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Long-term planning for the rehabilitation of opencast workings*

by J.D. WELLS†

SYNOPSIS

An account is given of the planning required for the rehabilitation of land that is to be disturbed by opencast mining, and of the preparation of rehabilitation plans for submission to the Inspector of Mines. The plans include the provisions that are to be made to allow for climatic conditions, land use, vegetation and wildlife, surface-water resources, geology and ground water, soils, land capability, rehabilitation method, location of discard dumps and slurry ponds, pollution control, and costs.

Monitoring of the operation is the only way that the rehabilitation plan can be improved, and both monitoring and planning are essential when provision is being made for the closure of a mine.

SAMEVATTING

Daar word verslag gedoen oor die nodige beplanning vir die rehabilitasie van grond wat deur dagmynbou versteur sal word en die opstel van rehabilitasieskemas vir voorlegging aan die Inspekteur van Myne. Die skemas sluit in die voorsiening wat daar vir klimaatstoestande, grondgebruik, plantegroei en natuurlewe, oppervlakwaterbronne, geologie en grondwater, grondsoorte, grondvermoë, die rehabilitasiemetode, plasing van afvalhope en slikdamme, besoedelingsbeheer en koste gemaak moet word.

Die enigste manier om die rehabilitasieskema te verbeter is deur die werk te moniteer, en sowel monitering as beplanning is noodsaaklik wanneer daar vir die sluiting van 'n myn voorsiening gemaak word.

Introduction

The Mines and Works Act[1] calls for rehabilitation plans for opencast mines that will remove more than 12 kt of mineral, including overburden, per year. In addition, the Water Amendment Act[2] restricts the use of water and places greater onus on mine management to prevent water pollution. In this respect, all rehabilitation plans must be approved by the Department of Water Affairs before the Government Mining Engineer (GME) gives his approval.

The Chamber of Mines' guidelines[3] for the rehabilitation of land disturbed by surface coal mining in South Africa provide mine management with fairly detailed information about how to define the pre-mining environment, how to protect water resources, and how to carry out the rehabilitation itself.

The purpose of this paper is to discuss the rehabilitation of an opencast mine to meet these constraints. Although an opencast coal mine is used as the example, the same principles apply to any opencast operation in which there is surface disturbance.

Feasibility Study

In the first place, a broad overview should be taken of the natural environment in which the mine is to be situated, and consideration should be given as to whether rehabilitation will be feasible, both from a practical and economic viewpoint. One would identify which types of environmental inventories need to be conducted and what are the most important natural resources requiring attention.

For example, in South Africa most opencast coal-mining operations occur in the predominantly agricultural region of the south-eastern Transvaal. Therefore, soil and water are the most important natural resources that will be disturbed, and they would need the most-detailed attention. As the fauna and flora would already have been disturbed, they would warrant less-detailed study. However, for mining in a more ecologically fragile area, more attention would have to be paid to the whole system and how each component interacts with the others, including socio-economic factors.

The amount of pre-mining capital required for these studies can therefore be included in the feasibility study.

The next step is a consideration of the proposed mine plan, the rate of advance of the strips, the schedule for topsoil stripping, the production rates of discard and slurry, and anything else that will affect the selection of equipment. This will enable the planner to estimate the capital and operating costs, and forecast how these will vary with time.

The whole project should be re-evaluated in the light of these cost estimates. The important point is that rehabilitation should be viewed in the same way as any other production parameter.

Rehabilitation Plans

Once the feasibility study has shown that the project is viable, plans must be prepared for submission to the Inspector of Mines before mining begins. The GME has recommended that the plans contain the following:

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† Manager, Environmental Protection Department, Rand Mines (Mining and Services) Ltd, P.O. Box 62370, Marshalltown, 2107 Transvaal.

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Name of Mine
(a) Owner
(b) Manager
(c) Owner of surface rights
(d) Owner of mineral rights
(e) Mine product
(f) Production rate
(g) Planned life.

Plan of the Mine
(a) Location and access from major and nearby towns
(b) Proposed layout of pit
(c) Proposed layout of infrastructure and housing
(d) Positions of box cuts and final voids
(e) Network of haulage roads
(f) Total mining area
(g) Surface drainage and pans
(h) Surface contours (suggested contour interval of 2m).

The plan of the mine is then used as the base map on which the following are marked: soils, pre- and post-mining land capability, and any other important parameter that needs spatial expression (for example, unique distributions of vegetation or wildlife).

Climatic Conditions

A brief description of the local climate must be obtained from existing records. This report should include the following:

(1) Rainfall: average rainfall, rainfall distribution through the year, variation between seasons
(2) Temperature: mean annual temperature, maximum and minimum for summer and winter, frost expectancy, diurnal variation
(3) Evapotranspiration: mean annual rates, and summer and winter rates
(4) Winds: predominant wind directions and speeds
(5) Extreme climatic events: frequency of droughts, floods, hail, very high winds.

All these factors have a direct bearing on the selection of plants for rehabilitation, the time of planting, and the length of the growing season.

Land Use

The land use should be recorded for the year before mining starts, and an indication should be given as to whether this was always the case. Some idea of the average types of crops and their yields, and of the carrying capacity for livestock of the veld or improved pasture must also be given.

These factors are dependent on the quality of management and may fluctuate widely. For this reason, historic information gathered should not affect rehabilitation planning in an agricultural area. If comparisons are made between rehabilitated areas and pre-mining or surrounding farmland, the management level must be established to allow meaningful interpretation.

The previous land use would obviously play a far more important role in a non-agricultural than in an agricultural area.

Vegetation and Wildlife

Only a brief description of these need to be included unless some special or unique association or veld type is discovered during the environmental inventory, such as at the site of the Majuba power station, where *Themeda* veld (Rooi gras) was identified as unique to the area and *Cordylus gigandeus* (the sungazer lizard) was found in large colonies. The result of this discovery was that an area of veld was left undisturbed and all the lizards threatened by the development were relocated in that area.

Surface-water Resources

The existing drainage density (in metres of river or stream per square kilometre) must be recorded because it has developed under the prevailing climate and a change in density may result in increased erosion. In addition, the occurrence of dams and pans, which constitute pre-mining wilderness land, must be noted.

The quality of the surface water is very important, and an adequate sampling and analytical programme must be undertaken before mining begins. This is particularly relevant in previously mined areas, where many surface-water resources are already polluted. Under the new Water Act, potential purchasers of such land must consider the cost of preventing this pollution.

Geology and Ground Water

Mineral exploration would have already defined the geology. All that needs to be indicated are the seams to be mined, their thicknesses, and the depth of the overburden.

The ground-water regime is significant for two main reasons:

(i) expected inflows into the pit will affect the pumping requirements; and
(ii) local users dependent on this resource may be affected, and compensation may be demanded if their supplies are depleted or become polluted.

The submission requires information on the depth of the watertable(s), the water quality, and the usage of ground water in the immediate area.

Soils

A detailed soil map must be presented, together with a brief description of the soil types, their erodibility factors, the slope on which they occur, and their agricultural potential. Particular emphasis must be placed on the depth of true soil as would be accepted by a soil scientist. The definition of topsoil in the Mines and Works Act as 'all cultivable soil material that can be removed mechanically to a depth of one metre without blasting' is pedologically unacceptable.

Included in this definition are lateritic and other gravel (which is very common in the south-eastern Transvaal); saline, sodic, or saline–sodic soils; heavy expanding clays; weathering rock; and waterlogged soils. These are all unsuitable as topsoil for rehabilitation.

The depth of soil recorded should be that of the A and B horizons of each soil type, and a note should be made of any reason why a particular soil is not suitable for rehabilitation. The map should also delineate the occurrence of gravel, which is a useful raw material in the construction of haulage roads.

Land Capability

A map of pre-mine land capability is the most important part of the submission. It is derived from a combination of the soil map, the topography, and the surface-water resources under the climate in which they occur. It expresses what the land is potentially capable of producing. It is important to recognize that the land capability map shows the *potential land capability* based on natural criteria, and not the actual *land use*, which may be very different.

Pre-mining land capability is divided into four classes, which are defined in the Chamber's guidelines[3]: arable land, grazing land, wetland, and wilderness land. The pre-mining land capability provides the only objective basis for the establishment of the post-mining land capability since no cognizance is taken of past management practices.

The pre-mining land capability forms the basis of the rehabilitation plan, which aims to re-create the same proportion of land capability classes after mining as existed before mining. For example, if 50 per cent of the disturbed ground was potentially arable before mining, the plan should be designed to make 50 per cent of the ground potentially arable after rehabilitation. This does not mean that the spatial distribution of the arable ground must be the same; the mine planner is free to choose where on the mine to rehabilitate to that standard.

However, there are certain problems arising from this overall objective.

(a) By definition, the final voids, any other water impoundments, and any infrastructure that is allowed to remain after mining are classed as wilderness land. This area could be larger than the area of the original wilderness land. To compensate for this, more grazing land can be created.
(b) Wetland will develop in low-lying areas and cannot be re-created immediately. If the rehabilitation plan is designed to re-create a drainage density similar to that existing before mining, a similar area of wetland should develop with time.

Post-mining Land Capability

Within the constraints mentioned above, a map of the proposed post-mining land capability should be drawn, showing the areas that have been designated to particular capability classes. The map shows the overall end-objective of the rehabilitation.

Proposed Rehabilitation Method

This section of the submission sets out how the mine proposes to achieve the overall rehabilitation goal. It should include the following.

(1) A brief description of the mining method since this can affect the rehabilitation plan.
(2) A schedule for the stripping of topsoil, explaining when and where the soil is to be stockpiled, at what stage it will be run directly onto levelled areas, and whether some will be stockpiled for final end-of-life rehabilitation. Wherever possible, the stripping of soil, particularly soil deposition, should take place during the dry season to avoid excessive compaction.
(3) The arable land must be such that the slope (in per cent) multiplied by the erodibility factor, K, of the soil to be used does not exceed 2. As the average K factor for arable soils in the south-eastern Transvaal is about 0,3, the slope should not exceed 6,7 per cent or 1:14. Once these slopes have been achieved, a minimum of 0,6 m of soil must be replaced.
(4) Grazing land will generally be sloped to 1:10, with the exception of the outslopes of the boxcut spoil, the sides of haulage ramps, the low-wall sides of final voids, and the soft material above the hard rock in the final voids, where a 1:3 slope should be the maximum. A minimum depth of 0,25 m of soil should be replaced.
(5) Because the south-eastern Transvaal has limited surface-water resources, it is felt that any mining activity resulting in storage areas for surface water will increase the value of the land to the end-user. By definition, these areas are classified as wilderness land. Thus, the final voids should be allowed to collect water, and drainage from rehabilitated land should be designed to flow into them. Areas that have no exit points for water should be engineered into pans, with due regard to compaction and sealing to prevent seepage. The surrounding drainage should then be guided into the impoundments. All wilderness areas should be covered by a minimum of 0,15 m of soil, and the maximum slope should be 1:3, except for the solid rock faces in the final voids, which will remain almost vertical.
(6) The width of the pit determines the distance between the peaks and valleys of the spoil piles. When the peaks are graded to their final elevations, the positions of the peaks and valleys persist, giving undulations superimposed on the original topography. When the width of the pit is 60 m, the distance between each parallel trough must be about 60 m.

    Although somewhat different from the original topography, this 'wash board' effect has certain advantages. Firstly, the length of slope from the top of each ridge to its trough is restricted to about 30 m (half the width of the pit). These short slopes considerably reduce the erosion hazard. Secondly, the slope along each trough is virtually the same as the original slope, which is gentle enough to allow each trough to dispose of its water without erosion along the trough. Thirdly, each trough receives more water than the adjacent ridge. The soil-moisture regime is therefore somewhat wetter here than on the ridges. Since the lack of soil moisture is the most limiting crop production factor in South Africa, this situation holds considerable promise for

    - increased crop yields because the ridge receives the normal rainfall while the trough receives additional water in the form of run-off,
    - the possibility of strip cropping, with a moisture-loving crop in the trough and a more drought-tolerant crop on the ridge, and
    - greater utilization during the dry winter months.

(7) Tillage, fertilization, liming, species selection, planting times, and after-care must all be included in the submission. All operations done on the land must be

done on contour to minimize erosion. It is important to note that all land regardless of its land capability class is treated in exactly the same way after soil deposition. The reason is that the regenerative powers of the vegetation are used to re-create an organic matter enriched A horizon, which is seen as the first step towards successful rehabilitation.

(8) The time between the completion of each mining strip and the rehabilitation activities must be specified. Bull-dozing usually starts one or two rows of spoil piles behind the open cut, soil is replaced during the dry season after the completion of bull-dozing, and planting takes place during the growing season following the topsoiling.

(9) The plan should specify what form of maintenance will be applied to the rehabilitated areas, for how long, and what provision will be made for failure. Three years of aftercare is usually regarded as a minimum requirement.

Discard Dumps and Slurry Ponds

Sites must be chosen so that potential pollution from these sources is minimized and the expected pollution load is intercepted. The sites must be demarcated on the mining plan and the method of operation described.

It is fairly well-accepted nowadays that new coal-discard dumps are compacted to prevent spontaneous combustion.

Slurry ponds remain problematical at present because little economic success has been achieved with other methods of slurry dewatering. However, properly designed and constructed ponds need not constitute a pollution problem.

Pollution Control

A pollution control system is an integral part of the rehabilitation plan and should show the following:

(a) a drainage system to handle clean water run-off from rehabilitated areas,
(b) a cut-off of clean water and a collection system for dirty water around discard dumps and slurry dams,
(c) clean and dirty water systems to isolate the industrial areas and the open pit,
(d) the location of facilities for treating dirty water and the method of treatment,
(e) the re-use or discharge of sewage effluent, and
(f) the source of make-up or main supply water, for which a permit must be obtained.

The overall objectives of this pollution control plan should be to minimize the chance of polluting rainfall run-off and ground water; and to contain, and re-use, the maximum amount of polluted water.

Cash Flow

The authorities concerned are anxious to know whether all these plans have sufficient financial backing to be brought to fruition. Estimated rehabilitation costs must be provided in the submission, together with a commitment that these costs can be met.

Submission and Approval

The completed rehabilitation plans must be submitted to the local Chief Inspector of Mines. They are then forwarded to the GME, who takes them to the National Advisory Committee on Opencast Mining. This Committee is chaired by the GME, and consists of representatives of the Departments of Water Affairs, Agriculture and Forestry, Health and Welfare, and of the Chamber of Mines and the Agricultural Union.

When the Committee approves the plans, they become legally binding, and any major deviation must be resubmitted for approval.

Monitoring and Control

The plans are implemented once mining begins on the basis of the normal monthly, yearly, and five-yearly plans.

Monitoring and control of the programme are the only ways to improve both the long-term and the short-term planning. This topic is large enough to form the subject of another paper, and only major aspects are discussed briefly here.

Stripping of Topsoil

During the soil survey, particular attention is paid to the depth of soil. If the depths are recorded on a separate map, the map can be used as a guide to the depth of stripping. This information can then be added to the data for each mining block, which will enable accurate scheduling of the soil-stripping equipment.

The distances that the topsoil has to be transported and the positions of the soil stockpiles can then be optimized.

Selection of Areas According to Land Capability Class

Wherever possible, arable land should be created between ramps adjacent to the former arable land. Since land of this class receives the greatest depth of soil, it makes sense to have the shortest haulage distances for topsoil in these areas.

Deposition of Topsoil

The depths of topsoil replaced on land of various land capability classes must be controlled by depth stakes. This ensures not only the correct depth but, more important, an even depth.

Final Contour Plans of Rehabilitated Areas

Final contour plans of the rehabilitated areas must be updated annually on a plan of the same scale as the premine contour plan. The updated plan must be available for inspection by the Inspector of Mines.

The most cost-effective way to do this is to make use of aerial photography, at least annually. The levelling of spoil can be designed accurately if the photographs include the spoil piles. Since the levelling of spoil is the most expensive of the rehabilitation operations, the optimization of this task justifies all the costs of photography and mapping. Furthermore, the control of the final drainage from these areas is almost impossible without accurate bull-dozing design.

Monitoring of Vegetation and Soil

Changes in soil fertility, structure build-up, and organic matter improvement in the A horizon must be monitored annually by means of soil analyses and examination of

soil profiles. Corrections can then be made to the fertilization programme, tillage methods, or pasture management.

Measurement of the vegetative cover at ground level, combined with a knowledge of the species making up the vegetation, is probably the most conventional way of measuring the success of the vegetation programme. The measurements should be taken at the end of each growing season.

Pollution Control

By law, all discharges from mine property have to be monitored, but it is important that the quality and quantity of any recycled water should also be monitored. This is required so that steps can be taken to protect process equipment, pipes, and pumps, and to schedule their maintenance.

Plans for Closure

The rehabilitation plan should be designed and implemented with eventual closure in mind. However, if closure is ignored until the end of a mine's life, the experience may be traumatic. Financial provision must be made during the productive phase of the mine, so that funds do not have to be provided when the mine is no longer generating an income.

The main items to be considered in the closure of an opencast mine are as follows.

Ramp Rehabilitation

Haulage ramps can be filled in progressively as the mine advances, but this is very costly and presents scheduling problems.

Although there are disadvantages, a simple way to rehabilitate ramps is to leave a row of spoil piles along each side of the ramp. Soil stockpiles are left outside the rows of spoil. When the ramp becomes redundant, first the spoil and then the soil are pushed into it. This results in a long shallow trough, which, if properly planned, will constitute the main drainage path for storm water from rehabilitated ground on either side.

Final Void

The GME will not issue a closure certificate unless the highwall and sides of the final void are made safe.

On the other hand, the vertical highwall can be a valuable asset from the point of view of wildlife conservation. For example, a highwall left as a vertical face at a rehabilitated pit in the Utrecht area of Natal encouraged the nesting of a colony of bald ibis—the only such nesting colony in the area and extremely rare away from the Drakensberg.

Water collecting in the void is also an asset as long as access is provided to it. Experience so far indicates that the quality of the water in these lakes remains good, and can support fish and plant life. Planting at least two rows of sisal plants (a plant with a sharp spike at the end of each leaf) at intervals of 1 m along the top of the highwall meets the safety conditions for closure, and obviates the need to blast and slope the face. The low-wall side should be sloped to 1:3 to allow safe access to the water.

Provision must be made for the construction of storm-water cut-off berms round the whole void, with suitably protected and spaced discharge points into the void, to prevent erosion.

Discard Dumps

If compaction and rehabilitation of the discard dumps is carried out at the same rate as discard production, very little has to be done at the time of closure.

A problem may be encountered if the discard is sold. In that event, the site chosen for dumping should be level, and soil to a depth of at least 1 m should be used to cover the compacted dump. When the dump is reclaimed, the soil is removed and stockpiled, the coal recovered, and the soil returned to the cleared area and revegetated.

Slurry Ponds

If adequate provision has been made for drainage from the bottom of slurry ponds, they can be emptied periodically; or they can be allowed to dry out, covered with soil, and revegetated. In the latter case, evaporation ponds must be constructed to collect seepage water to meet the conditions laid down for closure.

Any water pollution control measures taken at the time of closure must be designed so that no operating staff are required and maintenance is minimal.

Infrastructure

If there is some valid reason for leaving certain buildings, dams, railway lines, roads, etc., these may be left with the permission of the GME. Generally, however, all infrastructure must be demolished, and the disturbed areas revegetated to at least grazing-land standard. This could be very costly, and provision must be made to pay for it before the mine stops producing.

Conclusion

A considerable amount of planning is required for the rehabilitation of land that has been disturbed by opencast mining if it is to meet the legal constraints and the requirements of the Chamber's guidelines. In addition, if the planning is not done concurrently with other mine planning, the overall cost of rehabilitation will undoubtedly be higher than it would have been with proper planning.

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