# 4 Estimate of liability for current mines

## 4.1 Types of liabilities relevant to AMD/ARD

The costs or liabilities for acid mine/rock drainage can be divided into several categories.

**Operational costs**

These are the costs of operationally managing potentially acid generating wastes at currently operating mines. It includes the costs of selective handling, covering, encapsulation, the costs of waste characterisation and mine planning to manage the disposal of actual and potentially acid generating wastes. The presence of acidity also adds to costs of ore processing and environmental controls, including costs of water treatment, damage to impellers handling gypsum, and the need to establish due diligence must also be included.

The operational costs are based on an expectation that application of current technologies will satisfactorily control the release of acidity and heavy metals in the long term. The waste management practices to be applied will vary, depending on the orebody being mined, the benign materials available, the amount of potentially toxic wastes, acid generating wastes, and climatic factors.

The operational costs for waste management are paid by the individual mine operator as part of normal mining operational costs. The level of encapsulation and the engineering of the covers should be subject to normal cost/benefit analyses. For miners, the aim is to manage any sulphidic wastes by suitable covers and/or encapsulation to ensure that the site leases can be surrendered at the end of mining and potential liabilities are minimised. This requires demonstrating to the mine operator's own, the communities' and the regulators' satisfaction that any residual environmental impact is acceptable.

State Governments in Australia are imposing environmental bonds and controls to ensure that there will be enough funds available to ensure that a site will be rehabilitated at the end of mining. It is also in the miners best interest properly manage mine wastes; a poor environmental management record and poor rehabilitation make it more difficult for a company to be able receive approvals for new mine sites.

**Unexpected rehabilitation costs**

These are costs faced by the miner if acid drainage appears late in mine life or after closure. The likelihood of acid drainage appearing is of course greatest if there had been no waste characterisation and no attempt to integrate management of sulphidic wastes into mine operations. It can also occur where inappropriate or insufficient waste characterisation was performed, or the technology adopted to manage wastes was not effective. Many of the encapsulation and covering technologies now being used appear to be satisfactory but it will be many years before they can be considered proven.

In the case of unexpected rehabilitation costs, individual mine operators are liable for the additional costs involved in addressing and controlling the environmental impact. The costs can be high because remediation after mine operations cease involves remobilisation of equipment and the potential rehandling of large amounts of wastes.

**Historic site remediation costs**

Historic sites closed without adequate rehabilitation present a potentially large liability for governments and the community. Governments have had to accept responsibility for historic sites where mining ceased before current environmental regulations came into force. They can also become responsible for remediation of sites where it is not possible to assign remediation costs to the original site owner, for example because of lack of financial resources or that the company no longer exists. Even in recent times, there are examples of mines with acid drainage problems being sold by companies with the resources to fix the problem to exploration companies with little resources.

At some sites in Australia, a modern mining operation is being undertaken at the site of historic workings from earlier this century. Mine wastes from many historic operations have been reworked using modern technology to recover the residual resources that were left by earlier less efficient technologies, and this reworking usually results in more effective waste management with less likelihood of release of contaminants. At other sites, old deposits are being reworked with new more efficient mining techniques. This can be beneficial when the earlier workings are subsumed into the new mine which can lead to a reduction in long term environmental and safety problems. In some cases, the new opencut mine removes earlier shafts and wastes. In other cases, where the new mine is part of a larger historic site, the modern operator might not be held responsible for earlier workings. The final environmental impact can be lower if a responsible operator mines part of an abandoned site than if the whole site remains abandoned.

## 4.2 Costs of managing potentially acid generating wastes at operating sites

### 4.2.1 Kidston, Qld

Kidston is a large gold mine in the Mt Isa Outlier. Kidston has trialed two cover systems on one of its mineralised waste rock dumps. The first cover consisted of a 0.5 m compacted layer with a 1.5 m loose soil cover on top. The second cover consisted of a nominal 2.5 m loose material. The estimated cost of constructing these covers on other dumps is approximately \$60 000 and \$77 000 respectively assuming that the material can be recovered from the stockpile (N Currey, Kidston Gold Mines Ltd, Qld, pers comm, 11 April 1997).

### 4.2.2 Mt Leyshon, Qld

Mt Leyshon is a large open-pit mine producing gold, silver and copper with 5.5 million tonnes ore processed per year. The primary (unoxidised sulphidic) waste rock and ore contain various levels of sulphides mainly in the form of pyrite.

Much of the waste rock at Mt Leyshon has the potential to generate acid drainage. The dump is constructed with oxide waste and low-sulphur primary wastes placed around the periphery of the dump and potentially acid generating wastes in the centre. A 1 m layer of porphyry is placed on the dump and compacted. The porphyry has a significant acid neutralising capacity and is soft enough to be readily compacted to produce a low permeability cover. The cost of selective waste dumping and dump shaping is included in the mining costs. The total cost of dump rehabilitation for the flat surface, including covering, compaction, soil replacement, erosion control structures and quality control, was about \$12 000 $ha^{-1}$. The operational cost of producing the porphyry seal was \$4100 $ha^{-1}$ (Orr 1995b).

During mine operations at Mt Leyshon there are active unsealed areas of the waste dump and active ore stockpiles. To control the impact of these sources of acid drainage, the mine implemented a runoff control strategy based on runoff control dams, sumps, diversion weirs and water treatment. Total cost of the runoff control system at Mount Leyshon was approximately \$1 million, with annual operating costs of approximately \$40 000 (Orr 1995a).

### 4.2.3 Pajingo, Qld

Pajingo is a gold mine with both open cut and underground operations which commenced operations in 1987. Both the oxide waste and the sulphide waste at Pajingo have very low acid neutralising capacity. Even the low sulphur and low metal concentration oxide wastes are naturally acidic, and the sulphide wastes have significant net acid producing potential. In 1995, there was about 10 million tonnes oxidised waste, about 6 million tonnes sulphide wastes and 1.5 million tonnes tailings (Tredinnick & Cornwell 1995, Tredinnick 1995).

The sulphide and oxide wastes are segregated visually, basically by colour. The waste rock dumps and tailings dams were constructed with the sulphide waste encapsulated (below, around and on top) by oxide wastes. By designing the dump before operations began, only the oxide material for the dump caps had to be rehandled. The caps consist of a minimum of 3 x 0.5 m thick compacted layers of oxide wastes and on top a 0.5 m loose mulch layer. In some locations, up to seven 0.5 m compacted layers were required to achieve the desired surface slopes (Tredinnick & Cornwell 1995).

The rehandling of material for the cap involved a maximum haulage distance of 350 m. The capping operation was scheduled when equipment was available to avoid any mobilisation costs. The extra costs in managing the potentially acid generating wastes were limited to the capping operation; selective placement was considered to be within normal operations and incorporated into operational costs. The capping exercise cost approx \$50 000 $ha^{-1}$. The cost of supplies, minor earthworks and manpower for revegetation was approx \$1500 $ha^{-1}$ (Tredinnick & Cornwell 1995).

### 4.2.4 Pine Creek, NT

Pine Creek is an open cut gold mine which began operations in 1985 and closed in 1995. Acid drainage became a serious issue during the 1990/91 wet season when mining progressed into the unweathered primary rock zone. Acid seepage was detected leaching from the toes of the two waste dumps.

The North Dump of 10 ha and containing 900 000 bank $m^3$ (bcm) (ie the volume of rock before it is mined) was then reshaped, and capped with a low permeability layer of oxide material. The material used in rehabilitation was taken from a cut back in the open cut in progress at that time. The capping layer, 0.8 m on the batters and 1.2 m on the berms, was spread by graders and compacted by a vibrating smooth roller. Batters were covered with a layer of 0.4 m uncompacted oxide waste which was placed over the capping layer and seeded. Since placement of the capping, no evidence of acid drainage from the dump has been detected. The cost of capping the North dump in 1991 was \$36 000 $ha^{-1}$. This cost does not include the cost of mining and hauling the 150 000 bcm of oxide waste as it was necessary to mine this material and the costs were considered part of normal operations (Fawcett 1995).

The South dump, (45 ha containing 9 million bcm) started generating acid drainage in 1990. The first 7 ha was capped with spent heap leach material and the remainder with run of mine oxide material then available. The first 7 ha of capping cost \$27 000 $ha^{-1}$ (1991) but by 1993, the costs had been reduced to \$7000 $ha^{-1}$ (1993) (Fawcett 1995).

To manage potential acid production in the pit wall, the Enterprise Pit was flooded quickly by diverting a Wet season's flow from Pine Creek into the pit, which was then linked to Pine Creek to provide seasonal exchange of water and thereby prevent the long-term build up of acidity (Fawcett 1995).

### 4.2.5 Woodlawn, NSW

Woodlawn is a lead-zinc-copper-silver mine which commenced operations in 1978. It was initially an open cut operation but by 1989 all operations were underground. At Woodlawn, the severity of the AMD problem was grossly underestimated in the EIS produced in 1973/76 (Tarlinton 1995). Seepage from the waste rock dump turned acid four years after the initial placement of waste rock.

At the completion of open cut operations, the waste rock dump covered about 92 ha and contained about 80 million tonnes of overburden with approximately 6 to 7% sulphide content, mainly as pyrite. Most of the dump was sealed by compacting the top of the waste rock to 95% of the theoretical density to reduce infiltration. Areas where it was not possible to achieve the 95% theoretical density were treated conventionally with a 0.3 m layer of compacted clay. A 1 m layer of weathered rock and soil was placed on the compacted layer and revegetated (Tarlinton 1995).

The overall cost of rehabilitating the waste rock dump at Wood lawn was about \$7 million, or about \$50 000 per hectare (R Jackman, Woodlawn Mine, Tarago NSW, 16 April 1997). The cost of compacting the top surface of the Woodlawn dump with a large vibrating roller was \$3000 $ha^{-1}$ (Singline 1992).

## 4.3 Operational costs of managing potentially acid generating mine wastes

### 4.3.1 Covers

The costs discussed in section 4.2 for installing covers on wastes are summarised in table 4.1. The costs of compacting and/or covering potentially acid generating wastes are between \$10 000 to \$77 000 $ha^{-1}$. The costs depend greatly on the availability of suitable cover materials, the proportion of potentially acid generating wastes, the required thickness of covers, the number of layers compacted, the transport distances, whether material needs to be rehandled and the required hydraulic conductivity and/or oxygen diffusivity of the covers. On the basis of this limited information, it is estimated that the average cost of covering potentially acid generating wastes in Australia is \$40 000 $ha^{-1}$ if carried out during the life of the mine, and the potential for acid drainage is fully assessed before mining commences.

**Table 4.1** Estimated cost of covers for managing acid drainage at operational mines in Australia

| Site | Technology | Costs |
|---|---|---|
| Kidston | Cover<br>0.5 m compacted<br>1.5 m loose<br>2.5 m loose | <br><br>\$60 000 $ha^{-1}$<br>\$77 000 $ha^{-1}$ |
| Mount Leyshon, Qld | Compaction<br>Total inc revegetation etc | \$ 4100 $ha^{-1}$<br>\$12 000 $ha^{-1}$ |
| Pajingo, Qld | Capping,<br>3 x 0.5 m compacted layers | \$50 000 $ha^{-1}$ |
| Pine Creek, NT | Capping | \$7000 $ha^{-1}$ to \$36 000 $ha^{-1}$ |
| Woodlawn, NSW | Compaction cost only<br>Total rehabilitation | \$3000 $ha^{-1}$<br>\$50 000 $ha^{-1}$ |

The average cost of \$40 000 $ha^{-1}$ is consistent with the cost of constructing a 1 m cover if the typical costs of transporting and placing material at mine sites is \$4 per $m^3$. It is slightly higher than the unit costs of \$15 000 to \$30 000 $ha^{-1}$ used by the NSW Department of

Mineral Resources for the first pass estimate of rehabilitation costs in calculation of security deposits (Ken Hollands, NSW Dept. Mineral Resources, pers comm, April 1997). The cost of \$40 000 $ha^{-1}$ for operating sites is much less than the costs of rehabilitating wastes at historic or abandoned sites where there are additional costs of mobilisation, administration, usually greater transport distances and costs of establishing infrastructure. The costs of rehabilitating historic sites are discussed in section 5.2.

From the survey (section 3.6), the average amount of wastes at sites with significant amounts of potentially acid generating wastes is 20 Mt and 46 ha for waste rock dumps, and 14 Mt and 94 ha for tailings dams, giving a total area needing covers at each site of 140 ha. These numbers are based on a limited sample of sites, and are estimated to have an uncertainty of about ± 30%. The survey also indicated that 17% of mine sites responding were managing significant potentially acid generating wastes (section 3.5). If this proportion is representative of all sites in the survey, then there would be about 54 mine sites in Australia managing significant amounts of potentially acid generating waste rock, with a total area to be covered of about 7500 ha.

This area of 7500 ha is a snapshot of wastes at currently operating mines and includes all wastes at these sites to date. If this waste was produced in fifteen years, this would mean that about 500 ha of wastes would need to be covered in Australia each year. Assuming the average cost of covering the wastes is \$40 000 $ha^{-1}$, the operational cost of managing potentially acid generating wastes at these sites is about \$20 million per year.

As well as the sites identified as managing significant amounts of potentially acid generating wastes, there are other sites that have to deal with minor amounts of these wastes. Twenty per cent of the sites in the survey (63 sites) were considered to be managing minor amounts of potentially acid generating wastes (section 3.5). Costs of managing the wastes at these sites will be perhaps half, or less, those for the sites with significant wastes. Hence, the indicative total cost for installing covers across the Australian mining industry is \$30 million ± 10 million per year.

#### 4.3.2 Selective handling

Usually the management of sulphidic wastes will involve the selective handling of potentially acid generating wastes and placement either in separate dumps and tailings dams or at specific locations within waste rock dumps and tailings dams. Selective handling involves additional costs in establishing the appropriate operational mining plan, identifying waste types, sometimes transporting the wastes greater distances, and ensuring wastes are dumped at correct locations. These costs are usually included in mine operation costs. The cost of selective handling could be about 5 to 10% of the cost of transporting material, which suggests additional costs could be about \$0.2 per tonne. Based on an indicated average 20 Mt of waste rock at 54 mine sites and accumulated over a 15 year average mine life, the total amount of potentially acid generating waste is about 72 Mt per year. This would correspond to an additional cost for selective handing of about \$14 million per year.

#### 4.3.3 Analysis

Chemical analyses, monitoring and development of an appropriate management plan are additional costs for sites managing potentially acid generating wastes. The additional analyses required (mineralogy, chemistry, columns, waste characterisation, geology, block modelling) are estimated on average to cost about \$500 000 over ten years. This cost is based on 500 samples at \$250 per sample for acid base accounting and NAG, 10 column tests at a cost of \$10 000 per column test and 50 mineralogy samples at \$500 per sample giving a total startup cost for waste characterisation of \$250 000. Subsequent characterisation costs during mining are assumed to be 10% of the startup cost per year, ie $25 000 per year. The total over 10 years for analysis at a typical mine site is $500 000.

Most mines surveyed should undertake some waste characterisation, but the more significant costs only apply to those sites established as dealing with potentially acid generating wastes, both significant and minor amounts. Based on the 117 mine sites identified as managing some potentially acid generating wastes (section 3.5), the additional cost of analysis could be $6 million per year in addition to that spent on normal environmental issues.

#### 4.3.4 Water treatment

At sites located in higher rainfall regions, the presence of potentially acid generating wastes and ores will mean installation of water management and additional water treatment plants. Perhaps 30 mine sites will need to spend $2 million capital cost each 10 years and $200 000 per year operating costs and materials. On an annual basis this corresponds to $12 million per year.

#### 4.3.5 Total operational cost

The operational costs are summarised in table 4.2 with somewhat arbitrarily assumed uncertainties. The total operational cost for managing potentially acid generating wastes in the Australian mining industry is estimated to be about $60 million ± 20 million per year, where the uncertainty is assumed to be the sum of the uncertainties in each item. Over 15 years, the total cost for managing potentially acid generating wastes at current Australian mine sites would be about $900 million.

**Table 4.2** Estimated annual operating costs for managing potentially acid generating wastes at Australian mine sites

| Item | Annual cost |
|---|---|
| Cost of covers | $30 million ± 10 million |
| Selective handling | $14 million ± 5 million |
| Analysis & monitoring | $6 million ± 2 million |
| Water treatment costs | $12 million ± 4 million |
| Total | $62 million ± 21 million |

These cost estimates are indicative of what the industry has to spend to ensure that acid drainage does not become an issue during mine operations and after closure. Whether they are incurred depends to a large degree on the environmental criteria that have to be met and the technology available to manage potentially acid generating wastes. The costs for individual sites will be a function of the climatic conditions and the sensitivity of the receiving environment.

### 4.4 Limits on unexpected rehabilitation costs

Unexpected rehabilitation costs at the end of mine life, such as can occur if acid drainage is suddenly discovered being released from the site, are likely to be considerably larger than the costs of remediation undertaken as part of normal mining operations. At worst, a large quantity of waste might need to be rehandled and placed in a new location or in a better designed waste emplacement. The costs of rehandling the wastes would typically be in the range of \$2 to \$5 per tonne which can result in very large amounts for current operations. Rehandling 10 Mt of waste could cost between \$20 million and \$50 million.

Alternatively, it might be necessary to place appropriate covers on wastes after mining has ceased. Because this would involve remobilisation of plant and obtaining suitable materials and probably extra transport of materials, the installation of covers after mine operations have ceased is likely to cost between \$50 000 and \$100 000 $ha^{-1}$. For a typical site of 130 ha, the cost of these covers could be between \$6.5 million and \$13 million. For historic sites the costs are estimated to exceed \$100 000 per hectare, see section 5.2.

Additional costs could also include installation of a water treatment plant, perhaps \$2 million initially plus \$200 000 per year and possibly a wetland filter for rehabilitation of downstream surface waters.

This analysis has not included costs of remediating ground water contamination. Any requirement for remediation or containment of polluted ground water could add substantially to remediation costs.

# 5 Liability of historic mine sites

Australia has a large number of historic mines. In New South Wales there are about 20 000 locations scattered through the State from mining and prospecting activities; some are small scrapings, whilst others support currently operating mines (Department of Mineral Resources NSW 1996a). In Tasmania, there are 3000 recorded mineral deposits and mines, with probably a thousand historic sites of significance. In Queensland there are estimated to be 60 000 abandoned mining tenements (J Bywater, Qld Dept. Mining & Energy, pers comm, 27 March 1996). It is not known how many of these sites are releasing acid drainage, but perhaps between a tenth and a third involve potentially acid generating wastes. Most States are developing registers of contaminated lands or derelict sites which will include mine sites.

In 1995/96, the NSW Department of Mineral Resources with the support of the Department of Land and Water Conservation and the Environment Protection Authority began a 10-year program of orphan mine rehabilitation, with a funding of \$500 000 per year (Department of Mineral Resources NSW 1996a). In addition the NSW Environment Protection Agency has assessed about 2000 derelict sites in the north of New South Wales. Twenty-four were considered to be high environmental risk, and acid drainage was the main concern at two-thirds of these sites (A Read, NSW Environment Protection Authority, pers comm, 1996).

A selection of the more significant historic sites in Australia that have released acid drainage are described in the following section.

## 5.1 Historic mines in Australia that released acid drainage

### 5.1.1 Agricola, Queensland

Gold was mined at Agricola in Queensland's Sunshine Coast hinterland between 1975 and 1988 when the company went into liquidation leaving a 12 ha contaminated site with a pit containing about 10 ML water and acid generating waste rock. The site was rehabilitated in 1995/96 by capping the tailings dam, treating pit water to remove copper, blasting the pit walls to fill the pit, and capping the pit with a 1.5 m clay layer. Rehabilitation will allow the site to be returned to the Conondale National Park (Department of Minerals and Energy Queensland 1996, Hirsch 1996).