmental and heritage issues to be addressed and strategies to implement them.

The full Code package, including list of Code Coordinators who may be able to provide guidance on the Code, can be obtained from the Minerals Council of Australia.
8.3 Appendix 3 – Resource Material

The proceedings of the annual Minerals Council of Australia (formerly AMIC) Environmental Workshop have become a major source of data on the developing technology of mine site rehabilitation in Australia. The proceedings are available through the library of the Australian Mineral Foundation.

The Australian Minerals and Energy Environment Foundation (AMEEF) with the support of the Supervising Scientist Group of Environment Australia, has developed a Directory of Environmental Management and Science capabilities relevant to the Australian minerals and environment industry. The directory aims to raise the visibility of the wide range and scope of environmental management activities in Australia, including research, training, environmental management innovation and best practice, technology and government policy and regulations.

The directory is in the form of a searchable electronic directory on the internet (www.ameef.com.au) with links to other databases including EnviroNET. All listings in the directory, and use of the directory is provided free of charge. The database includes technical references and contact details for experts in areas relevant to rehabilitation and decommissioning.

Further resource material is listed below.

Computer-based Bibliographies/Data Bases

The following databases contain subject categories relating to minesite restoration:

Australia

- Australian Earth Sciences Information Systems (AESIS) - access available through Australian Mineral Foundation, SA.
- MINFINDER - access through Department of Mineral Resources, NSW.
- SAMREF - access available through Department of Mines and Energy, SA.
- GEOPAC (incorporates AESIS, MINFINDER and SAMREF) - access available through Info-One International, North Sydney NSW.
- AUSTRALIS - access available through CSIRO, East Melbourne, Vic.

Overseas

The following databases contain categories relevant to land reclamation and are available through major libraries or commercial information services.

- ENVIROLINE
- ENVIRONMENTAL BIBLIOGRAPHY
- AGRICOLA
- WATER RESOURCES ABSTRACTS
- NTIS (US National Technical Information Service)

Hard Copy Bibliographies

- Environmental Research and Development Abstracts - Abstracts of Environmental Trials and Research Conducted in their Operations by Seven Major Mining Companies (1987) - available from Department of Resources Development, WA.
- Mine Rehabilitation - An Annotated Bibliography 1932-82 with Supplement of Authors and Titles 1982-85 - available from Department of Environment and Planning, SA.

Publications

The following publications offer further practical guidance on aspects of minesite rehabilitation discussed in this handbook.
General

- Best Practice Environmental Management in Mining 1995 – Rehabilitation & Revegetation – Environmental Protection Agency.
- Best Practice Environmental Management in Mining 1995 – Tailings Containment – Environmental Protection Agency.

Arid Zone Rehabilitation

- Guideline for Environmental Management of Mining in Arid Areas - available from Western Australian Department of Mines, Perth.

General Rehabilitation

- Proceedings of the Annual MCA (previously AMIC) Environmental Workshop - indexed and available from the MCA.
- Land Restoration and Reclamation; Principles and Practice 1997- JA Harris, P Birch & J Palmer, published by Longman Higher Education.
- Guidelines for the Rehabilitation of Quarries and Extractive Pits - available from Tasmanian Department of Environment and Planning, Hobart
- Borrow Pits - Guidelines for Siting, Working and Rehabilitation - available from Department of Environment and Planning, SA
- Rehabilitation of Mine Waste Disposal Sites - by Dr GL Unwin published by Argus Printing Kempsey, NSW.
- Environmental Guidelines for Tracks and Roads - available from Department of the Environment and Planning, Tasmania.
- Guidelines for Effective Rehabilitation of Borrow Pits in the Top End - available from Department of Lands, Planning & Environment, Northern Territory.
- Rehabilitation and Erosion Control Guidelines for Mineral Exploration in the Top End - available from Department of Lands, Planning & Environment, NT.
- Guidelines for Mineral Exploration in Coastal Areas of the Northern Territory - available from Department of Lands, Planning & Environment, NT.

Plant Selection, Planting and Sowing Techniques

- Growing Trees for Farms, Parks and Roadsides - A Revegetation Manual for Australia - by Julianne Venning - published by Lothian
- Think Trees Grow Trees - available from AGPS and State Forestry Departments.
- How to Collect Native Tree Seed Easily - available from Australian Tree Seed Centre, CSIRO, ACT.
- A Guide to Mangrove Transplanting - available from State Pollution Control Commission, NSW.
- Establishment Techniques for Farm Trees - available from Department of Agricultural and Fisheries (NSW), Soil Conservation Service (NSW) and Forestry Commission (NSW).
• Tree Planting Guide - Reformed Open Cut Coal Mines - available from Forestry Commission (NSW), Soil Conservation Service (NSW) and Department of Minerals & Energy (NSW).

• Tree Planting Guide - Fact Sheet II - available from Department of Woods and Forests, SA.

• Species Lists for Climatic Zones - Fact Sheets 23 - 27 inclusive - available from Department of Woods and Forests, SA.

• Direct Seeding of Native Species - Research Note 102 - available from Department of Woods and Forests, SA.

• A list of Plant Species Suitable for Planting in the Top End - available from Department of Lands, Planning & Environment, NT.

• Pasture Establishment and Seed Mixtures for Newly Cleared Land, Farmnote No 134 - available from Department of Primary Industry, Tas.

• Reliability of Natural Regeneration for Broadscale Revegetation by GC Bishop 1987 - available from Department of Environment and Planning, SA.

• Rural Tree Guides: 91) Natural Regeneration, (2) Direct Seeding and (3) Advantages of Growing Local Plants - available from Department of Environment and Planning, SA.

• Broadscale Direct Seeding of Trees on Farms - Information Sheet No 2-88 - available from CALM, Perth.

• Australian Suppliers of Tree Seed - available from Forestry and Forest Products Division, CSIRO, ACT.

• Trees from Rural Areas - The South West of WA - available from CALM, Perth.

• Trees for Rural Areas - The Wheat Belt - available from CALM, Perth.

• Native Seed Collection and Storage - Information Sheet No 5-87 - available from CALM, Perth.

• Germination of Australian Native Plant Seed by ED. PJ Langkamp.

Erosion Control

• Guidelines to Meet Requirements for Information on Soil and Land Stability in Proposals for Open Cut Mining and Rehabilitation - available from Soil Conservation Service, NSW.

• Code of Forest Practice for Timber Production - available from Department of Conservation Forest and Lands, Vic.

• Control of Erosion on Construction Sites by MJ Ransom - available from Department of Conservation, Forest and Lands, Vic.

• Reclaim Erosion Gullies by Filling, Farmnote 115-88 - available from Department of Agriculture, WA.

• How to Build Contour Banks with a Road Grader - Farmnote 53/85 - available from Department of Agriculture, WA.

• How to Build Contour Banks with a Disc Plough - Farmnote 5/185 - available from Department of Agriculture, WA.

• Spoon and W Drains - Farmnote 120/84 - available from Department of Agriculture, WA.

• Designing Windbreaks for Farms - available from Department of Agriculture and Fisheries (NSW) and Soil Conservation Service (NSW).

• Guidelines for Minimising Soil Erosion and Sedimentation from Construction Sites - available from the Department of Conservation Forest and Land Management, Vic.

• Planting for Gully Erosion Control - available from Department of Agriculture and Fisheries (NSW) and Soil Conservation Service (NSW).

• Windbreaks and Shelterbelts - available from Department of Woods and Forests, SA.

• Controlling Wind Erosion - Farmnote No 156 - available from Department of Primary Industry, Tas.

• Broad Base Contour Bank Construction with Draw Graders - available from Department of Primary Industry, Qld.

• Farm Access Tracks - Erosion Control - available from Department of Primary Industry, Qld.

Fertilisers/Soil Treatments

• Soil Acidity - Fact Sheet 16/84 - available from the Department of Agriculture, SA.

• AFL Fertiliser Handbook by Ed J Glendenning 1986 - available from Australian Fertilisers Limited, North Sydney, NSW.

• Gypsum for Hard-setting Soils - Fact Sheet 50/85 - available from Department of Agriculture, SA.

• Liming Problem Acid Soils - Agfact P1.4.1 - available from Department of Agriculture and Fisheries, NSW.
• Nutrient Susceptibilities of Some Common South Australian Native Plants: Influence on Direct Seeding - available from Department of Environment and Planning, SA.

Management of Saline Soils
• A Simple Way to Monitor Saltland - Farmnote 87/85 - available from Department of Agriculture, WA.
• Trees for Saltland - Farmnote 110/88 - available from Department of Agriculture, SA.
• Controlling Saltland with Trees - Farmnote 46/88 - available from Department of Agriculture, WA.
• Saltland - How to handle It - Fact Sheet FS1/81 - available from Department of Agriculture, SA.
• Grasses for Saltland - Fact Sheet 30/80 - available from Department of Agriculture, SA.
• Establishment and Management of Salt-tolerant Grasses - Fact Sheet FS29/98 - available from Department of Agriculture, SA.

Weed Identification and Control
• Recommendations from the Control of Noxious Weeds in Victoria, 1983 available from Department of Conservation, Forest and Lands, Vic.
• NSW Agfact Sheets prefixed “PM” - available from Department of Agriculture, NSW.
• Declared Weed Leaflets A/W1 to A/W21 inclusive and M/W1 to M/W3 inclusive - available from Department of Primary Industry, Tas.
• Pestfact Bulletin P001/88 to P013/89 inclusive - available from Rural Lands Protection Board, Qld.
• Declared Plant Notes (by Species Name) available from the Animal and Plant Control Commission, SA.
• Declared Plant Control Handbook - available from Agricultural Protection Board, WA.

Sundry
• Construction Practice Near Tidal Areas in the NT: Guidelines to Prevent Mosquito Breeding - available from Department of Lands, Planning & Environment, NT.
• Drip Irrigation for Trees and Shrubs - available from Department of Lands, Planning & Environment, NT.
• Post-Emergent Herbicides for Weed Control with Direct-Seeded Native Vegetation - available from Department of Environment and Planning.
• Guides on Prevention of Water Pollution due to Losses of Cyanide from Gold Ore Processing Operations - available from department of Mines (Qld), Department Environment, Conservation and Tourism (Qld) and Water Resources Commission (Qld).
### Appendix 4 – Soil Tests

**Selected Tests for Soil, Overburden and Other Rooting Media**

<table>
<thead>
<tr>
<th>TESTS</th>
<th>MEDIUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Overburden</td>
</tr>
<tr>
<td><strong>Classification (structure, texture etc)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Particle size analysis</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Dispersion Index</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>X</td>
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<tr>
<td><strong>Electrical conductivity (EC)</strong></td>
<td>X</td>
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<tr>
<td><strong>Cations</strong></td>
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<td><strong>Anions</strong></td>
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<td><strong>Minor Elements</strong></td>
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<td><strong>Lime Requirement</strong></td>
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<td><strong>Total Sulfur</strong></td>
<td>X</td>
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<td><strong>Nitrogen</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Time Requirement</strong></td>
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</tr>
</tbody>
</table>

* Test and analysis will vary from site to site. In some cases, tests not listed above will be essential. Where topsoil is available and classifiable, testing and analysis will vary from site to site. In general, the more site specific the material being revegetated, the greater the need to determine the physical and chemical characteristics.
<table>
<thead>
<tr>
<th>Commercial Name Description</th>
<th>Analysis</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Superphosphate</td>
<td>N:15 P:30 K:0</td>
<td>Nitrogen nutrient, suitable for use on mine sites</td>
</tr>
<tr>
<td>Double Superphosphate Concentrate</td>
<td>N:17 P:5 S:15</td>
<td>Double dose P, but half dose of S less likely to affect pH levels</td>
</tr>
<tr>
<td>Single Superphosphate</td>
<td>N:9 P:1 S:15</td>
<td>Not recommended for reclamation of mine sites</td>
</tr>
<tr>
<td>Lime-Super Double Superphosphate/Lime Mixture</td>
<td>N:4.6 P:5.8</td>
<td>Suitable for use on neutral to low pH soils</td>
</tr>
<tr>
<td>Mo-Super Single Superphosphate with molybdenum</td>
<td>N:9.1 P:1.1</td>
<td>Suitable for use on mine sites, where low pH is a problem</td>
</tr>
<tr>
<td>Lime-Super Double Superphosphate/Lime Mixture</td>
<td>N:4.6 P:5.8</td>
<td>Suitable for use on neutral to low pH soils</td>
</tr>
<tr>
<td>Ammonium Nitrate</td>
<td>N:3.4</td>
<td>15.0 - 30.0</td>
</tr>
<tr>
<td>NPK Compost</td>
<td>N:13.1 P:10.3 K:1.5</td>
<td>Suitable for high pH soils, but high risk of affecting pH levels</td>
</tr>
<tr>
<td>Nitrogen Phosphate</td>
<td>N:15.0</td>
<td>15.0 - 30.0</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>N:10.3</td>
<td>15.0 - 30.0</td>
</tr>
<tr>
<td>Potassium</td>
<td>N:10.3</td>
<td>15.0 - 30.0</td>
</tr>
<tr>
<td>Overall</td>
<td>N:30.0</td>
<td>15.0 - 30.0</td>
</tr>
</tbody>
</table>

Selected Fertiliser Types

8.5 Appendix 5 – Effect of pH on Availability of Plant Nutrients

8.6 Appendix 6 – Selected Fertilisers
Commercial Name | Description (or % active constituents) | Analysis | Comment
--- | --- | --- | ---
Banana K | 6 - 10 - 30 | 9.5 2.4 24.1 | Applies high levels of K and other nutrients where levels of P are adequate
Grower 11 | 11 - 34 - 11 | 11.0 14.6 9.1 | Suitable as substitute for Starter 15 where low pH and K deficiency exists

* The products and trade names listed are manufactured by Australian Fertilisers Limited and marketed under the tradename “Greenleaf”. These products are widely available on the eastern seaboard of Australia. Similar products together with a wide range of other formulas are manufactured and marketed in other States.

8.7 Appendix 7 – Seed Suppliers

Commercial Suppliers of Native Plant Species Seed

<table>
<thead>
<tr>
<th>Supplier Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE O’Connor Pty Ltd</td>
<td>Montmorency (Vic)</td>
</tr>
<tr>
<td>APM Forests</td>
<td>Morwell (Vic)</td>
</tr>
<tr>
<td>Australian Seed Company</td>
<td>Hazelbrook (NSW)</td>
</tr>
<tr>
<td>Bendigo Wild Flower Farm</td>
<td>Bendigo (Vic)</td>
</tr>
<tr>
<td>Ellison Horticulture Pty Ltd</td>
<td>Nowra (NSW)</td>
</tr>
<tr>
<td>Far North Queensland Seeds</td>
<td>Walkamin (Qld)</td>
</tr>
<tr>
<td>Forest Seeds Australia</td>
<td>Drysdale (Vic)</td>
</tr>
<tr>
<td>Goldfields Revegetation</td>
<td>Mundurang (Vic)</td>
</tr>
<tr>
<td>Goldfields Native Seed Supplies</td>
<td>Kambalda (WA)</td>
</tr>
<tr>
<td>Goozeff Seeds Pty Ltd</td>
<td>Nowra (NSW)</td>
</tr>
<tr>
<td>Harvest Seeds</td>
<td>Terrey Hills (NSW)</td>
</tr>
<tr>
<td>Heritage Seeds</td>
<td>Brisbane (Qld)</td>
</tr>
<tr>
<td>R Horrer</td>
<td>Alice Springs (NT)</td>
</tr>
<tr>
<td>Kimseed Pty Ltd</td>
<td>Osborne Park (WA)</td>
</tr>
<tr>
<td>HG Kershaw Pty Ltd</td>
<td>Terry Hills (NSW)</td>
</tr>
<tr>
<td>Kylisa Seeds Pty Ltd</td>
<td>Weston Creek (ACT)</td>
</tr>
<tr>
<td>Landcare Services Pty Ltd</td>
<td>York (WA)</td>
</tr>
<tr>
<td>Minjaro Native Seeds</td>
<td>Broome (WA)</td>
</tr>
<tr>
<td>Nindethana Seed Service</td>
<td>Woogenilup (WA)</td>
</tr>
<tr>
<td>Northrup King Seeds</td>
<td>Dandenong (Vic)</td>
</tr>
<tr>
<td>Queensland Tree Seeds</td>
<td>Moura (Qld)</td>
</tr>
<tr>
<td>Rangeland Seeds</td>
<td>Carnarvon (WA)</td>
</tr>
<tr>
<td>Royston Petrie Seeds Pty Ltd</td>
<td>Kenthurst (NSW)</td>
</tr>
<tr>
<td>South Australian Seed Growers Co-op</td>
<td>Adelaide (SA)</td>
</tr>
<tr>
<td>Southern Forestry Services</td>
<td>Geeveston (Tas)</td>
</tr>
<tr>
<td>South West Native Seed Supply</td>
<td>Donnybrook (WA)</td>
</tr>
<tr>
<td>Tasmanian Eucalypt &amp; Native Seeds</td>
<td>Maydena (Tas)</td>
</tr>
<tr>
<td>Tasmanian Seed Centre</td>
<td>Hobart (Tas)</td>
</tr>
<tr>
<td>Top End Seeds</td>
<td>Darwin (NT)</td>
</tr>
<tr>
<td>Tropigrow Pty Ltd</td>
<td>Winnellie (NT)</td>
</tr>
<tr>
<td>Vaughans Wildflower Seeds</td>
<td>Gin Gin (Qld)</td>
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<tr>
<td>Western Wildlife Supply</td>
<td>Gilgandra (NSW)</td>
</tr>
<tr>
<td>Wildseed Tasmania</td>
<td>Tasmania</td>
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</table>
8.8 Appendix 8 – Declared Weeds

As in indicator only, the following plants have at some time been declared “noxious” or prohibited in some states, not all.

The level of control required under state legislation varies between species. Detailed information on declared weeds and their control levels and methods should be obtained from relevant state authorities. There are in addition many other species, not on this list of declared weeds, which can become environmental weeds.

<table>
<thead>
<tr>
<th>Botanical Name</th>
<th>Common Name</th>
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<tbody>
<tr>
<td>Acacia armata</td>
<td>Prickly Pear</td>
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<tr>
<td>A. catechu</td>
<td>Cultch tree</td>
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<tr>
<td>A. nilotica</td>
<td>Prickly acacia</td>
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<tr>
<td>Acanthospermum hispidum</td>
<td>Star burr (goats head)</td>
</tr>
<tr>
<td>Acroptilon repens</td>
<td>Hardheads, Russian knapweed</td>
</tr>
<tr>
<td>A. Vineale</td>
<td>Creeping knapweed</td>
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<tr>
<td>Adonis microcarpa</td>
<td>Small fruit Pheasants eye</td>
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<tr>
<td>Ageratine riparia</td>
<td>Mistflower</td>
</tr>
<tr>
<td>Alagi maurorum</td>
<td>Camel Thorn</td>
</tr>
<tr>
<td>Allium triquetrum</td>
<td>Three cornered</td>
</tr>
<tr>
<td>A. vineale</td>
<td>Wild garlic, crow garlic, field garlic</td>
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<tr>
<td>Alternathera philoxeroides</td>
<td>Alligator weed</td>
</tr>
<tr>
<td>A. pungens</td>
<td>Khaki weed</td>
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<tr>
<td>Ambrosia artemisiifolia</td>
<td>Annual ragweed</td>
</tr>
<tr>
<td>A. psilostachya</td>
<td>Perennial ragweed</td>
</tr>
<tr>
<td>A. spp</td>
<td>Yellow burr weed</td>
</tr>
<tr>
<td>Amsinckia spp</td>
<td>Stinking Magweed</td>
</tr>
<tr>
<td>Anthemic cotulla</td>
<td>Mexican</td>
</tr>
<tr>
<td>Argemone mexicana</td>
<td>Mexican poppy</td>
</tr>
<tr>
<td>A. ochroleuca</td>
<td>Bridal Creeper (Smilax)</td>
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<tr>
<td>Asparagus asparagoides</td>
<td>Onion weed</td>
</tr>
<tr>
<td>Asphodelus fistulosus</td>
<td>Groundsel bush</td>
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<tr>
<td>Baccharis halimifolia</td>
<td>African thistle</td>
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<tr>
<td>Berhheya rigida</td>
<td>Calotropis, Rubber bush</td>
</tr>
<tr>
<td>Calotropis procera</td>
<td>Indian hemp</td>
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<tr>
<td>Cannabis Sativa</td>
<td>White weed (Hoary Cress)</td>
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<tr>
<td>Cardaria draba</td>
<td>Nodding Thistle</td>
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<tr>
<td>Carduus nutans</td>
<td>C. pyrnocephalus</td>
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<tr>
<td>Cassia alata</td>
<td>C. tenuiflorus</td>
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<tr>
<td>C. obtusifolia</td>
<td>Carex buchananii</td>
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<tr>
<td>C. occidentalis</td>
<td>C. comans</td>
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<tr>
<td>C. echinatus</td>
<td>C. flagellifera</td>
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<tr>
<td>C. incertus</td>
<td>C. testaceae</td>
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<td>C. longispinus</td>
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<td>C. leucocaulos</td>
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<td>C. junceae</td>
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<td>C. vulgare</td>
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<td>Conium maculatum</td>
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<td>C. arvensis</td>
<td>Convululus arvensis</td>
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<td>Cortaderia selloanaq</td>
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<td>Cortaderia spp</td>
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<td>C. monogyna</td>
<td>Crataegus monogyna</td>
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<td>C. sinaica</td>
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<td>C. grandiflora</td>
<td>Cryptostegia grandiflora</td>
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<tr>
<td>C. testacae</td>
<td>Cuscuta spp</td>
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<tr>
<td>C. tasmanica</td>
<td>(excluding C. tasmanica)</td>
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<tr>
<td>C. cardunculus</td>
<td>Cynara cardunculus</td>
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<td>C. aromaticus</td>
<td>Cyperus aromaticus</td>
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<td>C. scoparius</td>
<td>Cytisus scoparius</td>
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<td>Datura ferox</td>
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<td>Slender thistle</td>
<td>Slender thistle or Shore thistle</td>
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<td>Slender thistle</td>
<td>Winged slender thistle</td>
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<td>Sedge</td>
<td>Sedge</td>
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<td>Sedge</td>
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<td>Saffron thistle</td>
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<tr>
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<td>Glaucous star thistle</td>
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<td>Sedge</td>
<td>Candle bush</td>
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<td>Sedge</td>
<td>Sicklepod</td>
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<td>Coffee senna</td>
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<td>Sedge</td>
<td>Mossman river grass</td>
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<td>Sedge</td>
<td>Spiny burr grass</td>
</tr>
<tr>
<td>Sedge</td>
<td>Spiny burr grass or Innocent Week</td>
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<td>Black Knapweed</td>
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<td>Hornwort</td>
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<td>Green cestrum, Chilean cestrum</td>
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<td>Skeleton weed</td>
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<td>Siam weed</td>
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<td>Sedge</td>
<td>Rubber vine</td>
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<tr>
<td>Sedge</td>
<td>Bitou bush, boneseed</td>
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<td>Sedge</td>
<td>Soldier thistle</td>
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<tr>
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<td>Perennial thistle</td>
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<tr>
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<td>Californian (creeping) thistle</td>
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<tr>
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<td>Spear thistle</td>
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<td>Dodder</td>
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<td>Sedge</td>
<td>Hemlock</td>
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<td>Field bindweed</td>
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<td>Pampas grass</td>
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<td>Sedge</td>
<td>May (Hawthorn)</td>
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<td>Sedge</td>
<td>Ayzarola (Hawthorn)</td>
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<tr>
<td>Sedge</td>
<td>Rubber vine</td>
</tr>
<tr>
<td>Sedge</td>
<td>Dodder</td>
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<tr>
<td>Sedge</td>
<td>Artichoke thistle, wild artichoke</td>
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<tr>
<td>Sedge</td>
<td>Nauva sedge</td>
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<tr>
<td>Sedge</td>
<td>English Broom</td>
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<tr>
<td>Sedge</td>
<td>Thorn apple</td>
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</table>
D. innoxia Thorn apple
D. leichhardtii Thorn apple
D. metel Thorn apple
D. meteloides Thorn apple
D. spp Thorn apple, Datura
D. stramonium Thorn apple
D. tatula Thorn apple
D. wrightii Thorn apple
Diplotaxis tenuifolia Lincoln weed
Dipsacus fullonum Wild teasel
Ecballium elaterium Squirting cucumber
Echium plantagineum Paterson's curse, Salvation Jane
E. vulgare Viper's bugloss, Paterson's curse
Egeria densa (Elodea densa) Leafy elodea, Dense waterweed
Echornia crassipes Spiny emex, double gee
Elodea canadensis Elodea or Canadian pond weed
Emex australis Spiny emex, double gee
Eragrostis curvula African lovegrass
E. spinosa African lovegrass
E. spp African lovegrass
Ermocarpus setiger Caper spurge
Erythroxylum coca Coca leaf
Eupatorium adenophorum Caper spurge
Eupatorium riparium Mist flower
Euphorbia hererophylla Common heliotrope
E. lathyrus Common heliotrope
E. terracine Common heliotrope
Froelichia floridana Common heliotrope
Genista monspessulana Common heliotrope
Gmelina asiatica Common heliotrope
Gomphocarpus fruticosus Common heliotrope
Gorteria petsonata Common heliotrope
Gymnocoronis spilanthoides Common heliotrope
Heliotropium europaeum Common heliotrope
Homeria breyniana Common heliotrope
H. flaccida Cape tulip
H. miniata Cape tulip
H. spp Cape tulip
Hydrilla verticillata Cape tulip, two-leaf
Hypericum androsaemum Cape tulip
H. perforatum Cape tulip
H. tetrapterum Cape tulip
H. triquetrifolium Cape tulip
Hyptis capitata Cape tulip
H. sauvoleans Cape tulip
Ibicella lutea Cape tulip
Iva axillaris Cape tulip
Jatropha curcas Cape tulip
J. gossypifolia Cape tulip
Juncus acutus Cape tulip
Lagarosiphon major Cape tulip
Lantana camara Cape tulip
L. montevidensis Cape tulip
L. vulgare Cape tulip
Leontis nepetifolia Cape tulip
Leucanthemum vulgare Cape tulip
Lycium ferocissimum Cape tulip
Malvella leprosa Cape tulip
Marrubium vulgare Cape tulip
Mentha pulegium Cape tulip
Mimosa invisa Cape tulip
M. pigra Cape tulip
M. pudica Cape tulip
Myriophyllum aquaticum Cape tulip
Myrsiphyllum asparagoides Cape tulip
Nassella trichotoma Cape tulip
Oleia europea Cape tulip
Onopordum acanthium Cape tulip
O. acaulon Cape tulip
O. illyricum Cape tulip
O. spp Cape tulip
Opuntia aurantiaca Cape tulip
Opuntia spp Cape tulip
Oxalis pes-caprae Cape tulip
O. spp Cape tulip
<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
</tr>
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<tbody>
<tr>
<td>Papaver somniferum</td>
<td>Opium poppy</td>
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<tr>
<td>Parkinsonia aculeata</td>
<td>Parkinsonia</td>
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<tr>
<td>Parthenium hysterophorus</td>
<td>Parthenium weed</td>
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<tr>
<td>Peganum harmala</td>
<td>African rue</td>
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<tr>
<td>Pennisetum macrorum</td>
<td>African feather grass</td>
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<tr>
<td>P. polystachion</td>
<td>Mission grass</td>
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<tr>
<td>P. villosum</td>
<td>Feathertop</td>
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<tr>
<td>Pentzia suffruticosa</td>
<td>Calomba daisy</td>
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<tr>
<td>Physalis viscosa</td>
<td>Prairie ground cherry</td>
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<td>Picnimon acarna</td>
<td>Soldier thistle</td>
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<td>P. macrorum</td>
<td>African Feathergrass</td>
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<td>P. stratiotes</td>
<td>Water lettuce</td>
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<td>Prospocidea louisianica</td>
<td>Devil's claw</td>
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<td>Prosopis limensis</td>
<td>Mesquite (Algeroba)</td>
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<td>Mesquite</td>
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<td>Reseda lutea</td>
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<td>Wild mignonette</td>
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<td>Castor oil plant</td>
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<td>Dog rose</td>
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<td>R. rubiginosa</td>
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<td>Rubus alcefolius</td>
<td>Giant bramble</td>
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<tr>
<td>R. brownii</td>
<td>Swamp dock</td>
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<td>R. conglomeratus</td>
<td>Clustered dock</td>
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<td>R. crispus</td>
<td>Curled dock</td>
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<tr>
<td>R. fruiticosus</td>
<td>Blackberry</td>
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<td>R. obtusifolius</td>
<td>Broadleaf dock</td>
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<td>R. pulcher</td>
<td>Fiddle dock</td>
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<td>R. spp (excluding R. idaeus &amp; R. Parvifolius)</td>
<td>Blackberry, Brambles</td>
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<tr>
<td>Rumex crispus</td>
<td>Curled dock</td>
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<tr>
<td>R. obtusifolius</td>
<td>Broad-leaf dock</td>
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<td>Sagittaria graminea</td>
<td>Arrowhead, Sagittaria</td>
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<td>S. montevindensis</td>
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<td>Pampas Lily of the Valley</td>
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<td>Salvia reflexa</td>
<td>Mintweed</td>
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<td>Salvinia</td>
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<td>S. molesta</td>
<td>Salvinia</td>
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<td>Scolymus hispanicus</td>
<td>Golden thistle</td>
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<tr>
<td>Sclerolaena birchii</td>
<td>Galvanised burr</td>
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<td>Senecio jacobaea</td>
<td>Ragwort</td>
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<tr>
<td>S. pterophorus</td>
<td>African daisy</td>
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<tr>
<td>Side acuta</td>
<td>Sida, Spinyhead Sida</td>
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<tr>
<td>S. cordifolia</td>
<td>Sida, Flannel weed</td>
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<tr>
<td>S. ep rosa</td>
<td>Ivy-leaf sida</td>
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<tr>
<td>S. rhombifolia</td>
<td>Paddy's lucerne</td>
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<td>Silieni vulgaris</td>
<td>Bladder comion</td>
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<tr>
<td>Silybum marianum</td>
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<tr>
<td>Solanum comutum</td>
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<td>S. elaegnifolium</td>
<td>Silverleaf nightshade</td>
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<tr>
<td>S. linnaeautum</td>
<td>Apple of Sodium</td>
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<tr>
<td>S. marginatam</td>
<td>White-edged nightshade</td>
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<tr>
<td>S. sodomaeum</td>
<td>Apple-of-Sodium</td>
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<tr>
<td>Sorghum alburnus</td>
<td>Columbus grass</td>
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<tr>
<td>S. Caudata</td>
<td>Johnson's grass</td>
</tr>
<tr>
<td>Tamarix aphylla</td>
<td>Snake weeds</td>
</tr>
<tr>
<td>Themeda quadrivalis</td>
<td>Espartillo</td>
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<tr>
<td>Thunbergia grandiflora</td>
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</tr>
<tr>
<td>Toxicodendron radicans</td>
<td>Tamarisk (Athel pine)</td>
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<tr>
<td>T. succedaneum</td>
<td>Grader grass</td>
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<tr>
<td>Tribulus cistoides</td>
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<td>T. terresris</td>
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<tr>
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<td>Rhus tree</td>
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<tr>
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<td>Caltroop</td>
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<td>Xanthium californicum</td>
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<td>X. cavanillesil</td>
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<td>X. occidentale</td>
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<td>X. orientale</td>
<td>Noogoora burr</td>
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<tr>
<td>X. pungens</td>
<td>Californian burr</td>
</tr>
<tr>
<td>X. spinosum</td>
<td>Noogoora burr</td>
</tr>
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<td>X. spp</td>
<td>Californian burr</td>
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<td>Zantedeschia aethiopica</td>
<td>Bathurst burr</td>
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<td>Ziziphus mauritiana</td>
<td>Bathurst, Noogoora, Californian &amp; Cockle burrs</td>
</tr>
<tr>
<td>Chinese lily</td>
<td>Arum lily</td>
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<tr>
<td>Chinese apple (Indian jujube)</td>
<td>Chinese apple (Indian jujube)</td>
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8.9 Appendix 9 – Grade Comparisons and Conversion Chart

9 GLOSSARY OF TERMS

acid drainage: acid water (low pH) drainage flowing from land affected by mining and usually the result of air and water coming into contact with pyrite to produce sulfuric acid. Certain bacteria may also act as a catalyst.

baseline studies: studies undertaken to establish the condition of the study area prior to mining or any other defined activity.

bulking (seed): mixing sand, sawdust or similar dry and fine material to increase the bulk of fine seed enabling it to be more readily handled and distributed.

capillary rise: the upward movement of the soil water held by cohesion as a continuous film around soil particles.

cation: an ion with a positive charge.

contour bench: an earth mound or similar, constructed exactly along the contour and which is designed to control water run-off.

decant structure: a collection system designed to collect the liquid which "ponds" on the surface of tailings impoundments.

direct seeding: broadcasting seed directly onto the area requiring revegetation (as opposed to germinating seed in nursery conditions and transplanting seedlings to the site).

dispersive soils: structurally unstable soils in which the soil aggregates readily break down into their constituent particles.

drainage density: the catchment area divided by the total length of definable stream channels that drain the area.

free cyanide: cyanide not combined with complex ions.

hydromulching or hydroteeding: a procedure whereby a mixture of seed, fertiliser and mulching material as a carrier is sprayed in a slurry on exposed soil surfaces for revegetation purposes. Common materials used as carrying agents are wood, straw and paper pulp. A coloured dye is usually mixed into the slurry in order to observe treated areas as the operation proceeds.
leachate liquid that has percolated through tailings material or other substances.

micro-organism a single celled plant, animal or bacterium.

neutralising capacity the capacity of a substance to restore the balance of hydrogen or hydroxyl ions.

pelleting (seeds) the process of coating seed in a material that effectively increases the size of the seed and facilitates handling and distribution.

pH a measure of acidity or alkalinity on a scale of 0-14 with pH 7 being neutral.

plant pathogens parasites which cause disease or affect plant growth.

precipitate a substance deposited in a solid form from solution.

runoff coefficient the rate of runoff to rainfall. (in national method of peak runoff rate prediction this definition is varied)

siemens a measure of electrical conductance.

sediment dam a dam structure designed to retain runoff sufficiently to allow sediment to be deposited and “clear” water to be discharged.

sediment load the extent of sediment being transported in suspension.

sedimentation the setting out of solid material held in suspension being transported in a stream etc.

soil amendment any additive to the soil that changes its structure.

storm return period the frequency of a storm event of a particular magnitude is predicted to occur.

substrate solid material onto which plants are able to become attached (by roots).

thiobacilli bacteria which act as catalysts in the oxidation of acid forming materials the leachate form which forms acid mine drainage.

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