



**Queensland
Government**

**Environmental
Protection Agency**

**FINANCIAL ASSURANCES
CALCULATIONS FOR LEVEL 2
MINES PROJECT**

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INTRODUCTION

The purpose of this manual is to provide EPA officers with a transparent and consistent tool to assist in the calculation of Financial Assurances for "Level 2 Mining Operations". The manual provides a list with examples of the various disturbance types likely to be encountered, proposes practical reclamation methodologies and provides calculations for determining the actual cost of reclamation.

The primary objectives of reclamation works to be undertaken on these types of mining operations are:

1. Remove safety hazards to humans, stock and native fauna.
2. Return the land as quickly as possible to accepted subsequent land-uses.
3. Minimise the potential for ongoing erosion.

The intention of the calculations for determining Financial Assurances is to set a realistic cost for undertaking reclamation works on a mine-site should the leaseholder default and the responsibility for undertaking the works falls on the state. For this reason, typical 3rd party rates have been used to calculate all of the tasks listed in this manual.

Throughout this document reference is often made to specific equipment types, eg; Caterpillar D6H dozer, this is done solely for the purposes of illustrating the type of equipment used for developing and costing the methodology, and typically would represent the most suitable size of equipment for that task. The use of a specific equipment model is based on the type most likely to be found in a contractors fleet in Australia, the use of other similar sized/performance equipment will not alter the cost to undertake the described task in any significant way. What may be encountered in the field is lower hourly rates quoted for similar model equipment that is significantly older than that used for these costings, for example a Caterpillar 950B loader built in 1980 compared with a Caterpillar 950G loader built in 2000. In this case the hourly rate will likely be lower for the older piece of equipment, however, its performance/productivity will also be lower compared with the newer model, hence the overall production unit rate will remain similar. The use of brand names is not an endorsement of one brand of equipment over another.

DISTURBANCE TYPES

This section of the manual details the various disturbance types likely to be encountered in the field by EPA staff when inspecting Level 2 Mines and provides typical examples of many of them.

Disturbances have been broken down into the following categories:

- Small to medium tracks
- Haulroads
- Exploration drill-holes
- Exploration costeans
- Exploration pits
- Shafts
- Adits
- Hardstands
- Stockpile pads
- Overburden & waste rock dumps
- Reject stockpiles from washing plants
- Topsoil stockpiles
- Borrow pits
- Shallow open pits
- Open pits >10 metres deep
- Water storage dams
- Tailings/slimes dams

TRACKS, ROADS and HAULROADS

Small Tracks are defined as those that have only been used for light vehicle access. The tracks will typically consist of two wheel tracks, frequently with grass still between the wheel tracks (Figure 1).

Figure 1 illustrates two forms of light vehicle tracks, the upper track has been constructed by side cutting the slope, while the lower is the simpler type, consisting of two wheel tracks.



Figure 2 Examples of light vehicle tracks

Reclamation Objective

To restore areas affected by road construction to a condition that will support the establishment of native vegetation or pasture, remove any interference with pre-existing drainage patterns, minimise visual impact and discourage vehicle access.

Reclamation Method

- Windrows are graded back onto the track surface.
- Track is ripped lengthwise using a Cat D6H dozer, or equivalent, fitted with triple tyne rippers, ripped to a depth of approximately 300 - 400 mm.
- Bunds are pushed up across the track at regular intervals to inhibit water flowing along the track.
- Seed will be hand broadcast immediately after ripping.

Medium Tracks and Roads (Figures 2 & 3) are those that:

- Are generally less than 4 metres in width.
- Have been constructed primarily for use by light vehicles and drill rig access.
- Do not use cut and fill in their construction and/or have not involved substantial earthworks.
- Have not been sheeted with primary rock.
- Have not been used as haul roads.



Figure 3 *Example of low impact medium track*



Figure 4 *Example of moderate impact medium track*

Haulroads

Haulroads are roads that have been used by heavy construction and mining equipment, usually for the transport of ore and/or waste rock to the processing plant and waste rock dumps respectively (Figures 4, 5 & 6). The surfaces are heavily compacted and have been constructed of imported fill. The surface has often been raised 0.5 to 1.0 metre above the surrounding land. The alignment typically has required significant modification to the original drainage patterns usually requiring the installation of culverts.

Usually there has been an additional buffer of up to 5 metres on either side of the road cleared of all vegetation to allow for table drains, this must be added to the footprint of the haulroad when calculating reclamation costs (Figure 4).



Figure 5 Example of well formed haulroad - note areas of impact beyond pavement surface

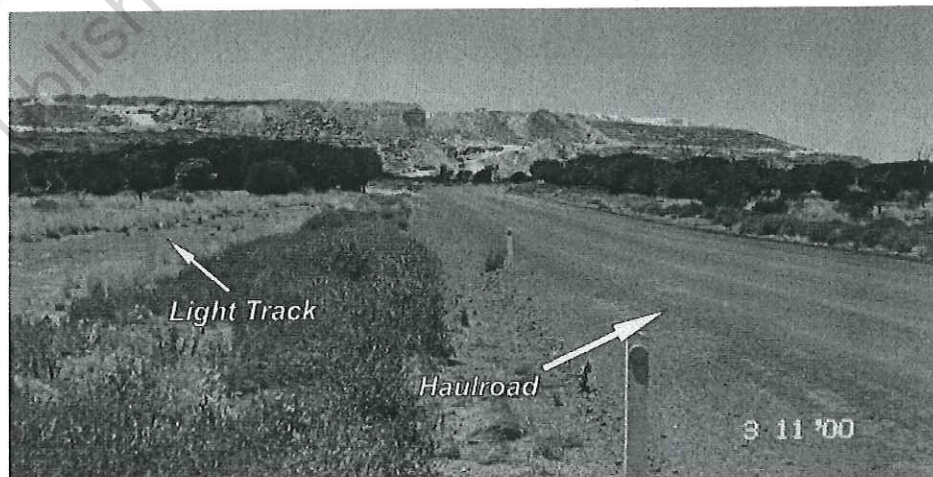


Figure 6 Examples of a haulroad and adjacent light vehicle track



Figure 7 *Moderate sized haulroad constructed without imported fill*

Reclamation Objective

To rehabilitate haulroads to a condition that will support the establishment of native vegetation, remove any interference with pre-existing drainage patterns, minimise visual impact and discourage vehicle access.

Reclamation Method

- Windrows are pulled back onto the road surface and where necessary the road edges are battered to 10° using a 20 tonne excavator, (it is assumed that 25% of the roads will require excavator work while the remaining 75% can be done with a 14G/16G grader or equivalent).
- Topsoil spread to a depth of 50 mm.
- Ripped to a depth of approximately one metre, spaced two metres apart, using a D10N dozer fitted with a single shank ripper.
- Bunds are pushed up across the track at regular intervals to inhibit water flowing along the track.
- Any pre-existing watercourses are reinstated.
- Culverts are removed
- Topsoil is spread to a depth of 0.05 metres thick prior to scarification.
- Scarified along contour to a depth of 300 mm with a D6 dozer or 14/16G grader or equivalent.
- Revegetate.

EXPLORATION DRILL-HOLES and SAMPLES

It is common to find exploration drill-holes in the vicinity of mining operations, sometimes they have been plugged as shown in the figures below, others will be found open (Figure 7). Un-rehabilitated drill-holes constitute a serious hazard to native fauna and a safety hazard to humans and stock. Open drill-holes function as a pit fall trap and have been known to trap large numbers of small mammals, reptiles and amphibians. A survey undertaken in the Fitzgerald River National Park in 1980 of two uncapped drill-holes found; 70 mammals and 209 reptiles had been trapped in them.



Figure 8 Typical exploration drillhole with PVC collar pipe - note conical concrete plug in top

Drill-holes can be either vertical or angled and some may have either a PVC or, occasionally, a steel collar pipe protruding from ground level (Figure 8).



Figure 9 Another example of a PVC collared drillhole - note in this case it has a PVC cap over the end



Figure 10 Example of an area with a high density of exploration drill-holes

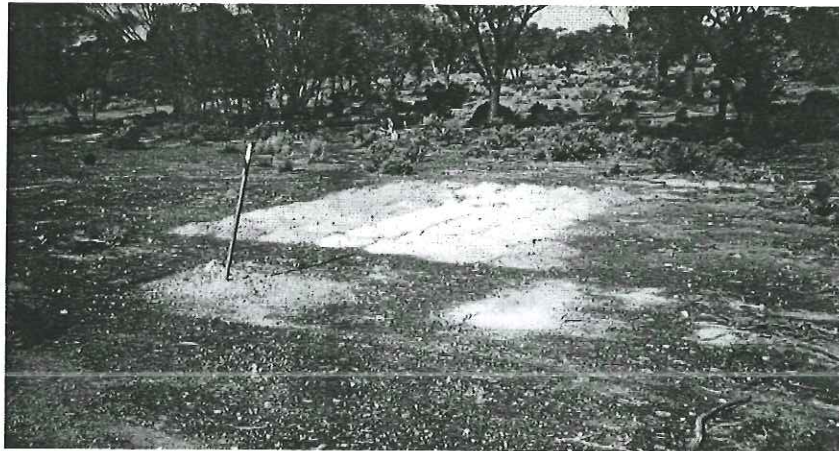


Figure 11 *Typical drill site with piles of drill cuttings laid out after sampling*

Open drill holes occur in a number of diameters and two basic forms:

- Holes that have an intact PVC collar pipe
- Holes without an intact PVC collar pipe

Each of these types requires a different plugging method to ensure the integrity of the plug.

Reclamation Objective

To permanently seal off drill holes and ensure that they cease to be a hazard to humans and animals.

Reclamation Method for PVC collar pipe

Drill holes that still have an intact PVC collar pipe may be rehabilitated in the following manner.

- The PVC collar pipe is cut off at least 500 mm below ground level (at least a 300 mm long section of PVC pipe should be left in the ground to allow the plug to seat and support it).
- The cut-off section of collar pipe is removed and collected for disposal.
- A cast conical concrete plug is then inserted in the hole and seated on the remaining PVC pipe.
- The hole is then backfilled to ground level.

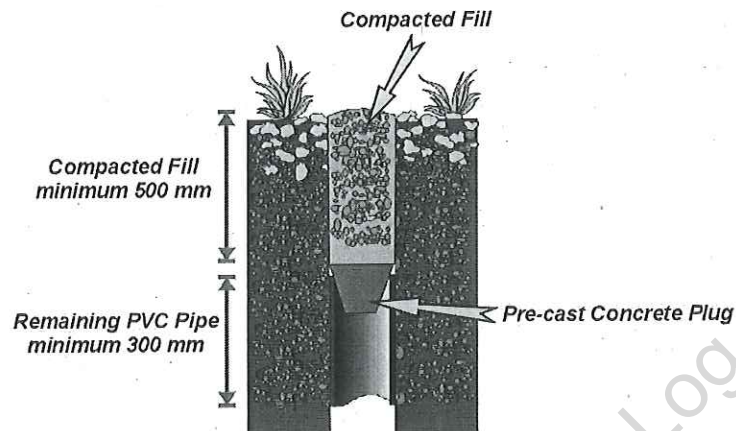


Figure 12 Reclamation method for drill-holes with a PVC collar pipe

Reclamation Method for non-PVC collar pipe

Reclamation of drill holes that do not have a PVC collar pipe requires particular care to ensure the long-term effectiveness of the plugging procedure. Failure to locate the plug securely will allow water to erode around it, causing it to sink and the hole to reopen. Plugs must be placed at least 0.7 to 1.0 metre below the natural ground surface.

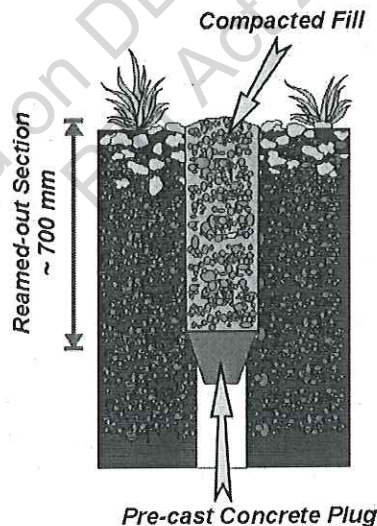


Figure 13 Reclamation of drill-hole without collar pipe

The reclamation procedure is as follows:

- The first 0.7 to 1.0 metre of the drill hole must be reamed-out or counterbored (ie: 100 mm holes opened to at least 150 mm and 150 mm holes to 200 mm) to ensure that the plug will stay in place and neither rotate, tip, or continue to slide down the hole during backfilling.

- A cast conical concrete plug is then inserted in the hole and seated at the bottom of the reamed-out section.
- The hole is then backfilled to ground level with compacted material. Failure to adequately compact the backfill material will compromise the integrity of the plug, leaving the backfilling slightly mounded above the surrounding ground level.

Samples

It is common to find sample residues (drill cuttings) adjacent to drill-holes, often they are in plastic or calico bags. Where the drill-hole has extended beyond the base of oxidation there is potential for the drill cuttings to be acid forming. Sample bags should be collected and either removed from site for disposal elsewhere. Where there is concern about the geochemical properties of the drill cuttings the following procedure should be followed.

An appropriately sized hole should be excavated and all of the sample material collected and placed in the base of the excavation, before backfilling it with the excavated material then, if available, covering it with a thin layer of topsoil. Where possible aim to get at least a 500 mm thick layer of cover over the sample material, (ideally 1.0 metre).



Cross-section of buried sample material

Figure 14 *Buried problematic sample material*

EXPLORATION COSTEANS

Costeaning is an exploration technique that will be encountered occasionally. Un-rehabilitated costeans represent a serious safety hazard to humans, stock and native fauna. Figures 14, 15 & 16 illustrate three levels of costean, Figure 14 is freshly dug, while Figure 15 & 16 have been left un-rehabilitated for some years.



Figure 15 Example of a large costean - costeans of this size are a significant safety hazard.



Figure 16 Medium sized costean that has been left unrehabilitated for some years



Figure 17 *Broad shallow costean left open for a extended period of time*

Reclamation Objective

To backfill costeans to ensure that they cease to be a hazard to humans and animals.

Reclamation Method

The most practical and effective method for rehabilitating costeans is to completely backfill them. Usually there is a spoil pile adjacent to the costean containing the material excavated during its construction. This material can either be reclaimed and placed back in the void using an excavator or backhoe, or pushed back in using a dozer or loader.

Backfilling using an excavator/backhoe is the preferred method as it allows for the material to be placed back in the costean in roughly the same order as it was excavated, this method more closely represents the original undisturbed soil profile. The use of an excavator/backhoe also allows for some compaction effort to be applied with the back of the bucket during the filling process, therefore minimising the amount of consolidation that will subsequently occur.

As with most backfilling operations, aim to slightly overfill the excavation, leaving it lightly mounded, this will allow for the effects of consolidation of the backfill overtime.

EXPLORATION PITS and DRILL SUMPS

Exploration pits will typically only be encountered in either historical mining areas or in areas where exploration for alluvial deposits has been undertaken. Depending on their condition or age they may be hazards to animal and/or human safety. Drill sumps will be found where diamond drilling has been undertaken.

Typically exploration pits are no more that 2 to 2.5 metres deep by a couple of metres square. In the case of old pits where there has been considerable slumping of the walls to the stage where a humans and animals could safely enter and exit the excavation, (and no spoil pile remaining adjacent to the pit), then it may be appropriate to leave them untouched, this will

depend on site specific conditions. Where the pits are steep sided or there is a spoil pile adjacent, the pits should be backfilled to surface.

Drill sumps will usually have similar dimensions to those mentioned above and will often be lined with plastic to minimise seepage. Sumps should be free of standing water before reclamation. Where a plastic liner has been used this should be removed for disposal off site, then the sump backfilled using the material excavated from it originally.



Figure 18 Example of an exploration drill sump using a plastic liner
(photo: Qld EPA)

SHAFTS & ADITS

Often small mining operations will have shafts and adits on them, as this is not usually a mining method for modern small miners (with the exception of the Gemfields) they date back to historic working of the sites. Unsecured shafts in particular, and to a lesser extent adits, represent a significant safety hazard to humans and animals.



Figure 19 Typical historic mine shaft

Abandoned historic shafts can present a serious safety risk to humans and animals. However, balanced against this, they have often acquired significant heritage value and may also retain some value for future mineral exploration.

Historic shafts are classified as those that were sunk from the late 1800's through to the early to mid 1900's. Typically, they are relatively shallow, ie. less than 50 metres deep, unlined, with dimension of 2.0 metres by 1.5 metres for the collar has been assumed. There is often some timber reinforcement remaining around the collar, and a bund of rock immediately surrounding the shaft.

Reclamation Objective

To rehabilitate historic shafts to a condition that prevents either accidental or intentional entry by people or animals, using a method that does not require ongoing maintenance or inspection, while maximising the opportunity to reopen the workings at a later date (if required).

Reclamation Method

The reclamation method is to excavate the collar out to a standard size, for example, 2.6 metres by 2.1 metres to a depth of 1.5 metres below ground level. A pre-cast reinforced concrete slab is then lowered into the shaft and set on the ledge created by the excavation. The shaft is then backfilled to slightly above ground level using rock from the collar bund and excavation.

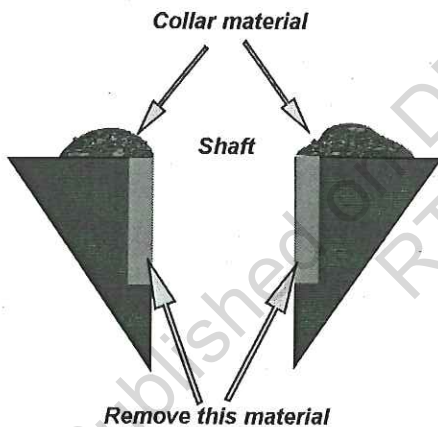


Figure 20 Shaft prior to excavation & cap placement

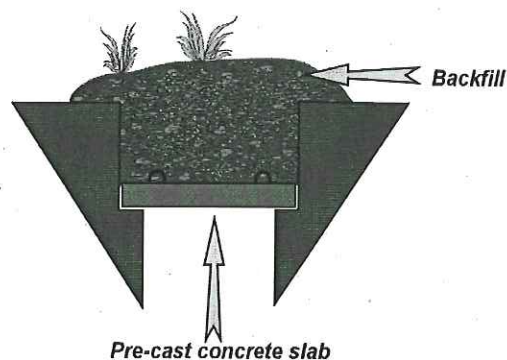


Figure 21 Shaft after cap placement & backfilling

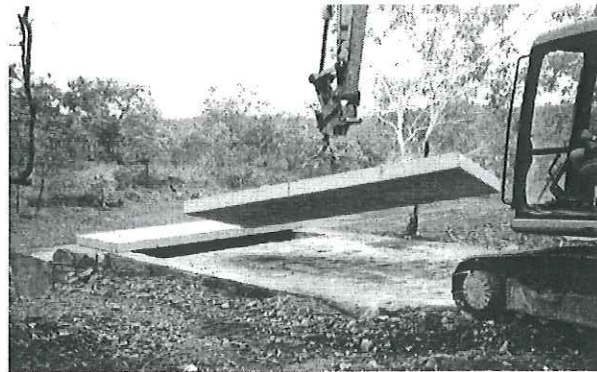


Figure 22 *Pre-cast concrete caps being placed over prepared shaft collar*

Place a sign with the following or similar wording: "CAUTION - Capped Mine Shaft Below" into the backfill mound.

When the concrete slab is being cast, it should have at least two (ideally four) steel lifting lugs and a number of drain holes (≥ 25 mm) set in it.

Where it is considered necessary to keep the shaft open (eg. for Bat access) then a steel grate can be fitted over the shaft opening. In this case, it will probably be necessary to cast a concrete collar (if one does not already exist) around the top of the shaft.

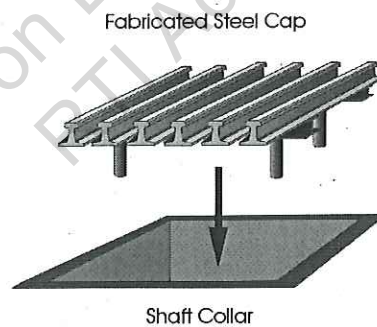


Figure 23 *Example of shaft cap using railway iron*

Alternative reclamation methods for shafts may include backfilling (particularly for shallow shafts), where backfilling is used particular care must be taken to avoid the backfill material bridging. When this occurs it frequently fails at a later date (especially after rainfall events), resulting in an open shaft again. When backfilling shafts use relatively small sized material that is clean (ie; no rubbish, steel, timbers or trees) to minimise the potential for brid

HARDSTANDS

Hardstand areas can be divided into two sub-categories; Medium Level Disturbance and High Level Disturbance, depending on their previous use and level of impact.

Medium Level Disturbance areas are those that have been substantially cleared of vegetation and possibly topsoil, and are subject to occasional vehicle traffic, and are frequently used for the short or long-term storage of materials and rubbish. Topsoil stockpile, low grade ore and reject stockpile areas may often fall into this category.



Figure 24 Example #1 of a Medium Level Disturbance area



Figure 25 Example #2 of a Medium Level Disturbance area

High Level Disturbance areas are those that have been completely cleared of vegetation and topsoil. They include the surrounds of processing plants, workshops, administration buildings, stores, transformer yards, etc. Active ore stockpile areas, run of mine (ROM - crusher/plant feed) pads are considered high level disturbance areas. Due to constant trafficking, they generally have a high degree of compaction. Depending on the activities that were undertaken within the area it may be necessary to undertake site-specific contamination investigations before planning reclamation works.

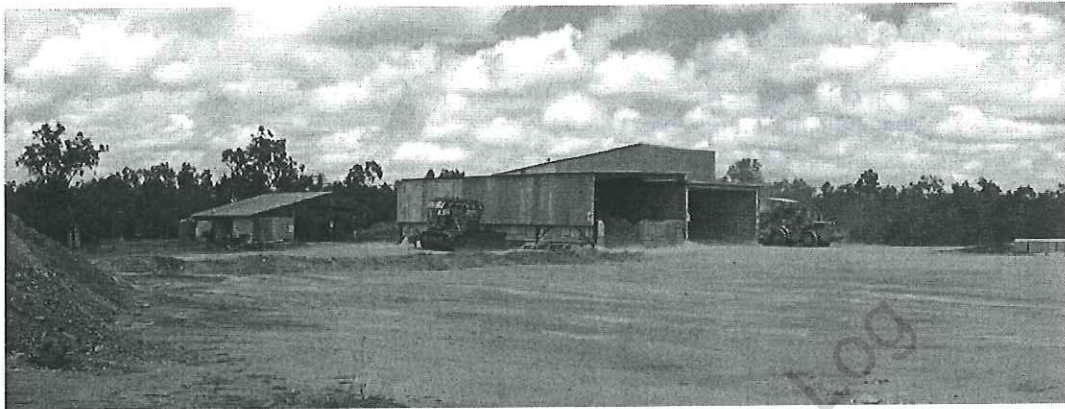


Figure 26 Example #1 of a High Level Disturbance Area



Figure 27 Example #2 of a High Level Disturbance Area

Reclamation Method

Objective

To rehabilitate laydown areas, hardstands, plant sites and other disturbed areas to a condition that will: support the establishment of pasture or native vegetation, remove any interference with pre-existing drainage patterns, minimise visual impact and discourage vehicle access.

Medium Level Disturbance areas will be rehabilitated in the following manner:

- Reprofiled with a D6 dozer to remove any windrows, hollows or incompatible land-forms.
- Scarified along contour to a depth of 300 mm with a D6 dozer or 14/16G grader or equivalent.
- Revegetate.

High Level Disturbance areas will be rehabilitated as follows:

- Reprofiled with a D10 dozer (or similar) to remove any windrows, hollows or incompatible land-forms.
- Ripped to a depth of approximately one metre spaced two metres apart using a D10 dozer fitted with a single shank ripper.¹
- Return the pre-stripped surface layer before scarifying.
- Scarified along contour to a depth of 300 mm with a D6 dozer or 14/16G grader or equivalent.²
- Sown with pasture or native shrub and tree seed.

STOCKPILE PADS

Most mining operations will have stockpile pads of varying sizes depending on the nature of operation. Typically they have been used to temporarily store excavated ore either prior to loading for transport to a processing plant, or as a feed stockpile at the processing plant. Given the nature of materials processed by mines designated as "Level 2 Mines" it is unlikely that land contamination from the ore will be an issue.

For the purposes of reclamation methodology and costs stockpile pads can be considered the same as "High Level Disturbance Areas".

¹ The methodology described above is used to derive the costings and is not intended to be overly prescriptive, depending on the site conditions it may only be necessary to rip to remove surface ponding and eliminate compaction.

² Scarifying is recommended in conjunction with ripping as it eliminates the deep furrows and the significant surface disturbance caused by deep ripping, this is desirable in forming a seed bed for revegetation and eliminates the safety hazard sometimes associated with deep ripped furrows.

OVERBURDEN & WASTE ROCK DUMPS

Overburden or waste rock dumps (WRD's) are common to most Level 2 Mines, however, their size (footprint and height) will vary considerably from site to site. For Level 2 Mines, leachate quality emerging from WRD's should not be an issue. The primary issues will generally be:

- Land-form stability.
- Land-use
- Preventing dispersion of erosion products (silt into waterways).
- Vegetation establishment.
- Safety.



Figure 28 *Example of moderate sized WRD after initial reshaping - prior to final works & revegetation*

Generally WRD's will have angle of repose faces (typically around 36°) and consist of a single lift.



Figure 29 *Typical small WRD with angle of repose faces*

Reclamation Method

Objective

To rehabilitate WRD's and overburden/spoil piles to a condition where they will be relatively stable compared with natural conditions and support vegetation. These methodologies and accompanying calculations assume that leachate emerging from the WRD's is of a quality that is acceptable for release into the receiving environment, this should be confirmed before planning reclamation works.

Initial land-forming

Initial land-forming will consist of reshaping the dump to remove steep slopes on the batters and managing surface flows after rainfall events. The upper surface of the dump can be shaped to be either water-shedding or water-retaining depending on individual requirements. For Level 2 Mines where leachate quality from WRD's is not considered to be an issue, then a water-retaining upper surface is generally preferable.

For the outer slopes of WRD's, the slope angles should be reduced to at least a minimum of 20° (~1 in 3). It is particularly important for final surface preparation to ensure a 1:3 slope minimum as this is the maximum angle that equipment can work safely and productively on. Ideally, the selection of final slopes will be made on the likely erosion properties of the material contained within the WRD. For dumps containing oxide waste rock, slope angles of around 12° (1 in 5) will be generally be more stable.

Surface preparation

Correct surface preparation is absolutely fundamental to ensuring the stability of WRD surfaces. If done incorrectly, erosion will initiate before vegetation can be established and in some cases may lead to the failure of revegetation programmes.

Where it has been decided to shape the upper surface of the WRD to be water-retaining, then the most stable land-form is a concave (dish shape) surface, rather than bunding the crest (Figure 28).

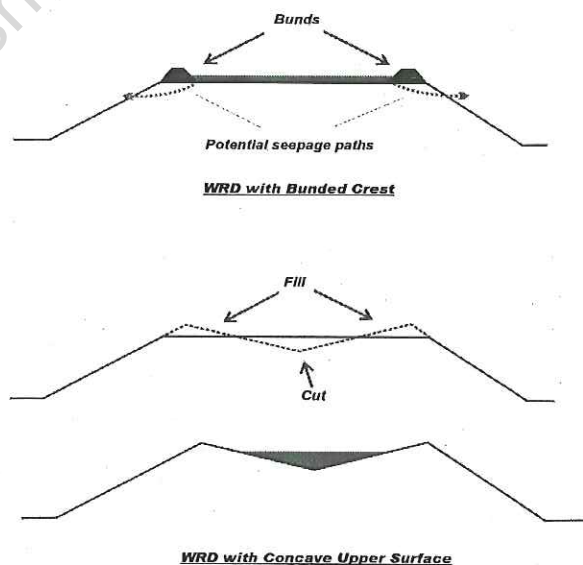


Figure 30 Bunding vs Concave Upper Surfaces on WRD's

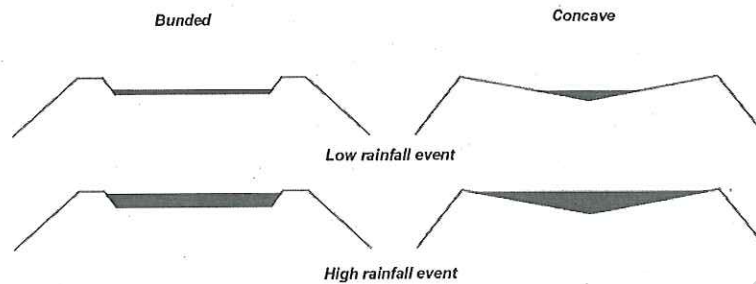


Figure 31 Water Storage Characteristics of Bunded vs Concave Upper Surfaces on WRD's

Figure 29 illustrates the advantages of a concave surface over using bunds on the crest.

With bunds, regardless of how little water is ponded on the upper surface, it will always be against the bund. This allows for potential seepage or piping to occur through to the slopes of the WRD, immediately below the bund. Once this occurs, even if only in one area, the integrity of the entire water retention system is lost. Another factor that contributes to the failure of bunds is that the edges of WRD'S are usually poorly compacted and hence very porous, therefore encouraging seepage of any water ponded behind the bund. Porosity of the bund itself is another issue, unless they are completely compacted, they will remain quite porous.

The primary advantages of having a concave upper surface are:

- A concave land-form will only allow water to pond near the outer edges of the upper surface during extreme design events. Under the majority of events water will only pond within the inner section of the land-form.
- If under an extreme, beyond design event upper surface containment is breached, there is only likely to be a partial loss of subsequent containment ability.

By contrast, a bunded upper surface stores water against the bund regardless of the rainfall event size. This increases the potential for piping to occur and hence the likelihood of failure, because once piping initiates, it becomes a preferential flowpath.

Where space permits, as a rule of thumb slopes should be approximately 1V:5H (12°) and should never be steeper than 1V:3H (~20°). For developing costings involving WRD reclamation it has been assumed that slope angles are currently at the angle of repose and require dozing down to the final slope angle.

The traditional approach to forming batters or outer slopes of waste rock dumps, tailings dams etc., has been to form the slopes at 20 degrees (1 in 3) with intermediate berms, typically at about 10 metres vertical spacing. Usually the berms were 5 to 7 metres wide sloped at 1 in 10 back to the face with 1 in 100 to 1 in 150 fall along them. Again, 20 degree slopes are approximately the steepest slope that earthmoving equipment can safely work. Drainage from the catch berms can be either managed via drop structures placed at regular intervals, or by running the berms into surrounding hills.

A WRD constructed to these guidelines is unlikely to be a stable land-form for a long period of time and will require continual ongoing maintenance.

Construction of intermediate berms or catch benches will ultimately lead to severe erosion and

gullying on dump faces when the berms fail, only continual repairs and maintenance will prevent the berms from failing. While intermediate berms will usually work for the short-term, they are almost certain to fail over the medium to long-term, once the following factors come into play:

1. Over time, sediment will collect in the cells created by the inter-bunds leading to a reduction in runoff storage capacity ultimately resulting in overtopping and containment failure.
2. Storing water in cells on the batter will almost certainly lead to piping over time, particularly as the berms and bunds will be constructed from essentially unconsolidated material.
3. Erosion of the bunds will reduce their storage capacity over time.
4. Differential consolidation of the WRD over time may cause sections of the bunds to no longer collect or retain runoff.

There is now a trend towards designing waste rock dumps with concave slopes without intermediate or catch berms. Ideally, the angles used to form the concave slopes are **site and material specific**, and should be based on the erosion resistance properties of the particular waste rock type used. The principal behind this type of design is to manage water velocities down the slope such that they do not exceed the critical shear value for the particular waste type; as the volume of water on the slope increases due to increasing catchment as it moves down the slope, the slope angle is decreased in order to reduce the velocity. Particular attention needs to be given to formation of slopes in order to avoid concentration of water flows as this will rapidly lead to formation of erosion gullies.

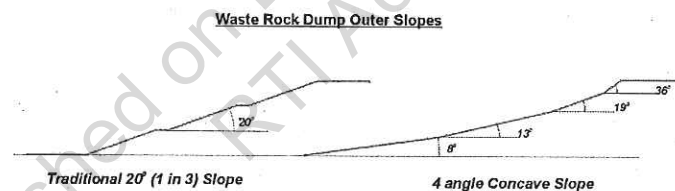


Figure 32 Comparison of Traditional vs Concave Outer Slopes on a WRD

Figure 30 represents the ideal situation, however, due to their small size and limited resources, it may not be practical to apply these principals to Level 2 Mines, hence the selection of 1V:5H (12°) wherever possible.

Correct final surface preparation is fundamental to both slope stability and the successful establishment of vegetation. The critical factors are final shaping methods and accuracy of contouring. All slopes must have their final shaping done along contour and not as is commonly done, down slope. The purpose of completing the final shaping along contour is to remove any linear features down slope that may have been formed during the primary shaping work.

Great care must be taken to ensure that all scarifying is also done exactly to contour, as only slight deviations from contour can initiate the formation of erosion gutters. Not only is this a concern from the point of erosion, but it also provides a potential conduit for seed to wash away. To ensure the operators keep their machines on contour while scarifying, the contours must be pegged out using a dumpy level. Contours should be marked out at between 4 to 10 metre intervals down slope and every 20 to 50 metres along contour, depending on the complexity of

the surface shape and size of the WRD. No matter how competent the machine operator is, it is impossible to stay exactly on contour without using marker pegs.

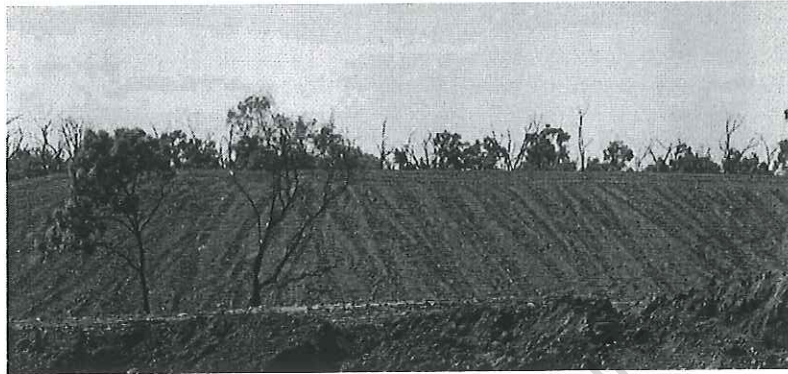


Figure 33 *Example of WRD Requiring Further Surface Preparation Prior to Revegetation*

REJECT STOCKPILES FROM FIXED WASHING PLANTS

Within the range of Level 2 Mines covered by this manual the most likely types that will produce washing plant rejects are: gem and alluvial gold operations. The reject from these operations should generally be considered benign.

Rejects are defined as, "the coarse product that comes off the top of the screen or out the end of the trommel", the remainder of the material that passes the screen or trommel in a wet process is the tailings or slimes and is usually discharged to a dam.

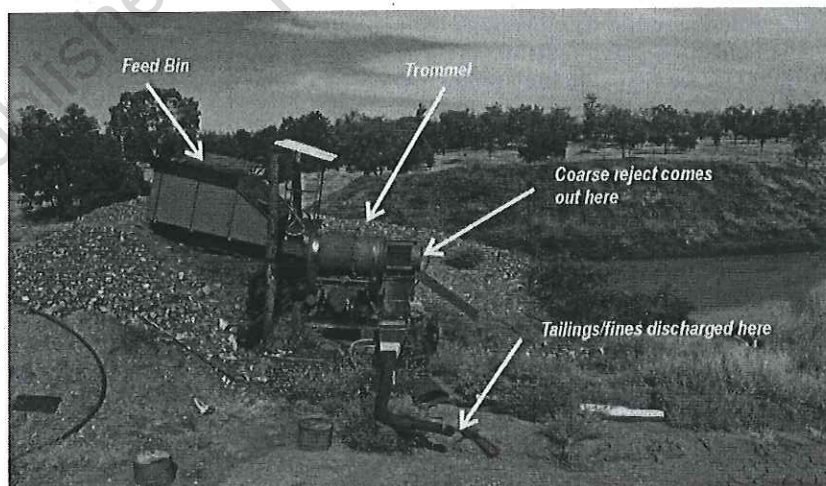


Figure 34 *Trommel type screening plant showing reject and tailings discharge points*



Figure 35 *Small scale screening/washing plant*

Figures 32 & 33 provide examples of typical small scale alluvial plants used in the gem fields.

As the fine fraction of the material has been removed during the screening process, coarse reject stockpiles are generally unable to readily support vegetation.

Reclamation Objective

To remove reject stockpiles and rehabilitate associated impacted areas, remove any interference with pre-existing drainage patterns and minimise visual impact.

Reclamation Method

Generally reject stockpiles will have to be removed and the area they occupied rehabilitated in accordance with the methods outlined in the Hardstands section. The coarse reject material may be useful as an erosion resistant material for lining watercourses, incorporating into waste dump surfaces or working into the surface of tailings dams.

Reject stockpiles for Level 2 Mines are assumed to not exceed 10,000 m³ in volume, the basis for this assumption is in selection of equipment most likely to be suitable and available to undertake reclaiming the stockpile. Where stockpiles significantly exceed this volume it may be practicable to use slightly larger equipment with some corresponding economies of scale to reduce the unit rate.

It is assumed that a truck and loader fleet will be used to undertake reclaiming the stockpile, alternatively an excavator may be used, the selection of a loader or excavator will not have any significant impact on the unit rate. A six wheel drive articulated dump truck in the 25 tonne range has been used for the costings as this is likely to be the most suitable type of vehicle for this task given that ground conditions may be poor, particularly if trafficking tailings dam surfaces.

TOPSOIL STOCKPILES

Many operations may have topsoil stockpiles resulting from pre-stripping of pits or stockpile pads. Where a site has topsoil stockpiles all efforts should be made to incorporate the topsoil into the reclamation works. It should be noted, however, that when the stockpiles have been sitting for a few years they are unlikely to be a significant source of desirable seeds or micro-organisms. Often old topsoil stockpiles have become colonised with undesirable plant species and/or weeds, if this is the case, they should be treated with appropriate herbicides before using them.

There may be cases where using weed infested topsoil, even after herbicide treatment, is not recommended, particularly where the stockpile was infested for some time with weed species whose seeds remain viable for many years. If this is believed to be the case then the topsoil should be buried.

BORROW PITS

Borrow pits will be encountered frequently on Level 2 Mines where they have been used as sources of road building material and for plant site and stockpile pad base formation. Generally borrow pits will not exceed 2 metres in depth.

Due to their shallow depth, reclamation of Borrow Pits is generally a simple and straight forward operation. For the purposes of costing the methodology and rates developed for Hardstands should be used.

OPEN PITS

Whilst the ideal option for closure of open pits and similar excavations may be backfilling, in many cases this is not economically viable. Where the pit must be left open, then the primary concern must be for human and animal safety. Other factors that should be considered when planning the reclamation strategy should include; land use objectives, access to stored water, final water quality and long-term stability. The methodology proposed following assumes that water quality will be suitable for stock watering.

There are two main methods for making open pits safe: ;

- Flattening the walls to an angle that removes the potential for falling into the pit.
- Erecting an abandonment bund around the perimeter of the pit.

Depending on circumstances and location it may also be necessary to erect a fence around the pit.

Flattening Pit Batters

This option is likely to only be suitable for shallow pits up to ~ 10 metres in depth, where increasing the footprint of the excavation is not an issue. Flattening batters can be accomplished using either a bulldozer or an excavator. If room and materials permit, the ideal slope to create should be around 1 in 3 (18 degrees). At this angle, it is possible for most earthmoving equipment to work along slope when required and will allow for light 4WD vehicles to access.



Figure 36 *Example of shallow open pit with potentially unstable batters and incorrect bunding*



Figure 37 *Example of shallow open pit with unstable batters and no bunding*

Abandonment Bunding

The Western Australia Department of Industry and Resources has issued guidelines for the construction of abandonment bunds around open pits. They are summarised following:

Bund walls should be:

- Located at least 10 m outside the area overlaying the potentially unstable rock mass, i.e. the total of the width of the "potentially unstable pit edge zone" plus 10 m away from the existing pit edge.
- Of the following minimum dimensions: height 2 m, base width 4 m.
- Wherever possible, constructed from unweathered, freely draining, end dumped rock-fill. When only oxidised rock is available for construction of the safety bund wall, the least weathered or hardest material should be used. In these cases, the bund wall may need to be supplemented by a properly constructed fence.
- Suitable signs, clearly stating public safety risk and prohibiting public access, should be erected outside the safety bund wall.
- Shrub and/or tree planting at the outside edge of the bund wall should be implemented where practicable, to lessen the visual impact of the wall.

The potentially unstable pit edge zone, in pits excavated in weathered/oxidised rock, is defined as the distance between the existing pit edge and the point where a plane drawn at an angle of 25° from the slope toe intersects the ground surface.

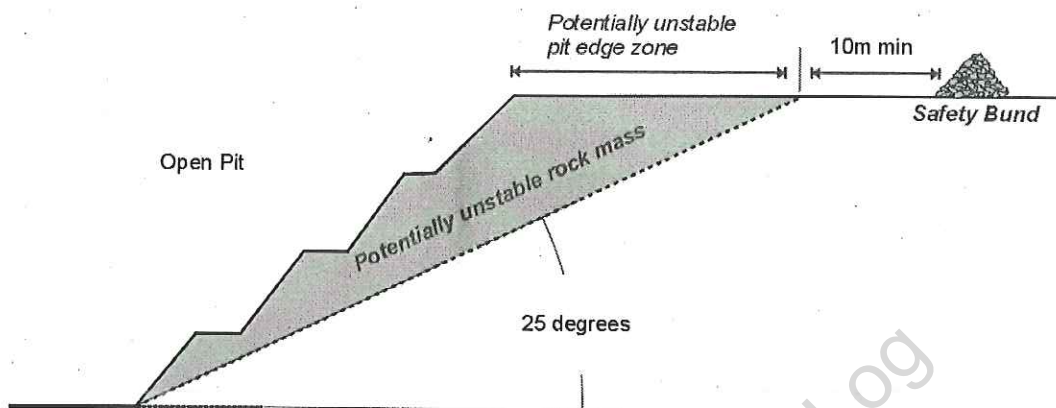


Figure 38 Potential area of instability for a pit excavated in oxide rock

The exact position of the safety bund wall can be calculated once the final pit depths are known, however, this does not affect the size of the bund walls or significantly affect the quantity of material required to construct them.

It should be noted that the Queensland Department of Minerals and Energy - Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland (1995) also reference the WA Guideline.

The minimum volume of material required to construct the abandonment bund is calculated as follows:

2 metres high by 4 metres wide at the base with 1 : 1 faces gives a sectional area of 4 m^2 or 4 m^3 per linear metre, under field conditions given the normal angle of repose of waste rock of about 36° , this will typically equate to 5 loose m^3 per linear metre of bund.

While it may not be practical to construct the final bund around an open pit during the early phase of mining due to unavailability of suitable material, an interim safety bund must always be constructed adjacent to the pit crest.



Figure 39 Example of a well constructed. Long-term stable pit bund

WATER STORAGE DAMS

Depending on whether agreements are in place with the landholder, it may or may not be necessary to allow for the reclamation of water storage dams, generally the landholder may view them as an asset.

Where requirements exist for the dams to be removed at the completion of operations, there are two methodologies that may be appropriate depending on the type of dam construction method used. Dams will generally fall into one of two categories, or occasionally be a combination of both, they are:

- Excavated into the surrounding landscape with the walls formed of material borrowed from the floor of the dam. The Figure below is an example of that type of construction.



Figure 40 *Dam with walls construct from material borrowed from the floor*

- The second common construction method is to dam off a valley by constructing a wall across the valley floor to retain water (Valley Fill). Usually the wall will be constructed from earth fill, though occasionally concrete walls maybe encountered.

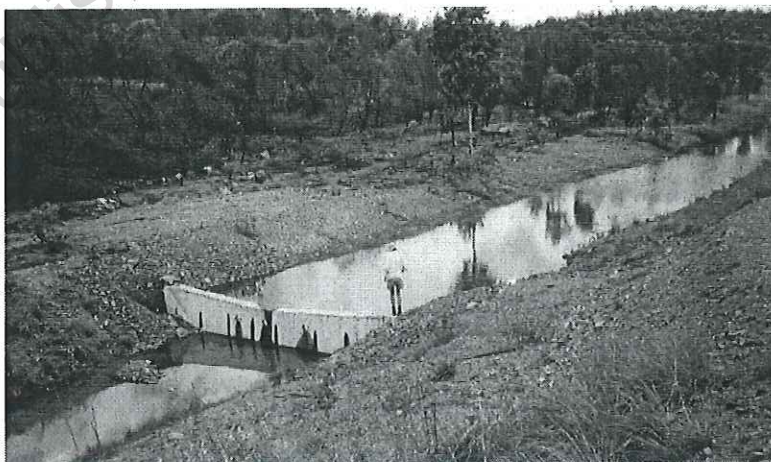


Figure 41 *Example of a small valley fill type dam using a concrete wall*

Reclamation Objective

To remove dam structures such that the former dam footprint is free draining, remove any interference with pre-existing drainage patterns and the area occupied by the dam will support the preferred vegetation type.

Reclamation Method

Type 1 - Borrowed and Pushed Up Walls

Either pump out any remaining water or breach the dam wall at the lowest point to drain remaining water. Note, care should be taken with regard to releasing suspended solids into receiving waterways if the latter method is selected. A water analysis should be completed before releasing any water from a dam.

Once the dam is completely drained, material from the walls can then be pushed back into the void, while doing this, note should be taken of any pre-existing drainage paths and these should be reinstated. If a drainage path is established along the dam floor, it should, if the material is available, be lined with erosion resistant material, alluvial plant rejects are ideal for this purpose.

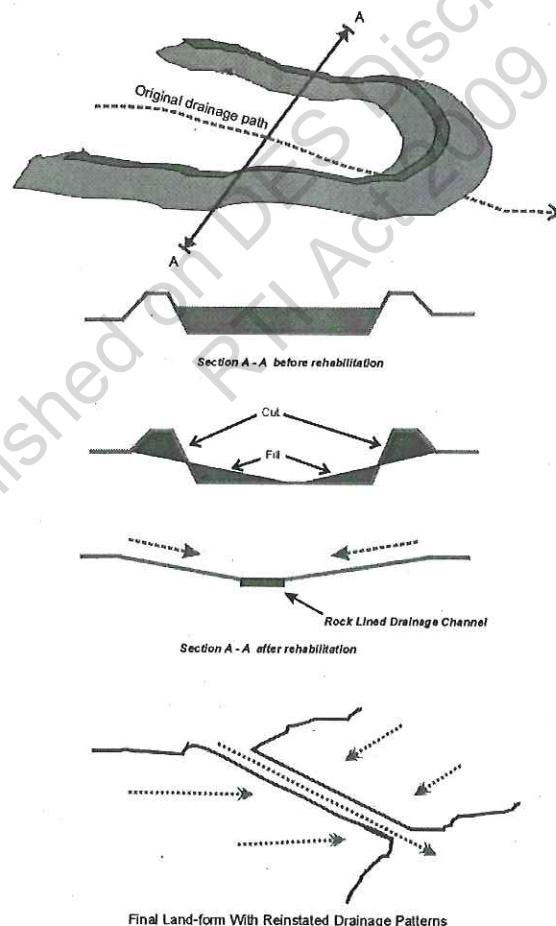


Figure 42 Reclamation of Type 1 Dam

Use the methodology outlined in the medium level disturbance section of Hardstands to rehabilitate the dam floor once the walls have been pushed in.

Type 2 - Valley Fill Walls

As with Type 1 Dams, any water behind the wall will have to be drained first, then for dams with earth fill walls, the wall material can either be excavated for disposal at a suitable location, possibly upstream of the wall in the former floor of the dam, or dozed and spread out.

Dams with concrete walls will have to have at least some of the wall removed, or entirely removed if that is the landholders requirement.

TAILINGS/SLIMES DAMS

As Level 2 mines do not use cyanide in their processing operations, nor do they contain residues from processing sulphidic ore, reclamation of their tailings and/or slimes dams is a relatively straight forward operation with the focus on long-term containment, erosional stability and surface water management.



Figure 43 *Old Valley Fill Tailings Dam with wall made from coarse tailings*

Within the scope of Level 2 Mines, tailings dams will generally contain either the fine screened fraction from alluvial plants or the residue from milling and grinding (particularly for oxide gold operations where the ore contains free gold and does not require cyanidation).

Reclamation Objective

The reclamation objectives are:

- Stabilise the surface of the tailings dam to a condition where it is safe for vehicles and animals to access.
- Reduce the rate of erosion from the surface and slopes (if any) to a rate acceptable to

stakeholders.

- Ensure long-term containment of the tailings.
- Create a free-draining surface that does not pond water.
- The surface will support the preferred vegetation type.

Reclamation Method

The methodology set out following assumes that cyanide was not used in processing the ore and that the tailings are not potentially acid rock drainage (ARD) producing. If the presence of either of these factors is suspected or there is a possibility of other environmentally harmful properties of the tailings, then a site specific investigation must be undertaken before determining an appropriate reclamation strategy.

It has been assumed that a 500 mm thick layer of competent, well graded, benign oxide material will provide a suitable cover material to meet the reclamation objectives.

Before placing the cover over the Tailings Dam the following issues need to be addressed:

- draining of ponded surface water.
- allowing sufficient time after tailings deposition has ceased for the tailings to have consolidated enough to support earthmoving equipment.
- reprofiling of the upper surface to create a free-draining surface.
- allowance for further consolidation of the tailings over time.
- embankment stability
- source of material to construct the cover with.

Initially the final land-form for the tailings dam must be formed, and if there is an above ground embankment, then it must have its batter angle reduced to a slope compatible with long-term stability; assume 1V to 3H.

Once the final land-form has been created, then the cover material should be placed in a single ~ 500mm thick layer, typically it will be necessary for the earthmoving equipment to stay on top of the cover layer during placement to avoid bogging in the tailings. As with waste rock dumps, all final land-forming should be done along contour to minimise the potential for initiating erosion gullies.

Slimes Dams from Mobile Processing Plants

This section deals with the management of slimes dams resulting from mobile mining operations located in ephemeral or seasonally affected watercourses. It sets out suggested management methods to minimise the potential for dispersion of the fine fraction (slimes) during high flow events. There is not a corresponding costing section for this item due to the fact that they should be managed during operations, it is unlikely that they will be present at closed down sites due to their inherent unstable nature if not managed correctly.

Alluvial mining for these types of operations usually only takes place during the drier months of the year when there is little if any flow. The exception to this is the use of dredges that are only limited by water depth and flow rate, although there is very little of this type of alluvial mining still

taking place. Mobile alluvial operations often do not have the option of constructing long-term containment structures beyond the flood level of the watercourse due to the terrain in which the operation is being conducted (steep and sheer sided valleys). In such a situation reject material must be returned into the channel itself. The rehabilitation method must reduce reactivation of the slimes and tailings during flow events. This can be achieved by encapsulating the finer fraction of reject material beneath the coarser fraction in the lower energy environments within the watercourse.

Conventional operation of mobile alluvial plants creates a slimes dam full of waterlogged clay-sized particles that can trap stock and native animals prior to it drying out. Addition of sand tailings to this material increases its load bearing potential, thus reducing the likelihood of bogging. Once the slimes material is partially consolidated the coarse cobble fraction of reject material can be placed as a rock armour over the entire dam area, keeping the structure as broad and low as possible. In order to minimise reworking of this material the dam should be located on the inside bend of the channel as high in the flood flow channel as possible. Taking these steps will reduce the rate at which the finer fraction of alluvium is returned into the riparian environment, reducing sedimentation rates further downstream.



Figure 44 Example of a slimes dam (photo: Qld EPA)

MOBILISATION/DEMOBILISATION

Mobilisation/demobilisation will typically not be a large amount for Level 2 mines given that the equipment used in general for reclamation works is relatively small and easily moved, and that the distances involved will also in general not be large.

Mobilisation & demobilisation is often set as 5% of the total earthmoving costs. For small to medium sized sites this is a fairly accurate estimate, however, if detailed composition of the proposed fleet requirements is known, then more accurate actual costs can be calculated using the table below.

Mobilisation / Demobilisation Schedule	
Equipment	Cost per km
773 (50 ton) Haul-truck	\$6.50
633 Scraper	\$5.00
25 ton articulated dump truck	\$4.50
769/773 Water truck	\$5.50
D10 Dozer	\$6.50
D6 Dozer	\$4.50
966 Loader	\$4.50
35 ton Excavator	\$5.50
20 tonne excavator	\$4.50
14G Grader	\$4.50
Road registered dump trucks	\$3.00
Service truck	\$2.50
Light vehicles	\$0.75

**GENERAL RECLAMATION METHODOLOGIES and
TECHNIQUES**

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GENERAL RECLAMATION METHODOLOGIES and TECHNIQUES

This section suggests reclamation methodologies that may be used to successfully rehabilitate the various disturbances identified in the preceding section. The costings developed in this manual are based on implementing the methodologies set out in this section. Before dealing with each of the specific disturbance types individually, the overall concepts of land-form stability, water management, surface preparation and revegetation are discussed.

LAND-FORM STABILITY

Long-term land-form stability is probably the most significant issue to be addressed during reclamation of Level 2 Mines. Failure to adequately account for the natural processes of weathering and erosion can lead to severe adverse environmental impacts.

The need to adequately manage surface runoff is just as important in arid areas of the state as it is in the higher rainfall areas. The reason for this is that initiation of erosion is related soil/rock material properties and surface water flow velocity. Surface water flow velocity for a given slope relates directly to rainfall event intensity and duration. Although the total annual rainfall in arid areas is substantially lower than coastal areas, the rainfall intensity during events and their duration is often similar, there are just less of them per year.

A guiding principal should be, wherever possible avoid concentrating surface flows, as this will create the highest likelihood of initiating erosion. In conjunction with minimising concentration of flows is the need to keep flow velocities as low as possible. In the absence of site/material specific data, water velocities should be kept below 0.5 m/sec in unlined diversion drains. It should also be remembered that virtually all constructed erosion control and water management structures will require ongoing maintenance to maintain their performance.

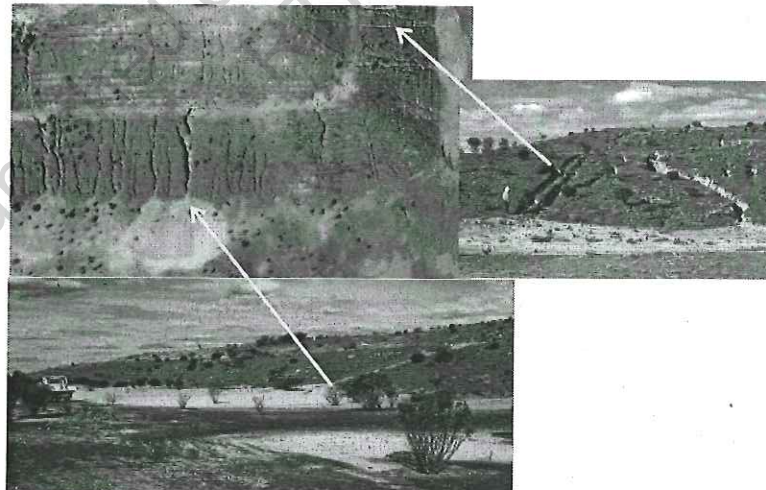


Figure 45 *Examples of waste dump erosion & long-term land-form instability*

Management of surface water flows is a critical component to ensuring long-term land-form stability. Runoff management techniques can be divided in to the following categories:

- Diversions - these may be divided into temporary and permanent structures, examples of temporary methods include:

Temporary diversion channels may be lined with; flexible membrane liner (HDPE etc), geotextiles, waste rock, straw matting

Long-term diversion channels may be lined with the following:

- Rock armouring (rip-rap).
- Gabion mattress (rock-filled wire baskets).
- Revetment mattress (concrete-filled geotextiles).
- Concrete.
- Vegetation.

It is sometimes necessary to construct energy dissipaters in order to reduce erosion at specific points in drainage channels, these energy dissipaters may take the following forms:

- Plunge pools.
- Rock or concrete impact aprons.
- Strategically placed large rocks.
- Vegetation barriers/screens (usually not suitable in high energy situations).

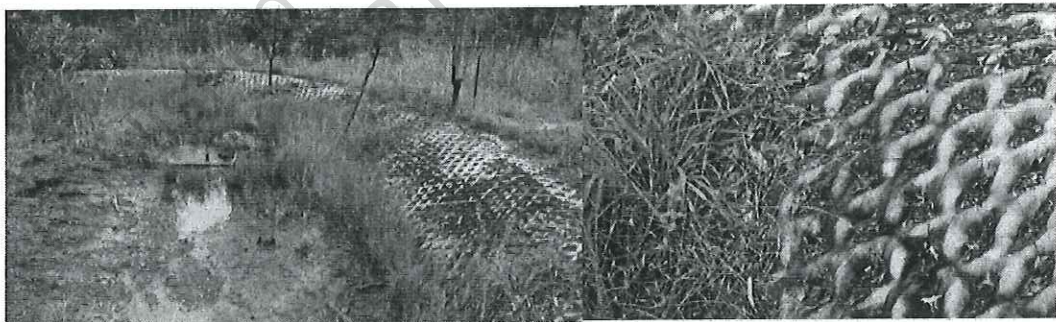


Figure 46 *Revetment Mattress installed on the outer radius of a drain to reduce erosion*

A common method used in construction of diversion channels is to step them along their fall rather than have them fall at a constant gradient. These types of drains are useful where larger volumes of water are involved and there is a shortage of suitable armouring material. This method reduces the water velocity and consequently potential erosion within the channel. It does however generally require construction of energy dissipaters at each fall.

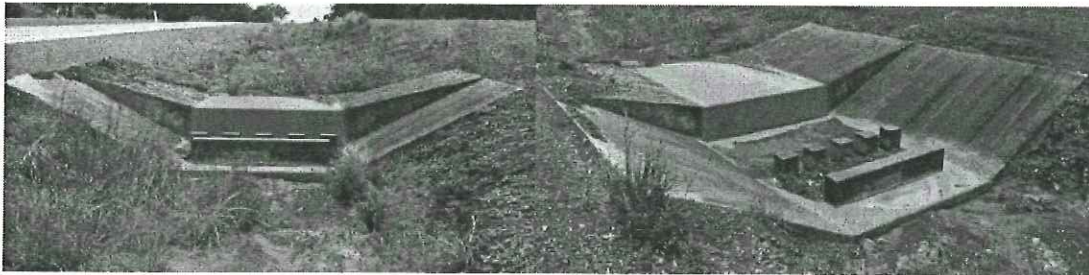


Figure 47 *Stepped drain with energy dissipaters installed*



Figure 48 *Stepped drain without energy dissipaters - note erosion that has occurred within 12 months of construction*

Sediment Control

Sediment control is another important aspect particularly during the early stages of mine development and during and immediately after reclamation works, when sediment loads are likely to be at their greatest. Techniques to minimise sediment discharges include:

- Silt fences (short-term).
- contour banks
- graded banks
- absorption banks
- sediment traps/dams
- vegetation filters/barriers
- temporary vegetative covers over disturbed areas.

Graded Banks

Graded banks or intermediate berms/catch berms are a frequently used method of managing flow on slopes of waste rock dumps in particular. Generally use of these types of structures should only be considered as short to medium-term solutions, due to their need for continual maintenance.



Figure 49 *Example of a waste rock dump with catch berms installed.*



Figure 50 *Example of a waste rock dump with recently installed graded banks.*

WATER MANAGEMENT

Management of water (both surface-water and groundwater) is fundamental to minimising potential impacts from mining operations. The guiding principal should be to keep non-impacted water away from potential impact sources as much as practicable, this will minimise the quantity of impacted water that then requires active management.

This section will also provide some overall guidelines for water management, also provides some simple tools that will assist site personnel in their day to day management of water resources.

The main tool that can be used for "keeping clean water clean" is construction of diversion channels (either temporary or permanent).

Designing Drainage Paths and Diversion Channels

This section is intended to provide some simple guidelines to enable site staff to quickly calculate the appropriate sizing for diversion drains, graded banks and similar structures. To design a watercourse it is necessary to know the peak flow.

The most common method of determining the peak flow is the Rational Method (SME 1992), the rational method is suitable for predicting peak flows for small to medium sized catchments (up to 400 hectares), the effects of infiltration are not accounted for, hence the results for larger catchments will be less accurate (WSDT 1997).

The formula for the rational method is:

$$Q_p = \frac{CIA}{360}$$

where: Q_p = peak runoff in m³/sec (cubic metres per second)
 C = runoff coefficient
 I = rainfall intensity in mm/hr (millimetres per hour)
 A = drainage area in ha (hectares)

where there are significant differing identified runoff coefficients within a single catchment the formula can be modified as follows:

$$Q_p = \frac{I(\sum CA)}{360}$$

where: $\sum CA$ = $(C_1 \times A_1) + (C_2 \times A_2) + \dots (C_n \times A_n)$
 ie: the sum of individual sub-catchment coefficients

Runoff Coefficients

The runoff coefficient (C) is the percentage of rainfall that becomes runoff, C will vary depending on a number of factors including; rainfall intensity and duration, vegetative cover, slope, surface features and antecedent rainfall events. While calculation of precise runoff coefficients is likely to be beyond the scope of most site personnel, the following table will allow calculation of approximate coefficients than when applied conservatively will allow peak runoffs to be determined.

A table providing runoff coefficients for various catchment conditions is provided in Appendix 1

Settlement Ponds

When calculating the size of a sediment or settling pond to contain runoff from a rainfall event the following formula can be used:

$$V = 10 \times C \times P \times A$$

where: V = the total runoff per event in k/L (kilolitres)
 C = runoff coefficient
 P = rainfall in mm/day (millimetres per day)
 A = drainage area in ha (hectares)

Example:

The catchment in question has a runoff coefficient estimated at 0.55

Rainfall event required to contain is 100 mm/day

Area of the catchment is 5 hectares

$$\begin{aligned}
 V &= 10 \times 0.55 \times 100 \times 5 \\
 &= 2,750 \text{ kl} = 2,750 \text{ m}^3
 \end{aligned}$$

SURFACE PREPARATION

Surface preparation is another area of high importance during reclamation and interim stabilisation works. Incorrect surface preparation will lead to the initiation of erosion and is also frequently the underlying reason for revegetation programme failures.

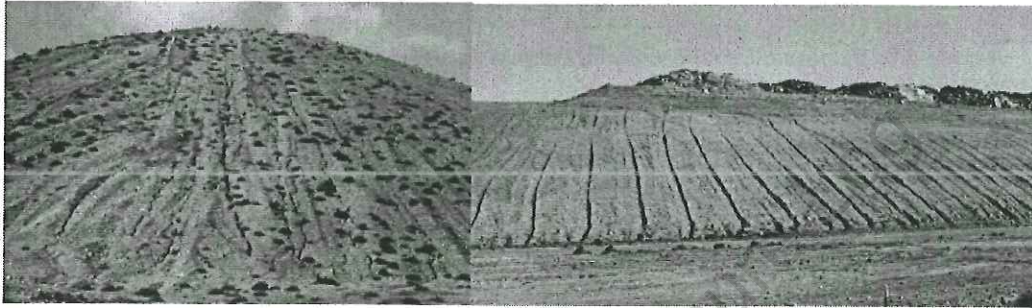


Figure 51 *Examples of poor surface preparation on waste rocks dumps*

The most common fault found on reclamation earthworks is the failure to prepare the final surface correctly before commencing the revegetation programme. This incorrect preparation is usually a combination of two factors;

- shaping and finishing of the surface with the machine working down-slope, and
- ripping or scarifying the surface other than exactly along contour.

The above figure provides examples of where the final shaping of a dump surface has been done down-slope, this has resulted in the formation of surface features that have initiated erosion.

Failure to rip or scarify **EXACTLY** to contour will also lead to the initiation of erosion gullies, this is because any slope in the rip lines will cause water to flow along them concentrating flow until the low point is reached, the accumulated flow then overtops the rip line and flows down slope to the next rip line to where it overloads it to failure point, and so on down the slope increasing the size of the erosion feature as it goes.

Incorrect surface preparation contributes to poor revegetation programme results when it allows surface water flows to concentrate to the point of cascading down the slope, this then washes away the majority of seeds sown, particularly lighter ones away as well as a significant portion of any fertiliser that was applied.

ROCK ARMOURING

Rock armouring is another useful method of reducing the rate of surface erosion to acceptable rates. Depending on the specific requirement, the amount of armouring material required may vary from a 100% coverage of the surface with a layer to a specified thickness, to incorporating 5% by volume of armour material into the upper 300 mm or so of the surface. This can be achieved using either agricultural cultivation equipment or dozer/grader mounted scarifiers/rippers.

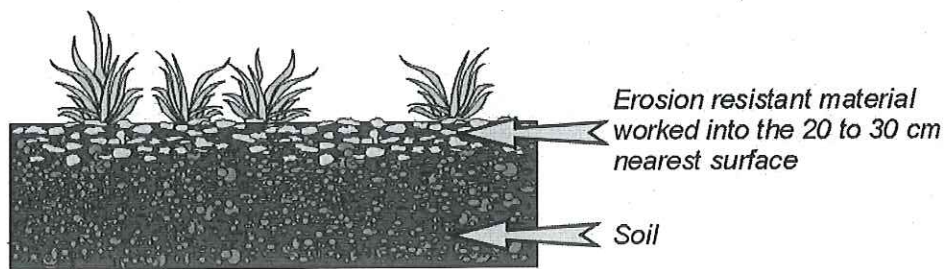


Figure 52 Illustration of working rock-armouring material into the upper surface.

REVEGETATION

The critical parameters that need to be correctly addressed in order to achieve successful revegetation are:

- Fertiliser application rate.
- Ground preparation.
- Timing of sowing.
- Soil type.
- Species selection.

While correct surface preparation is fundamental to the successful establishment of vegetation in reclamation areas, the timing and accuracy of contouring is also extremely important.

Timing

Timing of scarification is critical, and should only commence immediately prior to seeding. It may not be practical to scarify/rip more than one day ahead of sowing, as seed must be sown into freshly ripped furrows that have not been rained on. If an area receives rain before sowing the furrows will partially collapse and crust over, if this occurs the majority of seeds sown, particularly the lighter ones, will be washed away during subsequent rainfall events.

Surface Preparation

Great care must be taken to ensure that all scarifying is done exactly to contour, only slight deviations from contour can initiate the formation of erosion gutters. To ensure the operators keep their machines on contour while scarifying the contours should be pegged out using a dumpy level. No matter how competent the operator, it is impossible to stay exactly on contour without using marker pegs.

Reclamation areas should be scarified to a depth of approximately 200 to 300mm prior to seed sowing. Earthmoving equipment equivalent to a D6 dozer or 14G grader are ideal for this task, depending on the slope.

AREA, DISTANCE and VOLUME CALCULATIONS

Throughout this manual there is a need to estimate areas, distances and volumes in order to calculate the estimated reclamation cost for each item. Generally is not necessary to undertake detailed surveys in order to derive this information to the level of accuracy required for calculating this type of cost estimate. There are a number of simple techniques that field personnel can use to make these estimates to acceptable levels of accuracy.

Estimating Distance

This is the most important factor in most disturbance calculations, and there are a number of methods that can be used; the simplest being pacing. With a little practice it is usually possible to get the accuracy of pacing to $\pm 5\%$ over relatively smooth terrain, using a calibrated pedometer will assist in this task. The next level up would be to use a hip chain, these are worn on the waist and are used by tying cotton thread to the start point then walking to the end point, they measure distance by the amount of cotton thread fed out. Hip chains are very accurate with careful use ($\pm 1\%$). Hip chains are particularly useful over rougher terrain where it is difficult to maintain consistent pace length. GPS's can be used over larger distances where their levels of accuracy become acceptable. For measuring track and road lengths that are too long to pace practicably, using a vehicles odometer or a GPS will provide sufficient accuracy. Another simple method for estimating distances is to use ranging binoculars

Estimating Area

Estimating area for rectangular or square areas is straightforward; simply length times width, however, most disturbed areas are not regular rectangular shapes. Where this is the case the simplest approach is to break the area down into a number of regular shapes, ie; rectangles and triangles and calculate the area for each sub-component, see the example below where we want to estimate the area of the old hardstand (the perimeter is shown as a yellow dotted line):

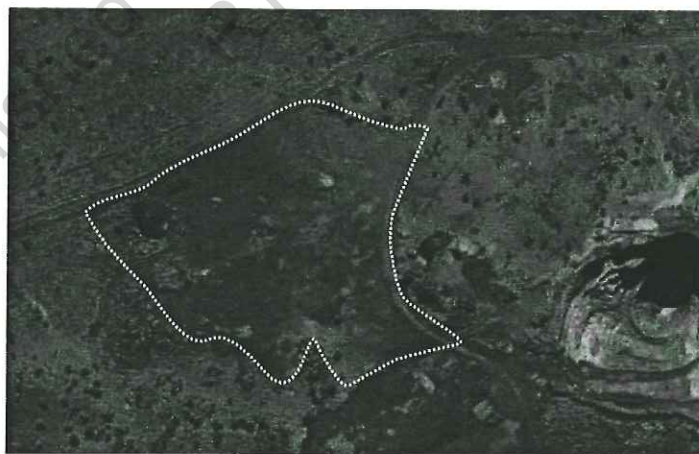


Figure 53 Example for area estimation

The area is broken down into a number of regular shapes as shown in the Figure below. When doing this on the ground it is best to mark each of the corners using pegs, flagging tape etc. the dimensions of the shapes can then be determined by pacing, using a hip chain or other suitable method.

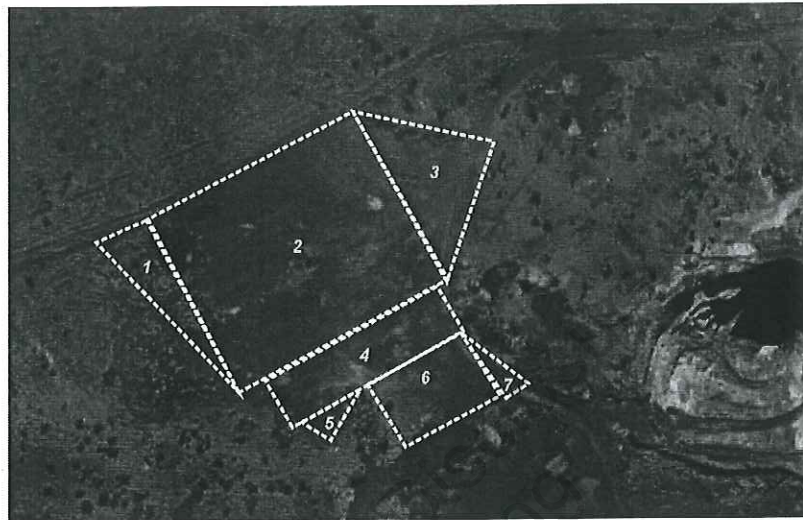


Figure 54 Example area broken down into regular shaped sub-components for simple area estimation

Estimating Height

Estimating height is somewhat more difficult than estimating areas, however, there are some simple techniques that enable estimation to a level of accuracy suitable for calculations in this manual. Set out following are some simple methods for estimating height of objects.

The Pen Method

To use this method you will need an assistant and a pen, pencil or similar length object.

- Have your assistant stand as close as possible to the item to be measured, ensure that they are as close as possible to the same distance away from you as the object you wish to measure the height of.
- Hold the pen/pencil vertically in your hand at arms length.
- Line up the top of the pen/pencil with your assistants head.
- Place your thumb in line with their feet on the pen/pencil.
- The pen/pencil now represents a calibrated measuring unit the same height as your assistant.
- Determine how many pen/pencil lengths it takes to reach the top of the object you require the height of and multiply that by your assistants height to determine the objects height.

Clinometer Method

This is a simple accurate method that can be undertaken by one person using a clinometer or Abney Level

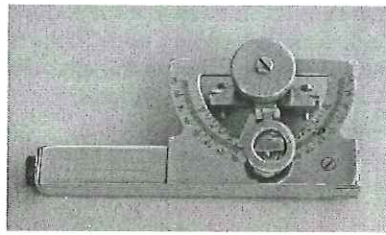


Figure 55 Abney Level

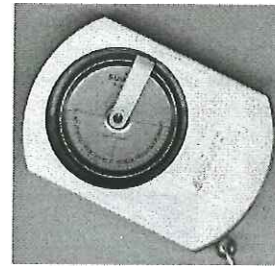


Figure 56 Suunto® Clinometer

Using the instrument take a sighting to the top of the object you need to measure the height of and record it, then measure the horizontal distance from your sighting position to the point you were measuring the angle to. Now calculate the height using the following trigonometric formula and then add your height to the result to determine the objects height.

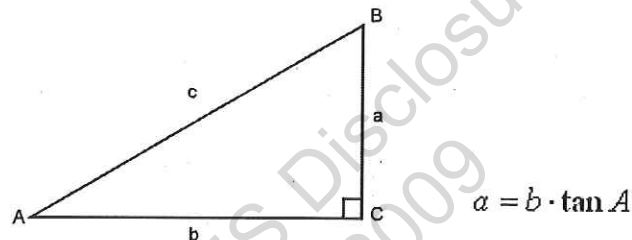


Figure 57 Right-angle triangles

Another simpler method is using a clinometer that gives readings in percentages, as shown in the example in the following Figure:

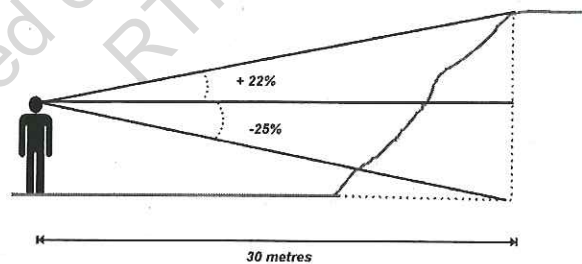


Figure 59 Height estimation using clinometer

$$\begin{aligned}\text{Object height} &= (22\% + 25\%) \times 30 \text{ m} \\ &= 14.1 \text{ m}\end{aligned}$$

Slope Angles

For the purposes of this manual assume that angle of repose faces on stockpiles, waste rock dumps etc are at 36 degrees. The actual angle will vary depending on the material type in the pile as well as its particle size, but these variations are not significant for the purposes of calculating volumes. If a more accurate reading is required or the face is not at angle of repose then a clinometer should be used.

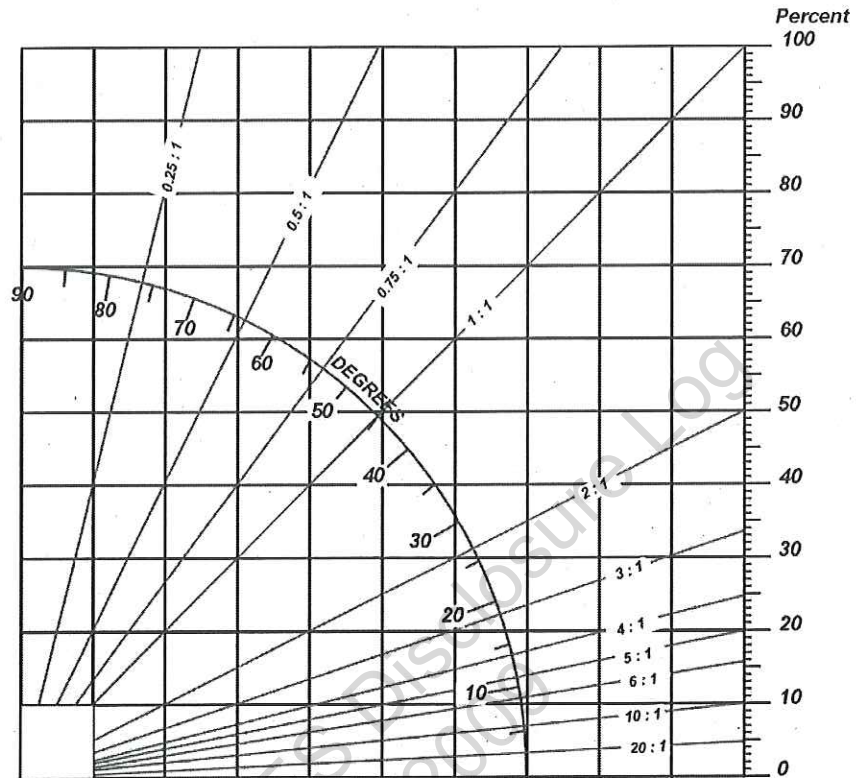
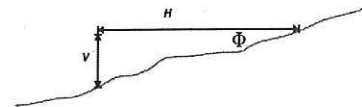


Figure 60 Chart of Slope Angles, Gradients and Percent

Grades in Degrees and Percent					
Degrees	Percent	Degrees	Percent	Degrees	Percent
1	1.8	16	28.7	31	60
2	3.5	17	30.6	32	62.5
3	5.2	18	32.5	33	64.9
4	7	19	34.4	34	67.4
5	8.8	20	36.4	35	70
6	10.5	21	38.4	36	72.7
7	12.3	22	40.4	37	75.4
8	14	23	42.4	38	78.1
9	15.8	24	44.5	39	81
10	17.6	25	46.6	40	83.9
11	19.4	26	48.8	41	86.9
12	21.3	27	51	42	90
13	23.1	28	53.2	43	93.3
14	24.9	29	55.4	44	96.6
15	26.8	30	57.7	45	100

$$\text{Gradient} = 1: \frac{H}{V}$$



$$\% \text{ grade} = \frac{100}{H} = 100 \tan \phi$$

To find slope angle ϕ

$$\phi = \frac{V}{H}$$

Appendix 1

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Rainfall Runoff Coefficient (C) Calculation Table - (Hannan 1984)

	75 - 100 mm/hr	0.30	50 - 75 mm/hr	0.25	25 - 50 mm/hr	0.15	<25 mm/hr	0.05
1 Rainfall Intensity								
2 Relief	<ul style="list-style-type: none"> Steep ugged ave slopes above 20% (12°) 	0.10	<ul style="list-style-type: none"> Hilly ave slopes 10 - 20% (6 to 10°) 	0.05	<ul style="list-style-type: none"> Rolling ave slopes 5 - 10% (3 - 6°) 	0.00	<ul style="list-style-type: none"> Ave slopes 0 - 5% (0 - 3°) 	0.00
3 Surface Retention	<ul style="list-style-type: none"> Negligible few surface depressions watercourses steep overland flow thin 	0.10	<ul style="list-style-type: none"> Well defined system of small watercourses 	0.05 +	<ul style="list-style-type: none"> Considerable surface depressions overland flow significant some ponds & swamps some surface cultivation earthworks 	0.05	<ul style="list-style-type: none"> Poorly defined & meandering streams large surface storage surface cultivation earthworks on 90% of the land 	0.00
4 Infiltration	<ul style="list-style-type: none"> No effective soil cover either solid rock or thin mantle 	0.25	<ul style="list-style-type: none"> Slow infiltration, eg: solodic soil when surface sealed 	0.20	<ul style="list-style-type: none"> Loam soil or well structured clay soils, eg: Chernozem 	0.10	<ul style="list-style-type: none"> Deep sand or well aggregated soils, eg: Kraznozems 	0.05
5 Cover	<ul style="list-style-type: none"> No effective plant cover 	0.25	<ul style="list-style-type: none"> Sheet eroded native pastures less than 10% under improved pastures clean cultivated crops 	0.20	<ul style="list-style-type: none"> Improved pasture not more than 50% cultivation or open woodlands 	0.10	<ul style="list-style-type: none"> About 90% of area with improved pasture or forest 	0.05

To use the above table, for each of the five parameters select the most appropriate condition for the catchment being studied. Add each of the five values together to get the runoff coefficient.

- * Reduce the runoff coefficient calculated by 0.05 when mean air temperatures exceed 25°C during rainfall (typically Northern & Northwestern Queensland).
- * Reduce the runoff coefficient by 10% for thick forests.

Appendix 2

COST CALCULATIONS

Notes for Cost Calculations

The costs set out in the following pages are calculated in 2005 dollars and do not include a component for GST. In the accompanying calculation spreadsheet a calculation for GST has been included. The examples following are provided to show the components included in each of the cost calculations used in the spreadsheet as well as providing examples for use in manual calculations.

The naming of specific equipment brands and models in the following pages was done for two reasons:

- Manufacturers productivity information was used (partially) in some of the calculations - in particular the Caterpillar Performance Handbook - various editions.
- Typically it is the type/size of equipment most likely to be found in a contractors fleet in Australia.

The use of other similar sized/performance equipment will not alter the cost to undertake the described task in any significant way. What may be encountered in the field is lower hourly rates quoted for similar model equipment that is significantly older than that used for these costings, for example a Caterpillar 950B loader built in 1980 compared with a Caterpillar 950G loader built in 2000. In this case the hourly rate will likely be lower for the older piece of equipment, however, its performance/productivity will also be lower compared with the newer model, hence the overall production unit rate will remain similar.

The costings have been calculated using the most efficient/practical piece of equipment for each task, significant variations away from these using smaller and or older models is likely to increase the overall direct cost of the task, as well as increasing indirect costs, in particular those associated with management and supervision.

PRODUCTION CALCULATIONS FOR Reclamation OF MINOR & MEDIUM TRACKS

Productivity & Costs

- Cat 140G Grader will grade in the windrows in second gear at 3 km/hr and require two passes, one on each side of the track. It will complete 1500 m of track per hour.
- At \$130 per machine hour the grading cost will be \$86 per kilometre.
- A D6H dozer will need two passes to rip the full width of the track, at an average ripping speed of 2 km/hr. It will complete 1000 m of track per hour.
- At \$130 per machine hour the ripping cost will be \$130 per kilometre.

Total \$ 216 per km

Note revegetation costs have not been included in the above calculations.

Note: the Financial Assurance Calculation Spreadsheet allows for the input of variables for pavement width etcetera, the above provides an example for manual calculation only.

PRODUCTION CALCULATIONS FOR Reclamation OF HAULROADS

Productivity and Costs

- Cat 14G grader will grade in the windrows at 1.5 km/hr and require two passes, one each side of the road, it will complete 750 metres of road per hour. Machine cost is \$130 per hour.
- A 20 tonne excavator will complete 250 metres of road per hour (both sides). Machine cost is \$115 per hour.
Total cost per km to pull in and level windrows is \$245 per km.
- A D10 dozer will require 5 passes to rip the entire width of the pavement, machine cost is \$285 per hour. At an average ripping speed of 1.5 km/hr, it will complete 300 m of haulroad per hour.
The cost per km of haulroad to rip the surface will be \$950 per km.
- Construction of bunds is assumed to cost \$50 per bund and the placement frequency is assumed to be one bund every 100 metres of road length.
The cost per km for bund construction is \$500
- It is assumed that two pre-existing watercourses will need to be reinstated per km of haulroad. Cost is assumed to be \$100 per item.
The cost per km for reinstating watercourses is \$200
- It is assumed that two culverts will need to be removed per km of haulroad. Cost is assumed to be \$250 per item.
The cost per km for removing culverts is \$500
- Topsoil is spread on the 12 metre wide section of the road by a 633 scraper at a cost of \$2.14 per m³ (= 600m³ per km).
The cost per km for topsoil placement is \$1284
- Scarification costs and production rates are calculated on using a Cat D6H dozer fitted with triple shank rippers ripping to a depth of approximately 0.3 metres. 3 metres width covered per pass. It is assumed that the full width of the road corridor (5 + 12 + 5) will require scarification.

D6H dozer \$130 per hour
Dozer speed 2 kph
= 4980 m²/hr (0.83 efficiency)
= \$574 per km

Cost

Windrows	\$245
Deep rip	\$950
Bund	\$500
Watercourses	\$200
Culverts	\$500
Topsoil	\$1284
Scarification	\$574
Total	\$4253/km

Note: the Financial Assurance Calculation Spreadsheet allows for the input of variables for pavement width, number of culverts (if any) etc, the above provides an example for manual calculation only.

Revegetation costs have not been included in the above calculations.

SHAFT CAPPING

A cost of \$2000 per shaft has been assumed based on the following:

- Slab dimensions of 2600 mm X 2100 mm X 150 mm
= 0.79 m³ of concrete - say 1.0 m³ @ \$200.00 per m³
\$200.00 per slab for reinforcing steel and lifting lugs.
\$500.00 per slab to allow for engineers design, fabricators formwork, handling costs and profit margin.
- \$200.00 per slab freight
- \$900.00 per shaft for excavation, slab placement and backfilling.

OPEN DRILL HOLES

Allow \$50 per open drillhole for reclamation.

Allow \$25 each for cleanup of sample bags and/or drill cutting piles

COSTEANS

The variables to be measured to enable calculation of the backfilling cost are:

1. Length
2. Width
3. Depth

The example costean is assumed to have the following dimensions: 300 metres long X 1.5 metres wide x 2 metres deep.

The preferred equipment for this task is an excavator of between 20 and 30 tonnes weight.

Excavator hourly cost is \$ 130

Hourly production is estimated at 280 m³

Cost per m³ = \$0.46

Cost to backfill costean = 300 x 1.5 x 2.0

= 900 m³ x \$0.46/m³

= \$414

Where there are a number of costeans on the site an allowance of \$65 per kilometre should be made for travelling time.

For calculating the revegetation costs the disturbed area requiring revegetation is assumed to be twice the width of the costean to account for area disturbed during reclaiming the backfill.

Note: the Financial Assurance Calculation Spreadsheet allows for the input of variable costean dimensions, the above provides an example for manual calculation only.

Revegetation costs have not been included in the above calculations.

COST CALCULATIONS FOR OPEN PITS

Abandonment Bunds Around Open Pits

The volume of material required to construct the abandonment bund is calculated as follows:

2 metres high by 4 metres wide at the base with 1 : 1 faces gives a sectional area of 4 m² or 4 m³ per linear metre.

A cost of \$4.00 per m³ has been assumed to construct bund walls or \$16.00 per linear metre, this cost allows for the haulage, placement and shaping of competent rock to form the bund wall.

Pushing Down Batters of Pits <10 Metres in Depth

Pits are assumed to have batters of approximately 1:1 (vertical/horizontal) and they are to be pushed down to an overall batter slope of 1:3 (18°) in a balanced cut to fill operation - see figure below.

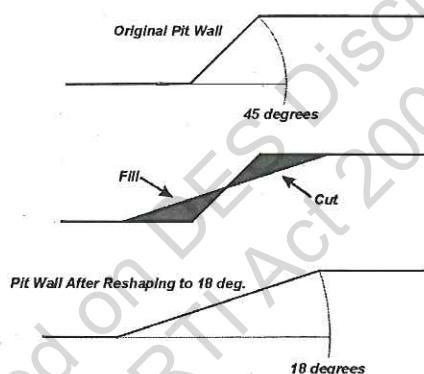


Figure 63 Illustration of balanced cut to fill

The cost per m³ to push down material is \$0.20 per m³

Pit depth	m ³ of material to doze	Cost per linear m of pit circumference
10	25	\$5.00
9	21	\$4.20
8	16	\$3.20
7	13	\$2.60
6	9	\$1.80
5	7	\$1.40
4	4	\$0.80

Where stock-proof fencing is required around an open pit an amount of \$8.00 per linear metre should be allowed.

COST CALCULATIONS FOR MEDIUM LEVEL & HIGH LEVEL DISTURBANCE AREAS

Productivity and Costs

- For medium level disturbance areas a Cat D6H dozer to tidy and reprofile areas. It is assumed that on average the dozer will be able to prepare 0.5 hectares per hour. At an hourly hire rate of \$130.00 the cost will be \$260.00 per hectare.
- Scarification costs and production rates are calculated on using a Cat D6H dozer fitted with triple shank rippers ripping to a depth of approximately 0.3 metres. 3 metres width covered per pass.

D6H dozer \$130 per hour
Dozer speed 2 kph
= 4980 m²/hr (0.83 efficiency)
= \$260 per hectare

Total cost per hectare for medium level disturbance areas: \$520.00

- For high level disturbance areas a Cat D10N dozer to tidy and reprofile areas. It is assumed that on average the dozer will be able to prepare 0.3 hectares per hour. At an hourly hire rate of \$285.00 the cost will be \$950.00 per hectare.
- Ripping costs and production rates are based on using a Cat D10N or equivalent dozer fitted with a single shank ripper, ripping to a depth of approximately one metre and two metres between passes.

D10N dozer \$285 per hour
Dozer speed 1.6 kph
= 2656 m²/hr (0.83 efficiency)
= \$1075 per hectare

- Topsoil spreading (0.05 metres thick) done using a 633 scraper at \$2.14 per m³ equals \$1070 per hectare
- Scarification is \$260 per hectare

Total cost per hectare for high level disturbance areas: \$3355.00

Note revegetation costs have not been included in the above calculations.

COST CALCULATIONS FOR RESHAPING WRD SLOPES

WRD's are assumed to have slopes that are at angle of repose (36°) that will be reshaped to 12° using a balanced cut to fill operation as shown in the figure below.

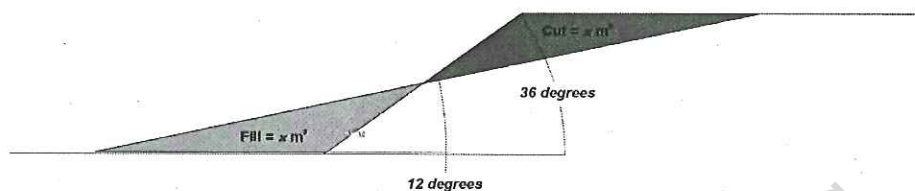


Figure 64 WRD Balanced Cut to Fill 12° Final Slope

WRD Height	m ³ to Doze	Cost per Linear m of Face
5	10	\$2.08
6	15	\$3.00
7	20	\$4.08
8	27	\$5.33
9	34	\$6.74
10	42	\$8.32
11	50	\$10.07
12	60	\$11.98
13	70	\$14.06
14	82	\$16.31
15	94	\$18.72
16	107	\$21.30
17	120	\$24.05
18	135	\$26.96
19	150	\$30.04
20	166	\$33.28

A base cost of \$0.20 per m³ has been used.

COST CALCULATIONS FOR RECLAIMING REJECT STOCKPILES

These calculations are based on using an excavator and articulated dump truck combination with a one way haul distance of 1000 m.

Average haul distance 1000m

Fleet:

- Cat 725 Articulated Dump Truck (x 3) at \$170.00 per hour = \$510/hr
- Komatsu PC350 excavator at \$150/hr
 - Load time 3.0 min
 - Manoeuver at loader 0.5 min
 - Haul loaded 5.0 min
 - Manoeuver & dump 1.0 min
 - Haul empty 3.0 min
 - Total cycle time 12.5 min
- PC 350 will produce 250 LCM per hour
- Cat 725E will average approximately 15 LCM per load
- 3 x 725's will haul 216 LCM per hour

Load & Haul = \$3.05 per LCM

See High Level Disturbance section for costs of rehabilitating the stockpile area once the reject material has been removed.

It is assumed that the stockpiles will be relatively small so a component for haul road maintenance has not been included.

COST CALCULATIONS FOR REHABILITATING WATER STORAGE DAMS

Type 1 Dams

A cost of \$0.35 per m³ of wall material should be allowed for dozing down walls and the rate used for medium level disturbances (\$520 per hectare excluding revegetation) then applied to the entire footprint of the dam including the pushed in walls.

- \$0.35 per m³ of wall material
- \$520 per hectare of foot print

Type 2 Dams

For concrete walls similar to that in shown the Figure above, \$200 per m³ (of concrete wall material) should be allowed for demolition and disposal. The wall in the Figure consists of approximately 6 m³, so \$1200 should be allowed for removal. For pushing in earth fill walls allow \$0.35 per m³ of wall material.

- \$0.35 per m³ of earth fill wall material
- \$200 per m³ of concrete wall
- \$520 per hectare of foot print

Note: Revegetation costs have not been included in the above calculations.

COST CALCULATIONS FOR REHABILITATING TAILINGS DAMS

Initial land-forming:

- Cat D6H dozer to tidy and reprofile dam surface (where access is possible) and embankments. It is assumed that on average the dozer will be able to prepare 0.5 hectares per hour. At an hourly hire rate of \$130.00 the cost will be \$260.00 per hectare.
- Scarification costs and production rates are calculated on using a Cat D6H dozer fitted with triple shank rippers ripping to a depth of approximately 0.3 metres. 3 metres width covered per pass.

D6H dozer	\$130 per hour
Dozer speed	2 kph
= 4980 m ² /hr (0.83 efficiency)	
= \$260 per hectare	

Cover placement:

based on using an excavator and articulated dump truck combination with a one way haul distance of 1000 m. Articulated 6 wheel drive trucks are assumed to be necessary due to potentially soft ground conditions.

Average haul distance 1000m

Fleet:

- Cat 725 Articulated Dump Truck (x 3) at \$170.00 per hour = \$510/hr
- Komatsu PC350 excavator at \$150/hr

Load time	3.0 min
Manoeuver at loader	0.5 min
Haul loaded	5.0 min
Manoeuver & dump	1.0 min
Haul empty	3.0 min
Total cycle time	12.5 min
- PC 350 will produce 250 LCM per hour
- Cat 725E will average approximately 15 LCM per load
- 3 x 725's will haul 216 LCM per hour
- Haulroad maintenance: 1 x water truck at \$70 per hour
- Spread cover material across dam surface 1 X D6H dozer or equivalent at \$130 per hour.

Load, Haul and Place = \$3.98 per LCM

= \$19,900 per hectare

Total cost per hectare = \$20,160 per hectare

Note: Revegetation costs have not been included in the above calculations.