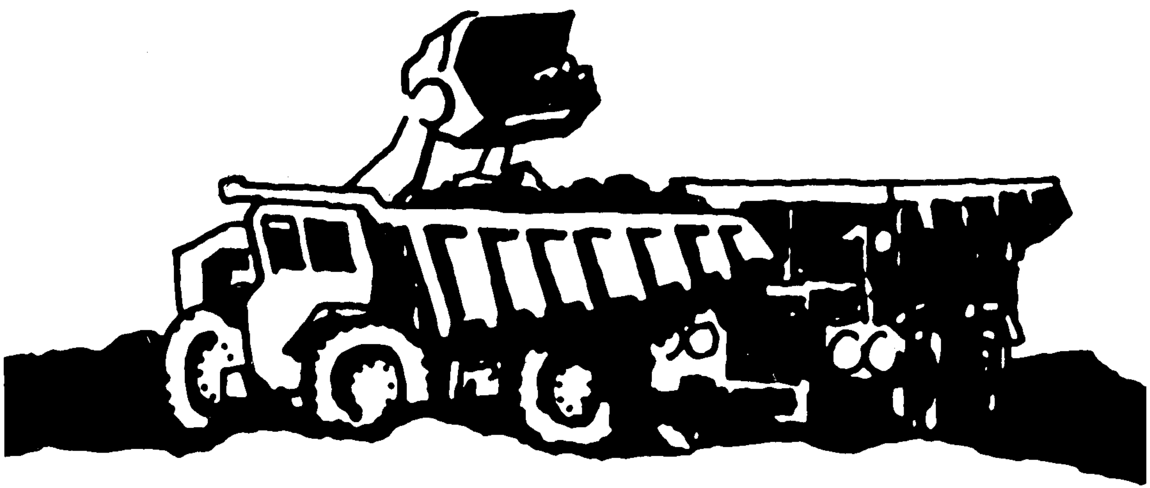
SMALL SURFACE COAL MINE OPERATORS HANDBOOK



UNITED STATES DEPARTMENT OF THE INTERIOR
OFFICE OF SURFACE MINING

DISCLAIMER NOTICE

This handbook was prepared during the period when many OSM regulations were being developed. As a result numerous changes have been made to the regulations which may not be reflected in the text of the handbook.

We anticipate possibly revising this handbook to include regulation changes. In addition, we would like users of the handbook to identify problems or suggest changes they see which would make improvement. We would appreciate receiving comments from handbook users regarding: usefulness, substantive detail of the material, and the presentation format. Comments should be sent to: Chief, Small Operator Assistance Program, Office of Surface Mining, 1100 "L" Street, Washington, D.C. 20240.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Office of Surface Mining or the U.S. Government.

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A HANDBOOK FOR SMALL SURFACE COAL MINE OPERATORS

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CHAPTER 1

PURPOSE OF THIS HANDBOOK

The purpose of this handbook is to interpret the Regulations of the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) (hereafter referred to as the Act) as they affect the operators of small surface coal mines (a small mine operator is defined in the Act as one with an annual coal production of less than 100,000 tons). Further, the purpose of this handbook is to make it easier for the small operator to compare his operation with the act in order to determine compliance with the regulations. Part 795 of the Regulations deals specifically with the Small Operator Assistance Program. This program relieves the operator of the cost of carrying out certain hydrologic and geologic analyses required by the Regulations.

The emphasis of this handbook is on the protection of water resources during mining and reclamation operations. As almost all the operations in surface mining directly or indirectly affect water we have included some operations which may only marginally affect water quality or hydrology.

Anthracite mining, lignite mining, coal processing, refuse disposal, and slurry disposal are not covered in this handbook. Design guidelines for slurry impoundments and coal refuse piles may be found in "Design Guidelines for Coal Refuse Piles and Water, Sediment, or Slurry Impoundments and Impounding Structures," MESA Technical Support Center, Pittsburgh, PA, April 1976.

The area covered by this handbook includes only that east of the 100th meridian west longitude.

USE OF HANDBOOK

The best way to use this handbook is to look directly at the drawings in Chapter 4 which describe various surface mining methods and the operations which are involved in each. The first drawing for each method shows an unregulated mine, and the key below identifies problems which arise during and after mining and the Sections of the Regulations which are intended to solve these problems. The next drawing for each method shows phases of a mine which meet the requirements of the new Regulations. The key below identifies each operation, the Section of the Regulations relevant to that operation and the title and number of "Data Sheets." These data sheets make up Chapters 6 and 7 of the Handbook and contain guidelines for measures necessary to meet the Performance Standards of the Regulations.

Chapter 5 is *very* important. It contains information on premining surveys and planning. Careful pre-planning of mine operations is critical if the requirements of the Regulations are to be met, (particularly the need for contemporaneous reclamation) at a reasonable cost. Failure to preplan will inevitably result in non-compliance notices, double handling of overburden and other time and money wasting problems.

Many of the measures which are described on the data sheets are required as part of the Performance Standards contained in the Regulations, most of which are included in Part 816, Chapter VII, Subchapter K, though Performance Standards for specific categories of mining mountain top removal, steep slopes, prime farmlands and auger mining, are found in Parts 824, 826, 823 and 819 respectively.

The effectiveness of some of the measures in this handbook have not actually been established. The lack of experiments which have monitored the impact of various mining methods and protection measures is a serious problem. EPA is at present sponsoring a study in Kentucky to monitor the effectiveness of the Modified Block Cut Method of surface mining in controlling sediment. The assumed advantages of the Modified Block Cut Method (no spoil on the down slope, complete elimination of the highwall, 60% less acres disturbed, minimization of double handling, etc.) and the disadvantages (scheduling complications, higher capital requirement for equipment, etc.) will be quantified. The study will also monitor water quality and quantity to satisfy a need to quantify the effectiveness of the method itself in reducing sedimentation (DNR, Kentucky 1977).

Costs of measures in this handbook have not been included. The Regulations require that the reclamation plan (requirement for Permit Application) include a cost estimate [780.18(b)(2)]. Costs, however, are mostly so site-specific that general cost guidelines are of doubtful value. Only where realistic costs can be given have they been included.

The operator will find little information on costs in published sources as most refer to operations which do not conform to the new performance standards. It was also noted by Davis in 1977 that often, costs vary widely due to differences in the procedure used to estimate costs. He suggested that reclamation costs were approximately 10% of gross revenue, 5-8% of the $11-$22 a ton cost of production or 30% of the cost of coal production (4). Some 1974 costs are also given by Doyle (et al.) in a report in which he analyzes pollution control costs (6).

The small operator should understand his true unit costs and break-even stripping ratios in order to stay solvent, particularly in a time of rapidly shifting costs and sales prices for coal. The authors of this handbook realize that the small mine operator has to work within a tight profit margin in a high risk, high front-end capital undertaking. This handbook advocates self reliance in premining planning for cost-effective reclamation meeting the requirements of the Act.

THE OPPORTUNITY FOR SMALL OPERATOR

The surface mine operator, in extracting small, or isolated deposits of coal, thin or faulted seams, is playing an important role in the national energy policy of maximizing the use and conservationof the coal resource which is one of the stated objectives of the Performance Standards (Subchapter K). Probably more than 30 million acres (12 million ha) of land in the Eastern coal province alone cover strippable coal reserves (see Table 1). As large operators expand and concentrate on more extensive blocks of coal for largely automated machinery, the role of small operations in exploiting isolated and difficult coal deposits will expand. The public's acceptance of, and confidence in, the coal mining industry generally depends on the performance of all operators in solving some of the problems which are described in Chapter 2.

Both large and small surface mine operators can help local communities achieve some of their goals by creating post-mining landforms which are consistent with the needs of the community. Cases of airstrips, lakes, waterstorage impoundments, industrial sites, recreational centers, residential and commercial sites have been recorded. Variance from the "approximate original contour" requirement [816.101(b)(1)] can be obtained for approved post-mining land uses [824.11]. "Restored lands can be more fertile than before, aquifers constructed that can be relied upon to meet the growing demand for water within mining regions, mines can be used to dispose of solid waste and to treat sewage effluent and sludge produced by our growing population, to reduce flood flows, increase base flow, or to provide new recreational opportunities." (9) The actual improvement of the capability of land as a result of surface mining may not be feasible in all cases, particularly in the difficult terrain of Appalachia, but it is frequently a possibility. It should be noted that not only land-use but also the hydrologic environment can be improved as a result of surface mining.

New mining methods make feasible a more comprehensive approach to surface mining. For instance, the isolated "apple cores" or "biscuits" of unmined mountain tops in hilly terrain can be eliminated by Mountaintop-Removal. Many of these new methods rely on large-scale operations and are therefore beyond the scope of smaller mine operations. Some new methods are applicable to small operations. A more comprehensive approach and more attention to the post-mining use of land is what is needed and this means more emphasis on preplanning. Comprehensive planning also makes possible the more extensive reclamation of orphaned land (unreclaimed land previously affected by surface mining). This not only can result in an improvement in the land use of the area but also significantly improved water quality, mainly through a reduction in acid mine drainage and sedimentation. In the early 1970's land in Appalachia was being disturbed by strip mining at the rate of about 31,000 acres per year (12 ha/year); at that date 1 million acres (404,700 ha) had already been affected by strip mining and very little had been done to reclaim it (5). Between 1930 and 1971 3.6 million acres (1.46 million ha) of land in the US were used for surface mining of which barely 40 percent were reclaimed (2).

It is possible through the preplanning of mining operations not only to reclaim abandoned surface mine workings, but also in some cases to "daylight" old underground workings to reduce acid mine drainage. In some cases it has been possible to dispose of coal refuse heaps in surface mine workings. SMO's should explore the SOAP provisions which present incentives to operators for the reclamation of orphaned lands as part of their surface mine operations. (Grants available under Parts 872 and 886 of Subchapter R.)

The Regulations contain a procedure for identifying lands which are unsuitable for surface mining because mining operations would be imcompatible with existing land-use plans, significantly damage natural systems, result in a substantial loss in the productivity of water supply, or endanger life or property due to flooding [762.11]. This handbook applies to those lands which can be mined and shows how to prevent problems from occurring. An understanding of water movement over the surface and through the topsoil and spoil is important in designing measures to establish vegetation, to control erosion, to stabilize spoil and to control water pollution on drastically disturbed lands (1).

Table 2 presents the characteristics of small mine operations. The SMO will be well aware of these. The implications of these characteristics and any pertinent provisions of the Small Operators Assistance Program (SOAP) are included in the Table.

TABLE 1

STRIPPABLE RESERVES OF COAL IN THE US EAST OF THE 100TH MERIDAN W LONGITUDE

Coal Province	Strippable Resource	Strippable Reserves*	STRIPPABLE RESERVES/MILLIONS OF SHORT TONS Low Sulphur	Medium Sulphur	High Sulphur
Eastern-Province Appalachian Region	26,533	5,171	1,862	1,433	1,876
Interior & Gulf Provinces	32,785	7,296	13	535	6,748

*Reserves - coal available to be stripped with existing technology.

Source: Bureau of Mines, "Strippable Reserves of Bituminous Coal and Lignite in the US," US Dept. of the Interior, Information Circular 8531, 1968.

TABLE 2

SMALL MINE OPERATIONS

Characteristics of Small Operations	Implications	Provisions of SOAP
1. Small operations are capable of exploiting small or isolated deposits and coal rights.	More complete utilization of the resource.	None.
2. Lack of specialist exploration team and specialized exploration equipment.	Tendency to minimize exploration.	SOAP will pay to have exploratory test borings analyzed by a qualified laboratory and consultant.
3. Lack of specialist to carry out pre-mining surveys, data collection, application processing, etc.	Tendency to minimize pre-planning and application preparation.	SOAP will pay for the determination of the probable hydrologic results of the proposed mining and reclamation operation and for a statement of results of analyses of test borings and core sampling.
4. Lack of capital restricts purchase of equipment with large capacity.	This may make some mining methods unfeasible (especially those requiring the shifting of large amounts of overburden), e.g. mountain top removal.	None.
5. The expense and lack of flexibility of large prime earthmoving equipment.	Tendency of small operators to rely on smaller, more flexible machinery.	None.
6. Small operations rarely have coal preparation plants and coal is either sold directly to the consumer or preparation is carried out by contract.	More coal trucks on the public roads.	None.
7. Most small operations do not employ full-time maintenance crews.	Small operations may experience serious delays due to down time of equipment making scheduling difficult.	None.
8. Small operations often sell coal on the spot market and do not have the capability to blend coal.	Small operations are therefore susceptible to market fluctuations which may make it difficult to stick to the program outlined in the operation plans (Part 780).	None.

REFERENCES:

(1) Gardner, H.R., Woolhiser, D.A., 1978, "Hydrologic and Climatic Factors," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W. and Sutton, P., (eds.), ASA, CSSA, SSSA, Madison, WI.

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(3) Ramani, R.V., Grim, E.C., 1978, "Surface Mining - A Review of Practices and Progress in Land Disturbance Control," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W. and Sutton, P., (eds.), ASA, CSSA, SSA, Madison, WI.

(4) Davis, H., July 1977, "How Mining Companies Use Reclamation Experts," Coal Age, pp. 43-44.

(5) Curtis, W.R., 1971, "Strip Mining, Erosion and Sedimentation," Transactions of the ASAE, Annual Meeting, Minneapolis, MN.

(6) Doyle, F.J., Bhatt, H.G., Rapp, J.R., 1974, "Analysis of Pollution Control Costs," EPA 670/2-74-009.

(7) Kentucky DNR, July 1977, "Onsite Control of Sedimentation Utilizing the Modified Block-Cut Method of Surface Mining," EPA 600/7-77-068.

(8) US Mining Enforcement and Safety Administration, April 1976, "Design Guidelines for Coal Refuse Piles and Water, Sediment, or Slurry Impoundments and Impounding Structures," MESA's Tech. Support Center, Pittsburgh, PA.

(9) Ramini, R.V. and Clar, M.L., 1978, "Users' Manual for Premining Planning of Eastern Surface Coal Mining - Executive Summary," Intragency Energy/Environmental Research and Development Program Report, EPA 600/7-78-180.

CHAPTER 2.

PROBLEMS OF SURFACE MINING

Table 6 gives a list of the main environmental problems in surface mining. The operator can use this Table to anticipate the problems which may result from the proposed mine operation, and to learn how these problems can be solved, largely by careful planning of the operations in advance. In the Appendix, which follows Chapter 5, there are three Tables which describe the Remedial Measures in more detail and the relevant Sections of the Regulations.

The amount of water which either runs off or infiltrates during a rain storm depends on several factors, including the slope, the cover or vegetation, the soil and the degree of compaction. Removal of vegetation and compaction by equipment will increase the proportion of runoff, as will haul roads which are heavily compacted and sometimes paved. However, the actual process of mining may result in cast spoil, full of voids and with much greater permeability than previously and also capable of holding much greater volumes of water if it is confined by impermeable strata. This is the case for cast spoil but overburden moved by either scraper or truck will tend to be consolidated and may have a runoff coefficient as great or greater than the undisturbed site. The ratio of runoff to infiltration in natural conditions may be 1:3 in the Eastern and Interior provinces on gently sloping sites. The desirability of increasing the infiltration depends on the existing groundwater and the hydrologic balance, and also whether or not an increase of infiltration will cause instability of the spoil mass.

Increasing the groundwater storage capacity can be very valuable in Appalachia where most of the surface mining activity is in areas where the groundwater component is small. Curtis suggests that cast spoil may store 50" (127 cm) of water as compared to the unmined soil horizon that could have a total retention of 19.7" (50 cm) only (9). In fact, the increase in capacity is likely to be greater but will clearly depend on the method of working and also the type of spoil. Curtis suggests that "recharge zones can be created by selecting those portions of the overburden that have the best infiltration rates and placing them so that surface water can be diverted into them" (9).

Increased infiltration usually means a greater baseflow to streams when the water reappears in springs or seeps. This may be very desirable, increasing stream flow during dry weather and prolonging flow in streams which normally flow only intermittently. Studies in some small watersheds in the New River basin of the Cumberland Mountains in Tennessee indicated a probable increase in dry weather stream flow due to surface mining. This was implied through continued stream flow in small disturbed watersheds while all three streams draining undisturbed watersheds were dry during the summer (5).

The ratio, runoff:infiltration, will also be an important factor in flooding. Old pits on unreclaimed mine sites impound water. This detention and the increase in storage capacity of the overburden tend to reduce flood peaks. This theory is supported by studies in Breathitt County, Kentucky, and Raleigh County, West Virginia, where "stream flow from surface mine watersheds peaked (16%) lower than from adjacent or nearby unmined watersheds." The study showed that more than 1" of rain went into retention storage in the two mined watersheds while very little went into storage in the unmined watersheds (7). Studies at the Northeast Forest Experimental Station at Berea, Kentucky showed that surface mining resulted in increases in peak flows 4-5 times higher during and immediately after mining, but that peak flows were significantly lower after reclamation was complete (9). This appears to conflict with the previous hypothesis but was found to be due to the intentional dewatering of pits during heavy rain.

Grading during reclamation will have a major effect on the ratio runoff:infiltration. Small surface impoundments due to rough grades will be eliminated during the smoothing operation associated with grading. Slopes will tend to be longer and continuous, giving runoff a chance to buildup on these slopes. Larger impoundments and pits will also be eliminated and during the process the spoil may become heavily compacted by the passage of scrapers and other earth-moving equipment. The increase in runoff due to reclamation activities may be reduced by various surface modifications, such as terracing and also by various surface treatments, such as ripping and gouging. (Scarification of regraded spoil is required in the performance standards [816.24(a)] but terraces are only permitted with the approval of the RA [816.102(b)].) It was found, for instance, by Curtis that total surface runoff averaged 42% less on terraced plots of mining spoil shale than on unterraced plots (9).

The amount of runoff and the velocity of runoff will also be a major factor in the amount of erosion and hence the amount of sedimentation. This brings us directly to water quality.

PROBLEMS - WATER QUALITY

The impact of surface mining on water quality is fairly well documented, but the emphasis in the past has been on the impact of abandoned surface mines on water quality. The emphasis has also tended to be on water quality of surface water rather than on the quality of groundwater.

Experiments in small watersheds in Tennessee have shown that surface mining has a very serious impact on stream health. Streams draining affected areas were found to be virtually sterile relative to fish. Diatoms in water samples were extremely deficient due to heavy sediment loads, and the insect population showed a reduction in both population size and number of species. Populations crashed after mining and then returned slowly to the original size over a period of more than 20 years (this example pertains to abandoned surface mines). Although the number of insects recovered, the composition remained changed (10). A study in the Beaver Creek basin (KY) indicated that strip mining caused changes in the chemical quality of both surfacewaters and groundwaters in the area. Water draining from surface mines often has a low pH, a solids content in excess of 400 ppm and large amounts of aluminum, iron, manganese, magnesium and sulphate (11). (The performance standards set maximum limits on iron, manganese and suspended solids in discharge waters and a pH range [816.42(a)(7)].) Work is in progress to assess the mobilization of heavy metals and other contaminants from strip mine spoils as part of the Appalachian Resources Project. The purpose of this is, in part, to enable measures to be devised which are more specific and cost-effective (12). In a study in the New River basin in the Cumberland Mountains in Tennessee, streams unaffected by surface mining were found to be notably similar in nearly all respects and uniform in water quality characteristics. On the other hand, streams and basins affected by surface mining exhibited distinct differences one from another and periodic large variations in concentrations of constituents in the water. The concentration of suspended solids rapidly increased following disturbance in the watershed but in some streams the high levels (frequently in excess of 100 mg/l) continued for prolonged periods. Disturbance also produced high levels of calcium, magnesium, sulphate and manganese. The requirement for contemporaneous reclamation [816.100] will undoubtedly reduce the problem of continued pollution of both surfacewater and groundwater following surface mining (5).

The major problems associated with water quality and surface mining are acid mine drainage (AMD) and sedimentation.

ACID MINE DRAINAGE

Sheet 6:9 deals in detail with the problem of acid mine drainage (AMD). This problem is caused by the oxidation of pyritic materials followed by leaching causing sulphuric acid to pass into solution. It is estimated that in Appalachia about 25% of the total acid drainage is caused by strip-mining activities. The problem of acid drainage is considerably worse in the northern one-third section of the Appalachian coal field than in the southern two-thirds. It is reported that Pennsylvania and West Virginia contain over two-thirds of the stream mileage which is adversely affected by coal mine acid drainage in Appalachia. This is probably due to a larger amount of sulphuritic material exposed per ton of coal mined in the north than in the south (18). If oxidation can be prevented by burying pyritic materials at levels above the water table, AMD will be minimal. "It is unlikely that material buried several feet or more below the surface can undergo significant oxidation because of the restriction of oxygen diffusion to these depths" (15). It is on this premise that requirements for burying acid-forming or toxic-forming material in the Regulations are based [816.48]. In studies in Beathitt County, Kentucky, it was found that before mining, the concentration of sulphate in the surface water was generally less than 15 ppm but after mining the concentration was usually more than 100 ppm. Undoubtedly, the requirement for contemporaneous reclamation [816.100] will reduce the concentration of salts after mining has ceased. But to minimize concentration during the mining process, careful handling of spoil [816.41(d)(2)(vii)-(viii)] and attention to site drainage [816.43] are necessary (17). Extensive neutralization of acid drainage occurs within the coal regions. Biesecker and George report that "the mixture of outlying streams with mine drainage waters eventually neutralizes all acid streams in Appalachia." Thus, acid drainage is most serious in head-water streams near active or abandoned surface mines (18).

SEDIMENTATION

Many experiments have quantified the increase in sediment caused by erosion on both active and abandoned surface mines. For instance, in studies of mined and unmined watersheds in Kentucky (Leatherwood Creek and Bear Branch), the impact of surface mining on both the suspended sediments and the bed loads sediments in the streams was investigated. These studies were pre-SMCRA and quantified the continued sediment generation in areas affected by surface mining after abandonment (1). A study in Beaver Creek Basin in Kentucky found that the annual sediment production from land affected by surface mining was 42 tons/acre, 1,000 times higher than the yield of sediment from an unmined watershed (13). Table 3 below shows representative rates of erosion from various land uses.

TABLE 3

SEDIMENT GENERATION BY VARIOUS LAND USES

Land Use	Tons/Mi²/Year	Relative to Forest
Forest	24	1
Grassland	240	10
Abandoned surface mines	2400	100
Cropland	4800	200
Harvested forest	12,000	500
Active surface mines	48,000	2,000
Construction	48,000	2,000

Source: US EPA, October 1973, "Method for Identifying and Evaluating the Nature and Extend of Non-point Sources of Pollutants," EPA 4030/9-73-014, Washington, DC

TABLE 4

COMPARATIVE RATES OF EROSION FROM SURFACE MINING ACTIVITIES

Area	Yield (Tons/Mi²)	Factor
Unmined Watershed	28	1
Mined Watershed	1930	69
Spoil Bank	27,000	968
Haul Road	57,600	2065

Source: EPA, October 1976, "Erosion and Sediment Control Surface Mining in the Eastern US - Planning," Technology Transfer Seminar Publication.

SOME CLIMATIC FACTORS AFFECTING SURFACE MINING

The performance standards of the Regulations contain different requirements in a number of cases for areas where the annual rainfall is above 26" (66 cm) or below 26" (66 cm). For instance the extended responsibility lasts for 5 years in areas where annual precipitation is more than 26" (66 cm) but for 10 years when it is less [816.116(b)]. The whole of the area covered by this Handbook, i.e. the Eastern Coal Province and Interior Province east of the 100th Meridian W longitude, has an annual precipitation of more than 26" (66 cm). (Figure 1)

Figure 1. Mean Annual Precipitation (cm) and Major Coal Reserve Areas. Eastern and Interior Provinces.

Source: Gardner, H.R., Woolhiser, D.A., 1978, Hydrologic and Climatic Factors," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W., Sutton, P. (Eds), ASA, CSA, SSSA.

The higher rainfall found in the more humid areas of the Eastern and Interior Coal Provinces is not necessarily indicative of a high erosion potential as erosion is affected by rainfall *intensity*. The humid climate however does favor the rapid and effective establishment of vegetation. Consequently, meeting the requirements for revegetating Eastern and Interior surface mine sites is much easier than in drier regions in the west.

The proportion of rainfall which runs off to that which infiltrates into the ground and that which is evaporated or used by plants varies a great deal, and may be altered considerably by surface mining. The proportion which infiltrates and then reemerges in springs and seeps is important in maintaining the base flow of streams in dry weather. That which infiltrates to deeper groundwater may be important in maintaining water supplies which rely on groundwater sources. Hence the impact of surface mining on this balance is very important.

The amount of water which can potentially be used by the vegetation is called the potential evapotranspiration (PEVT). In the Appalachians the rainfall is greater than the PEVT but in the west the PEVT exceeds rainfall by 2 or 3 times, making water a crucially important factor in revegetation.

The slope, both its steepness and the direction it faces, will have an impact on the microclimate and also the establishment of vegetation. South-facing slopes are hotter and drier than north-facing slopes.

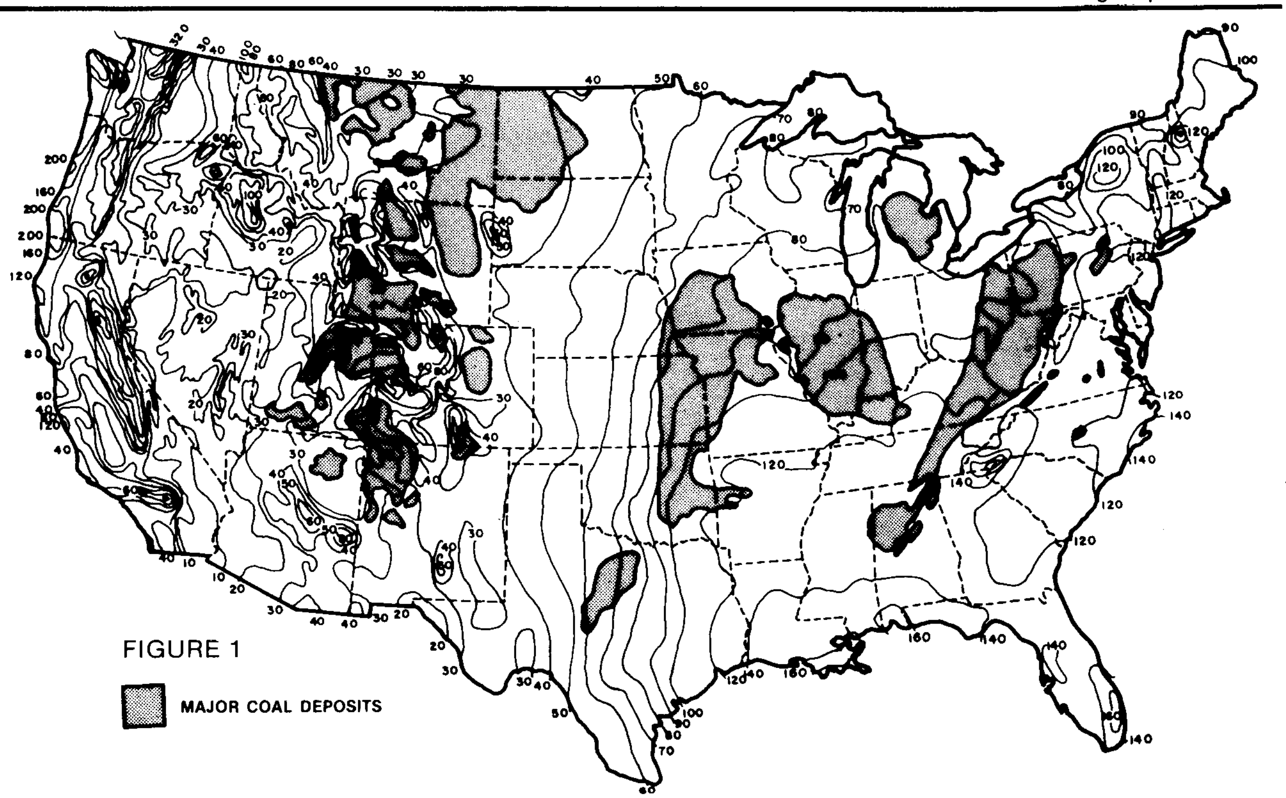

FIGURE 1

TABLE 5

MAJOR WATER RELATED IMPACTS OF SURFACE MINING

1. WATER QUALITY	Description of Impact	Major Operation Causing Impact	Remedial Measures [Regulations]*
1:1 Alteration of flow patterns of streams.	Disturbing the surface during mining may cause increased infiltration of water. But often, consolidation causes increased runoff and reduced infiltration which can cause flooding and erosion problems, and may reduce recharge of aquifers and base flow of streams. Local increases in runoff also may originate from haul roads, etc. Runoff will increase due to excessive compaction during reclamation and the elimination of surface storage by creating smooth slopes.	Removal of vegetation, and all operations involving shifting and regrading and consolidation of overburden. All operations which increase the impermeability of the land surface.	Disturb smallest practicable area at any one time [816.45(b)(1)]. Reclaim as contemporaneously as practicable [816.100]. Design haul roads so as to minimize any increase in runoff [816.153].
1:2 Lowering of groundwater.	Dewatering the pit may cause a lowering of the groundwater. Deep exploratory boreholes may also break through an impermeable stratum which confines an aquifer causing the aquifer to leak to lower strata.	Pit dewatering. Exploration boreholes. Mining through a stratum which previously confined an aquifer.	Casing and sealing of drilled holes [816.13-816.15]. Plan mine excavation so as to prevent adverse impact [816.50(b)].
1:3 Change in storage capacity and transmissibility of overburden.	Decrease in groundwater recharge may result from reduced permeability caused by the removal of vegetation. The removal and replacement of overburden will change both its storage capacity and transmissibility (often increasing both which can be a significant improvement). Vertical leakage to underlying aquifers can increase transmissibility.	Clearance of vegetation. Shifting, regrading and consolidation of overburden. Exploration boreholes. Blasting which causes fracturing and disturbance of basement rock.	Use straw dikes, riprap, check dams, etc. to reduce runoff volume [816.45(b)(b)]. Minimize disturbance to prevailing hydrologic balance [816.51(b)].
2. WATER QUALITY			
2:1 Acidity.	Highly acidic runoff from mined sites results from the exposure of pyritic materials to air and water. Low pH tends to make some compounds toxic to plants, particularly Al and Mn. May cause local groundwater supply to become less than potable.	Exposure of pyritic material, often lying in close proximity to coal, to oxygen and water. The cause may be material exposed in exploration boreholes, material in the pit bottom, material backfilled too close to the surface, or material used in road construction. Also, careless hauling of previously identified acid-producing materials causes this problem.	Conduct coal exploration in a manner which minimizes disturbance of hydrologic environment [Part 815]. Prevent or remove water from contact with acid-forming materials during mining operations [816.43]. Bury acid-forming spoil [816.48]. Correct pH before discharge of water from site [816.42(c)]. Acid-forming materials may not be used in construction of haul roads [816.152(d)(13) and 816.154(b)].
2:2 Sedimentation; Suspended solids.	Erosion of overburden materials may result in very high levels of sediment in runoff from mine sites, which causes a deterioration of stream health, silting of streambeds, etc. Loss of topsoil. Lessens the potential for post-mining use.	All mining operations involving earthmoving. Also haul roads may be serious sources of sediment.	Minimize erosion to the greatest extent possible [816.45(a)]. Reclaim as contemporaneously as practicable [816.101(a) and 816.113]. Manage haul roads so as to cause no additional contribution of suspended solids to runoff flow [816.150(b)]. Provide sedimentation ponds [816.46].
2:3 Hardness; Deposit of iron hydroxide.	Hardness is rarely a serious problem. However, acidic drainage which is neutralized by treating with lime or limestone will increase in hardness. Neutralization will cause the deposit of iron hydroxide (Yellow Boy) and other compounds which may cause problems.	Operations involving the treatment of acid-forming materials.	Monitor surface water and groundwater [816.52]. Treat acid water only as needed [816.42(c)].
2:4 Groundwater pollution.	Groundwater pollution can result from acid water leaching into the groundwater. This may be a problem when acid-producing material is placed so as not to prevent oxidation and leaching. Consolidation and in some cases sealing the acid-producing material should prevent this problem.	Results from placement of acid-forming materials during regrading where oxidation and leaching can take place.	Place backfill material to prevent groundwater pollution [816.101(b)(2)].
3. OTHER WATER RELATED PROBLEMS			
3:1 Instability.	Infiltration of water into the spoil may cause instability and slumping. Most reclamation measures seek to reduce runoff and increase infiltration but in cases where spoil has low shear strength the policy should be to prevent excessive seepage. A slide may have an adverse effect on public property, health, safety or the environment.	This problem occurs mostly on steep sites, particularly for large fills, Head of Hollow and Valley Fills. Providing bench or barrier on outslope. Backfilling and grading.	Provide barrier so as to assure stability [816.99(a)]. Backfill and grade so as to insure stability [816.101(b)(1)]. Construct a subdrainage system [816.71(e)].
3:2 Erosion.	Besides giving rise to sedimentation problems, gully erosion may be so serious to make it necessary to regrade the site. Careful attention to surface configuration and rapid protection with vegetation will avoid this problem.	Regrading operations. Revegetation operations.	Reclaim as contemporaneously as practicable [816.101(a) and 816.113]. Perform regrading operations along contour [816.102(e)]. Regrade or stabilize rills or gullies [816.106].

*For a detailed listing of Remedial Measures, see Tables in Appendix following Chapter 5.

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CHAPTER 3

SURFACE MINING METHODS AND EQUIPMENT FOR SMALL MINE OPERATIONS

The Surface Mining Control and Reclamation Act (1977) does not specifically outlaw any method of mining, but it outlaws certain practices such as the placement of spoil on the downslopes above 20 degrees in steepness [Section 515(d)(1) of the Act]. Each mining method is described in Chapter 4. These illustrations do not try to show how the operation should be carried out, but are intended to give the operator an easy, quick method of identifying sections of the Regulations which are relevant to the mining method chosen.

Skelly and Loy found that mining methods can generally be subdivided by region as shown in Table 6.

TABLE 6

Region	Predominant Terrain	Mining Method	States
1	Steep Slopes	Contour Mining	E. KY, WV TN, VA
2	Rolling	Modified Area & Multiple-Cut Contour	PA, MD, AL, S.E. OH
3	Flat Terrain Thick Overburden	Area Mining	W. KY, IL, IN, OH, MO, OK, KS, AR, IA

Source: Skelley and Loy, February 1975, "Economic Engineering Analysis of U.S. Surface Coal Mines and Effective Land Reclamation," USBM Contract S0241049.

Each mining method has different environmental and reclamation problems which are covered by the Regulations. The choice of the method of mining will still be determined mainly by economic factors. The smaller operator will often be constrained by the equipment which he has available and therefore may not have much choice in the method of mining.

SELECTION OF MACHINERY

Operators should be very aware of the capability of machinery in terms of capacity to shift overburden economically. The Regulations, however, do have some implications in terms of the choice of machinery. The following requirements should be considered carefully before selecting equipment: 1) Stripping and stockpiling of topsoil [816.22, 816.23]; 2) Selective handling, placement and consolidation of overburden [816.41(d)(2)(vii)-(viii), 816.71]; 3) Contemporaneous backfilling [816.101(a)]; 4) Grading, ripping, etc. [816. 101-816.106]; 5) Replacement of topsoil, revegetation and management [816.111-816.117].

Mine operations in hill terrain used to prefer to move overburden by blasting and pushing rather than hauling. However, techniques using blasting and pushing are not possible with the new Performance Standards. This means a different emphasis in machinery requirements with heavy investment in loaders and haul trucks. It also means more precise planning of earthmoving operations to keep the equipment fully utilized. These considerations may be difficult for the small operator to meet.

Clearly, versatility is one of the most important factors governing the choice of equipment and mining method by the small operator. Machinery that can perform at least two tasks will be preferred (dozers, pan scrapers, front-end loaders, etc.). For instance, it is important that whatever machinery is used for coal removal on a small site, it can be deployed on another task also as coal removal can usually be done much faster than removal of overburden.

Some new developments in mining machinery seem to be emphasizing versatility but there is also a strong trend towards the development of various continuous (rather than cyclic) methods of handling overburden removal, involving huge capital investments far beyond the resources of the small operator. Yet, as continuous, largely automated methods are adopted by the large companies, the role of the small operator in exploiting deposits unsuitable for those methods becomes increasingly important.

SCRAPERS

The removal, stockpiling and replacement of topsoil required in the new Regulations [816.21-816.25] is likely to be carried out mostly by scrapers. Therefore there may be a tendency to use mining methods which can also use scrapers to remove overburden where it is unconsolidated and where terrain makes it possible. Operational costs are usually higher for scrapers than for a dragline of a shovel but scrapers can selectively place overburden material, consolidate it and regrade in the same operation. Scrapers may cause excessive consolidation making ripping necessary. However Section 816.24(a) requires that the surface be scarified.

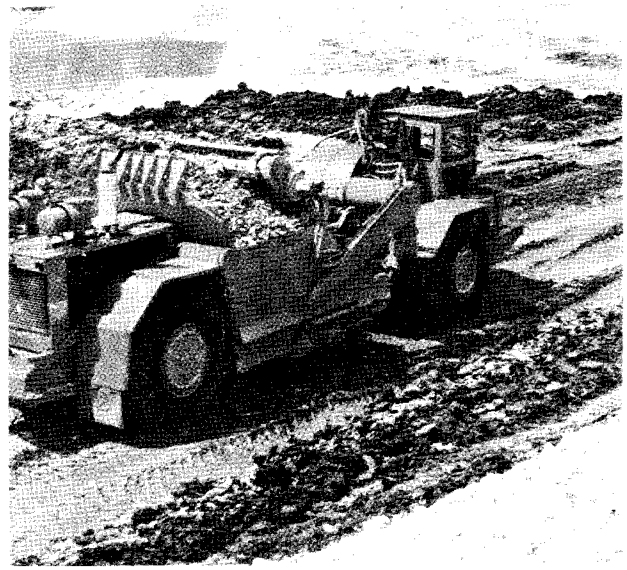
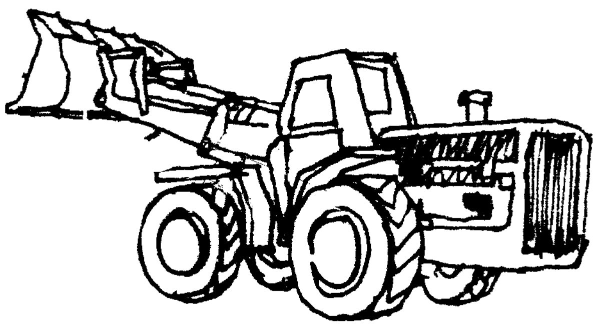


FIGURE 2
The scraper has many advantages though the small operator might only justify its employment in multiple use situations.

The flexibility of scrapers and their ability to dig, load and haul makes them especially valuable for meeting the contemporaneous reclamation requirements of the Regulations. In addition, their ability to handle overburden selectively makes them valuable in meeting the requirements for selective handling and placement of acid-forming spoil [816.48]. They also have the versatility of being able to build and maintain their own haul roads. Scrapers are an expensive investment for the small operator. Unless he has plans for also using it for tasks other than topsoil removal he may be better off to use bulldozers or front-end loaders.

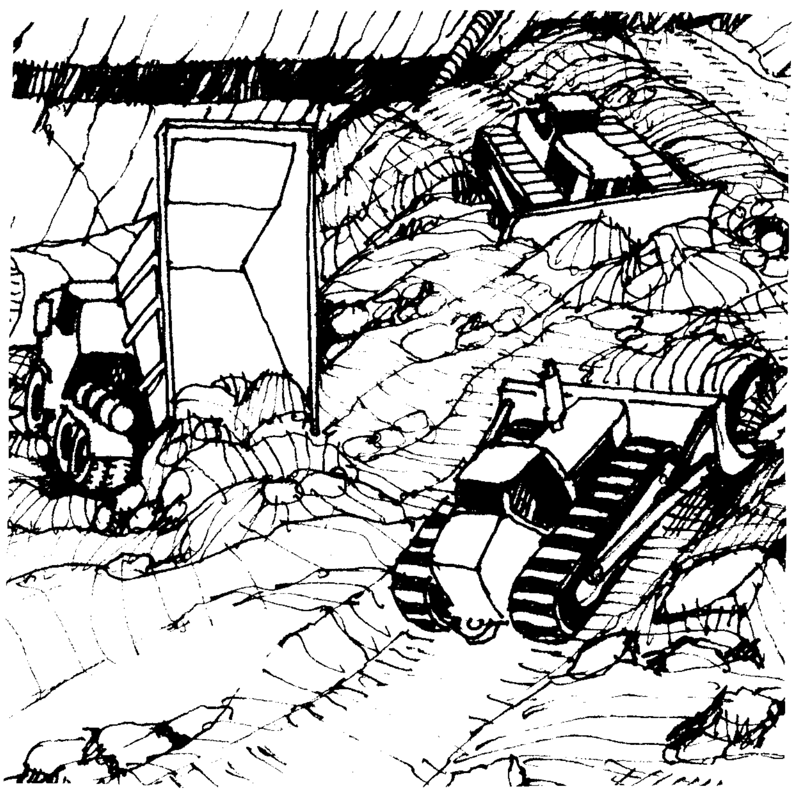
FRONT-END LOADERS

The requirement of the Regulations for selective handling and placement of overburden materials and the precision with which this can be done by front-end loader/haul truck combination, together with the great range of tasks for which front-end-loaders can be used, makes these highly versatile machines ideal for use on many small surface mine operations. The mobility of the front-end-loader-and-loaders, its ability to dig and load, and its uses in construction of sedimentation ponds, diversions, etc. makes it especially useful. The tracked versions used for difficult terrain do not have the speed and maneuverability for most applications. They do however have a lesser bearing pressure making them useful on sites where compaction is to be avoided. Front-end loaders are now being used increasingly on sites of all sizes.



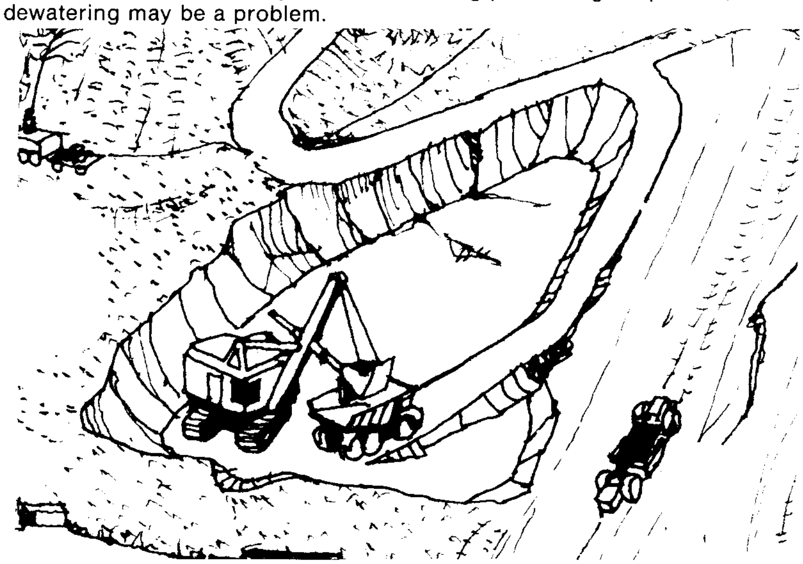
DOZERS

Bulldozers will continue to be used heavily in all surface mining operations both for earthmoving and increasingly for other operations such as root grubbing (during site clearance prior to topsoil removal), regrading, ripping, various cultivation operations, and push-loading scrapers, etc. However, their use in shifting overburden may become less important particularly in contour mining where haulback is necessary to keep spoil off the downslope, though they will continue to be used widely for this purpose in area mining on small sites.



LOADING SHOVELS

Though large stripping shovels have low operating costs they do not have the flexibility required for most small mine operations. When being used to cast overburden, their ability to place material selectively is limited, nor is spoil consolidated when cast. This can lead to AMD problems. Also when casting spoil the pit is very confined, making pit drainage important; and dewatering may be a problem.



Loading shovels (illustrated) used in combination with haul trucks solve the problems of selective placement of acid-forming and toxic-forming spoil. Consolidation is also achieved through the use of haulage trucks, and the pit will be less confined. Because of their high breakout capacity however, shovels avoid the need for blasting in lightly consolidated material, and thus the blasting restrictions in the Regulations would not apply.

HYDRAULIC EXCAVATORS

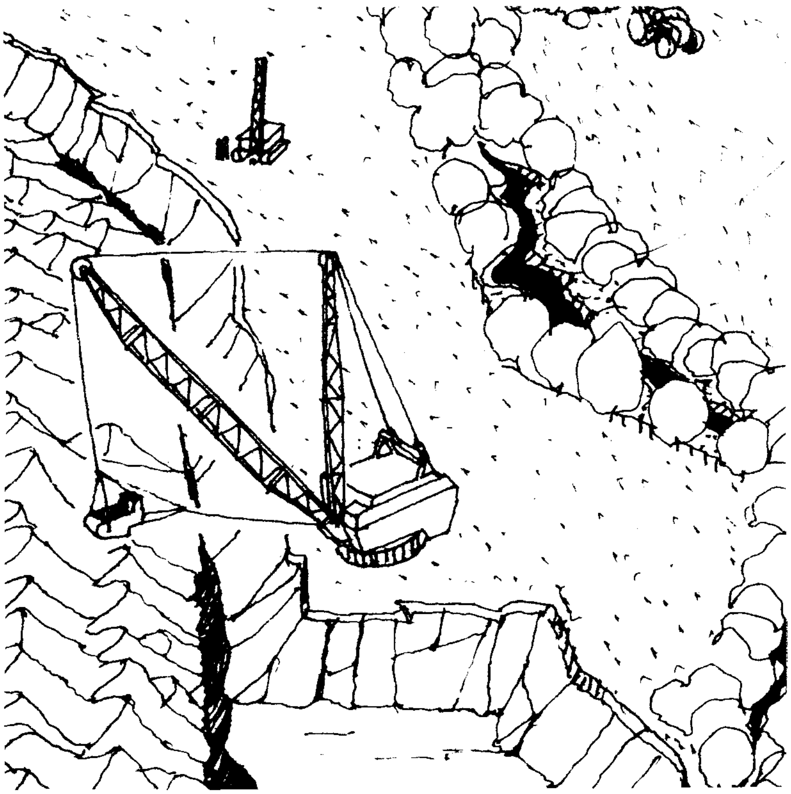
Hydraulic excavators are very versatile and may perform a number of tasks on the mine site besides that of excavating overburden. Excavation of sedimentation ponds with excavators with back-hoe configuration can be accomplished quickly and easily due to their long reach.

If the excavator is digging and casting overburden, spoil is not consolidated. If used to load haul trucks, careful placement and consolidation is possible. Crawler tracks enable excavators to negotiate poorly drained land.

Hydraulic excavators have much more breakout capacity than loaders but loaders are more economic and maneuverable for loading loose material. Thus the excavator might be used on sites with more consolidated overburden.

DRAGLINES

Operating costs of large draglines, like shovels, are low but their requirements for secondary equipment and their lack of maneuverability make them inflexible for most small operations. Many small operators in northern Appalachia though do own small draglines. They can segregate spoil quite well but cast spoil will need grading and consolidation. In some cases, where high infiltration rates are required, the high permeability of ungraded spoil may be an advantage. Where scrapers have dumped the spoil and heavy tires have compacted them the infiltration may be one or two orders of magnitude less than dragline-dumped spoils. (3).



The lack of consolidation of dragline cast spoil could result in groundwater pollution where overburden contains large amounts of acid-forming material. In cases where the proposed post-mining use is for industrial, commercial or residential development, settlement of unconsolidated spoil may give problems for several years.

BUCKET WHEEL EXCAVATORS

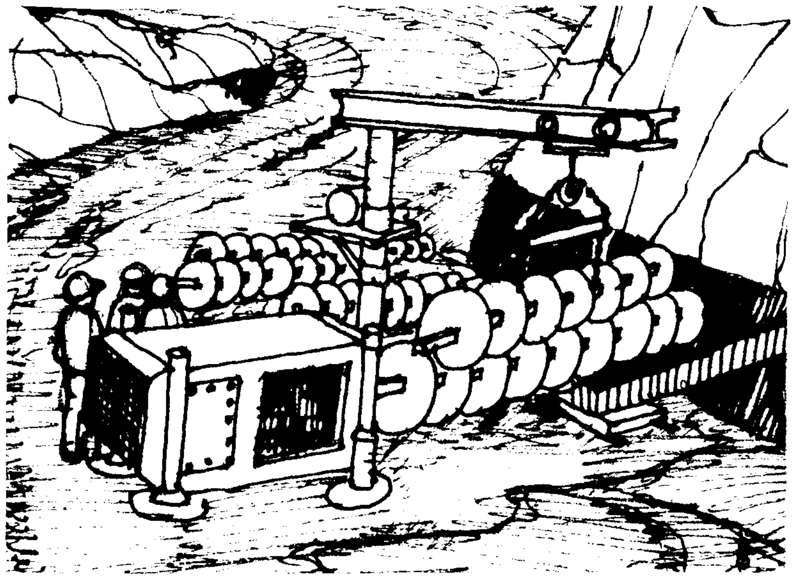
- not applicable

REVEGETATION EQUIPMENT

Reclamation requirements will create the need for various pieces of agricultural equipment. The more sophisticated reclamation equipment (hydroseeders, tree planters, etc.) will be provided by contractors but small operators may find it advantageous to own disc harrows, rippers, seed drills, fertilizer spreaders, etc.

AUGERING

Although auger mining gives a poor recovery of coal it may increase the overall recovery rate in situations where coal cannot be further exploited by other methods (seams too thin for underground mining or overlaid by a thick hard sandstone stratum) but the conditions for auger mining are rather restrictive.



The Regulations contain specific Performance Standards for augering [Part 819]. Probably the most difficult problem which the Regulations pose for small mine operators is that of contemporaneous backfilling. The expense of auger equipment makes it unlikely that small operators will operate their own and will therefore rely on contractors. But to justify using contractors, the small operator must either have sufficient highwall exposed at any one time to make the operation economic, or be able to operate at sufficient speed to keep ahead of an auger outfit which is unlikely. It may be that on submission of a "written analysis" [780.18(b)(3)] additional time may be granted for backfilling and grading [816.101].

The danger of penetrating abandoned (or active) surface mines forbids any auger hole closer than 500' (horizontally) to underground mine workings [816.11(b)]. The problem of unmapped underground workings and the danger of sudden release of large quantities of groundwater, often seriously polluted, is a constant hazard of auger operations in previously mined regions.

Auger holes can be a serious source of acid mine drainage and Section 819.11(c) contains very specific requirement for plugging auger holes (within 72 hours for holes discharging polluted water or within 30 days for holes not discharging water).

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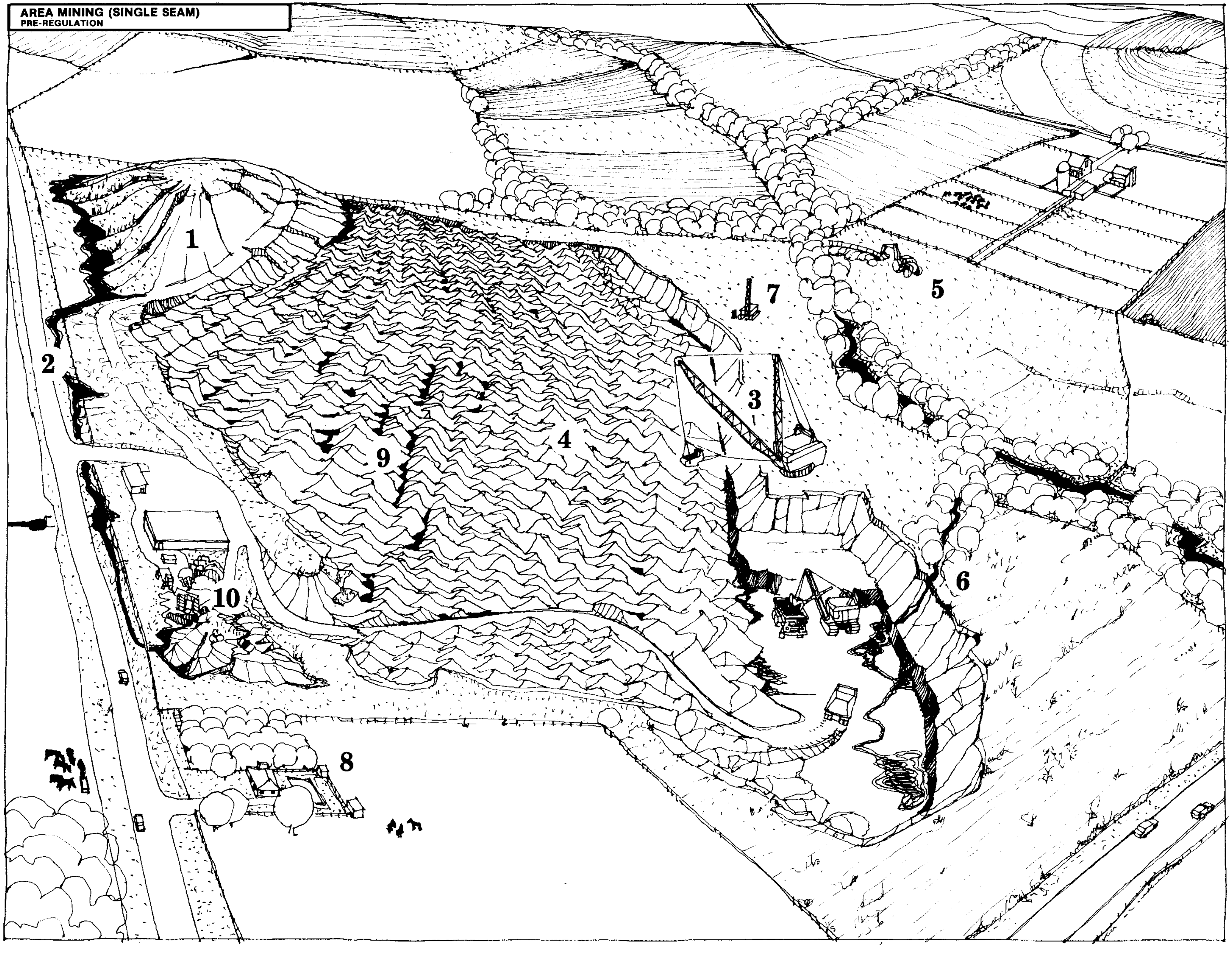
CHAPTER 4

MINING OPERATIONS

The drawings on the following pages illustrate various surface mining methods, and the operations which are involved in each. The first drawing for each method shows an unregulated mine, and the key below identifies problems which arise during and after mining and the Sections of the Regulations which are intended to solve these problems. The next drawing for each method shows phases of a mine which meet the requirements of the new Regulations. The key below identifies each operation, the Section of the Regulations relevant to that operation and the title and number of "Data Sheets" which are found in Chapters 6 and 7. These illustrations obviously do not cover all situations encountered during surface mining. However we hope that operators will be able to identify commonly occurring problems in these hypothetical examples.

AREA MINING (SINGLE SEAM)
PRE-REGULATION



AREA MINING (SINGLE SEAM)
PRE-REGULATION

More coal is extracted using area mining than by any other technique. However, due to the economics of scale most operations are large. Much of the coal which is exploitable by area surface mining is found in states west of the 100th meridian but large quantities are also found in midwestern states, often beneath good farmland.

Small operators are probably more likely to work a site using scrapers, dozers and/or loader-truck or shovel-truck combinations; but some will use draglines or shovels as the prime earthmovers. Shown here is a drag-line, working a single seam site with a ratio of overburden to coal of about 8:1 and swell factor of 10%, prior to any regulations requiring reclamation.

In order to be economic, area mining operations must minimize double handling of overburden. Thus, a pile of overburden is usually made close to the initial box-cut. The overburden from subsequent cuts is then cast into the previous cut leaving a series of hills and dales. Upon completion of the mining operations prior to the enactment of regulations, the final cut remained, often partially filled with water and with the highwall exposed.

Depending on the machinery and working methods being used, spoil was usually inverted, the topsoil and subsoil being buried, the strata close to the coal on top. This often resulted in a surface layer which was unsuitable, chemically or physically, to support plant life.

Where this technique is used, the problems of soil erosion are not as severe as in the case of mining in mountainous terrain; nor is acid mine drainage, mostly because runoff is easier to control. Nevertheless, where large areas are stripped at one time, and no reclamation is carried out, the impact of area mining in terms of loss of farmland, deterioration of the quality and quantity of surface and groundwater and other environmental values can be serious.

The Regulations

The Regulations require that all land which is surface mined is restored to its "approximate original contour." This means that some double handling of spoil from the initial box-cut will be required. The highwall and all depressions must be eliminated and, to do this, hauling much of the box-cut spoil will be necessary. All topsoil must be removed separately and placed on reclaimed areas immediately when possible. The Regulations require a minimum delay in restoration so that it proceeds in conjunction with the working.

These operations require careful pre-planning if machinery is to be fully and effectively utilized while meeting the requirements of the Regulations.

In cases where the land is classified as "prime farmland" special performance controls will be enforced. These include the requirement that 4' of soil and soil material be reconstructed during reclamation. If an operator is using scrapers to remove topsoil and unconsolidated (drift) overburden, and to replace these materials on regraded areas immediately, this requirement may not increase costs of earthmoving greatly if the operations are planned carefully.

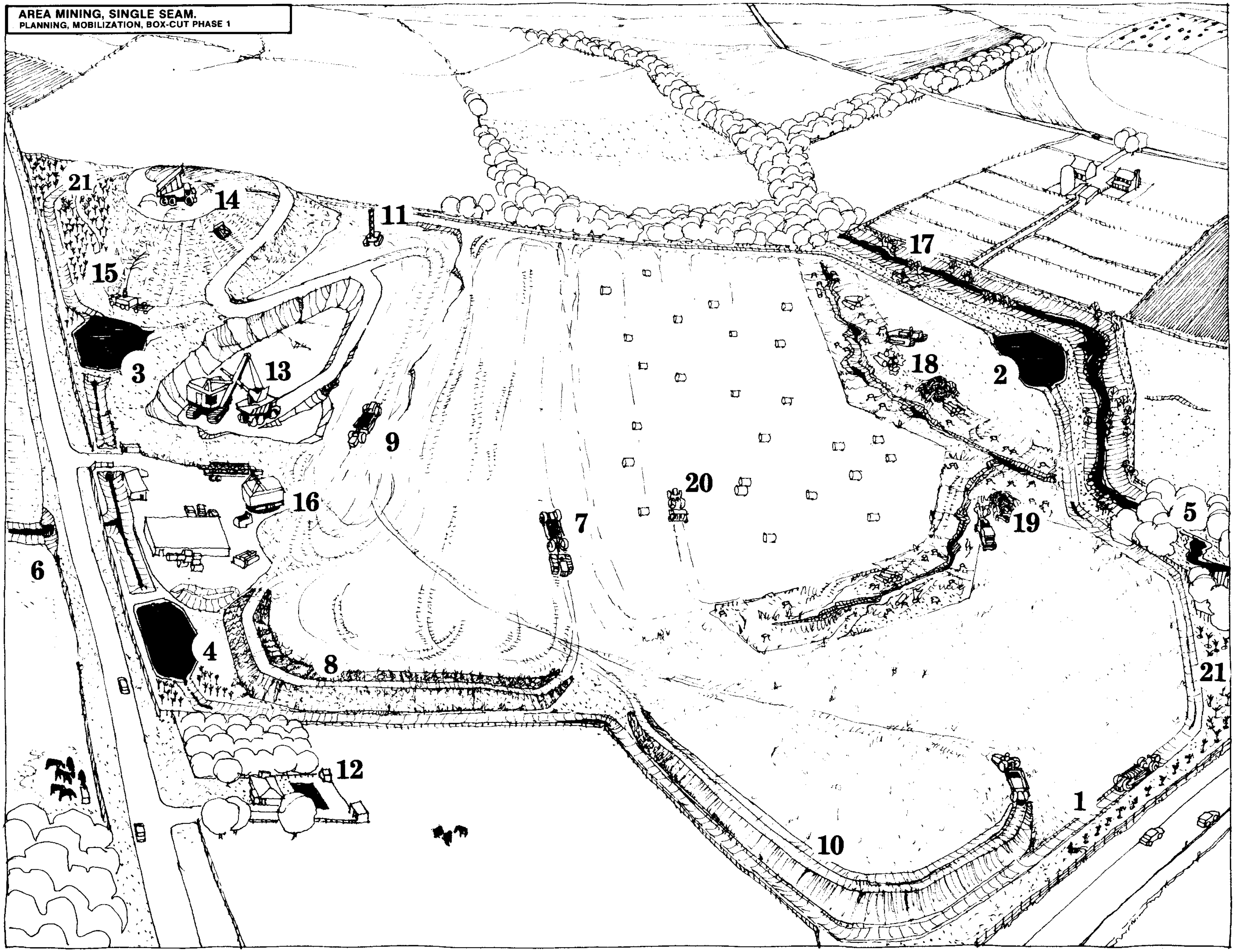
Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

(NOTE: Text includes references to illustration opposite.)

OPERATION KEY	OPERATION DESCRIPTION	PROBLEMS
1	Overburden from an initial box-cut is dumped on a spoil heap (1) using scrapers or shovel /dump-truck combination.	— Topsoil and subsoil are not stripped from the box-cut and stockpiled but are dumped with overburden. — Topsoil is buried beneath the soil heap. — Overburden on spoil heap begins to erode immediately. If pyrite is present in the spoil, acid mine drainage may be a problem. — Sediment as a result of erosion causes surface water pollution and (in this case) is clogging roadside ditches and culverts (2).
2	Ditching	
3, 4	Dragline (3) casts overburden from subsequent cuts into the one before in a continous digging operation. A series of ridges and furrows (hill and dale) results (4).	— Topsoil is mixed with overburden. — Acid-forming material, drift overburden and solid overburden are cast in no orderly way resulting in spoil of highly diverse quality, which is often unsuitable for survival and growth of vegetation. — The physical form of hill and dale does not allow any economic post-mining land use.
5, 6	Backhoe (5) digs diversion for stream which will be mined through. The size of the channel is based on the operator's judgment.	— A tributary of the stream is already being mined through (6) resulting in some backflow into the pit making pit dewatering a major problem. — Poorly designed and constructed diversions will result in water pollution, flooding and bank erosion problems.
7, 8	Drilling rig (7) drills and shoots overburden.	— Probably due to fracturing of the aquifer, groundwater at farmers well (8) has been polluted and the yield has become unreliable.
9	Runoff collects in "dales" (9) and seeps into the unconsolidated overburden.	— Where overburden contains pyritic materials, acid drainage will result. This can contaminate groundwater resources.
10	Dumping of miscellaneous refuse from the maintenance yard (10).	— This is an eyesore and a nuisance to the nearby dwelling. It can also cause a pollution hazard to surface water.
11	Unrestored land results in permanent loss of farmland (11 not shown).	— Unrestored mine lands may continue to erode and contribute sediment and acid drainage to receiving waters for years after mining ceases.

REQUIREMENTS OF THE REGULATIONS*

SECTION	REQUIREMENT
816.21 816.23 815.45 816.42(a) 816.42(a)(7)	Before disturbance of an area, topsoil and subsoil to be saved must be removed and segregated from other materials. This includes topsoil from areas to be used for spoil dumps, haul roads, diversions and sedimentation ponds. Topsoil shall be stockpiled "only when it is impractical to promptly redistribute such materials on regraded areas." The temporary mound of box-cut spoil should be protected from erosion by mulching and seeding. "All surface drainage from the disturbed area . . . shall be passed through a sedimentation pond." Discharges of water from disturbed areas are also subject to effluent limitations.
816.101 816.103	Rough backfilling and grading shall be completed within 180 days following coal removal and shall not be more than four spoil ridges behind pit being worked. Any acid-forming or toxic-forming materials identified in the "Geology Description" [779.14] must be selectively handled and be covered with a minimum of 4' of non-toxic material.
816.44 816.44(d)	Diversions must be approved by the RA. Temporary diversions must be designed to carry runoff from a 10 yr/24 hr precipitation event. Permanent diversions must be designed for a 100 yr/24 hr event, and they should be restored to "approximate pre-mining stream characteristics" including pools, riffles, meanders, etc.
816.62	Where mining operations are carried out within ½ mile of a dwelling, the owner can request a pre-blasting survey which shall give special attention to the condition of wells.
816.50	Mining shall be carried out to prevent discharge of acid, or otherwise harmful drainage water into groundwater systems.
816.89	"Disposal of non-coal wastes" shall be placed in a controlled manner in a designated portion of the permit area.
Part 823	Part 823 contains special performance standards for restoration of prime farmland.
816.116	Part 816, however, requires restoration of other farmland to a level of productivity of at least 90% of the productivity of the approved reference area.



AREA MINING, SINGLE SEAM.
PLANNING, MOBILIZATION, BOX-CUT PHASE 1

AREA MINING, SINGLE SEAM.

PLANNING, MOBILIZATION, BOX-CUT PHASE 1

If area mining is carefully preplanned and carried out in an orderly way, it is usually feasible to restore land to its original productivity within a short period and to minimize the impact on surface water and groundwater during and after working.

It is also possible to plan contemporaneous reclamation operations to occur steadily as mining progresses without incurring large increases in earth-moving costs. The importance of avoiding the double handling of overburden to the economics of area mining is recognized. However, it may be necessary to rehandle much of the overburden taken from the first box-cut in order to fill the final void and to eliminate the highwall. In cases where there is excess of fill in the site [816.105] it may be possible to place much of the overburden from the first box-cut permanently and avoid the need to double handle it as backfill for the final void.

The control of surface water on area mine sites is usually much easier than on contour mines. Points at which drainage from the site is discharged can be minimized. In the illustrated example drainage and overland flow is directed around the edge of the permit area in diversions to sedimentation ponds before discharging into receiving waters.

When the site is "prime farmland" the special performance standards in Part 823 apply. Whether or not the site is prime farmland is determined during the application process [779.27]. This Section contains a list of conditions, any one of which will result in the land not being classified as prime farmland. One important condition is that the Soil Conservation Service soil survey has not designated any soil map units as prime farmland.

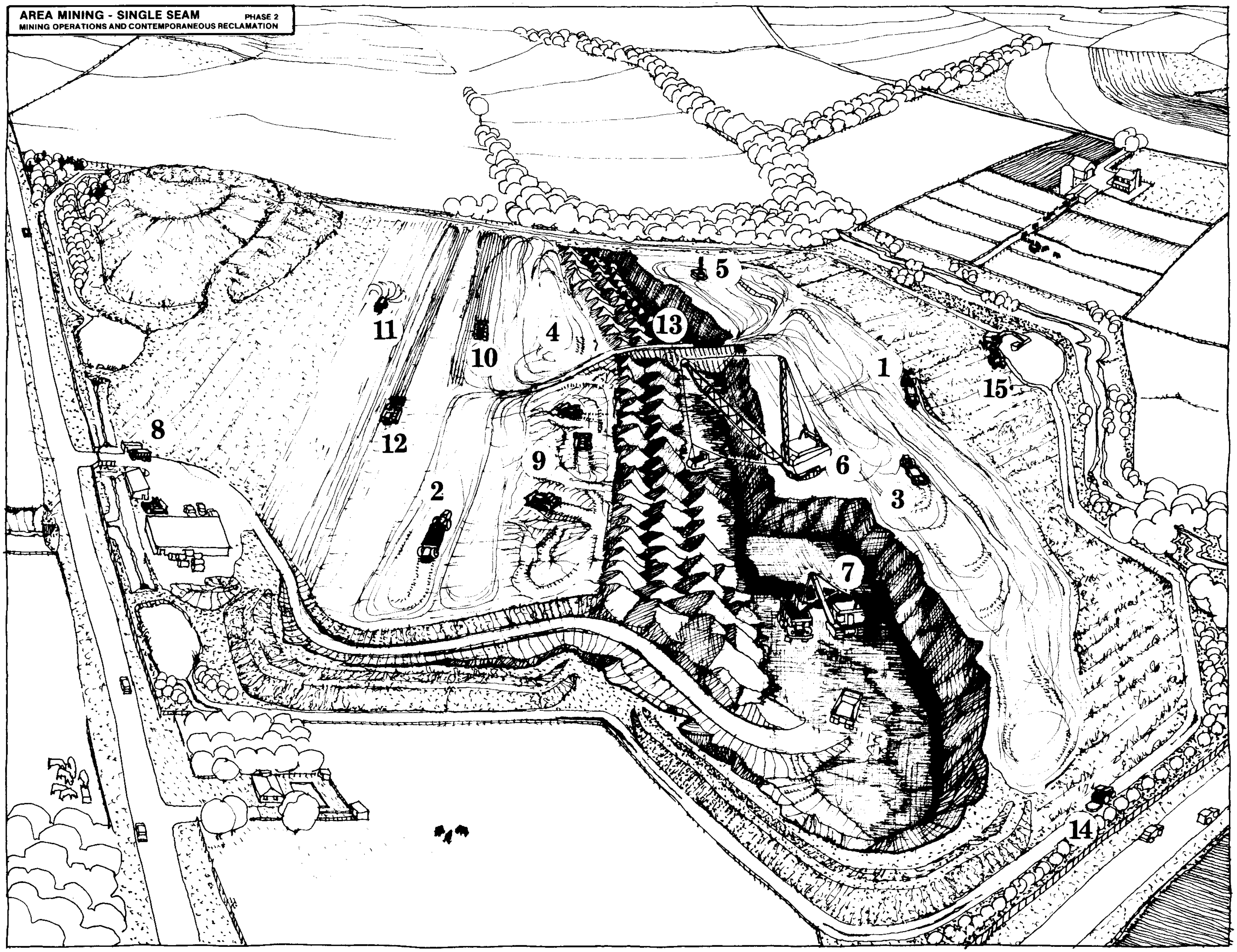
Probably the major difficulty posed by the new Regulations for the small surface mine operator will be the greater amount of machinery required and the precision with which the operation must be planned to avoid delays. The requirement for contemporaneous reclamation will increase the importance of scrapers in the operation, and the requirement to transport box-cut spoil (to eliminate depressions and the highwall) will necessitate a large number of haulage trucks.

The Small Operator Assistance Program provides assistance for the small operator during the application process, notably with the analysis of overburden from core samples and assessment of the impact of the proposed mining activities on surface and groundwater [Part 795]. In spite of this assistance, the operator will be well aware of the need for careful preplanning of area mining operations if the requirements of the Regulations are to be met.

Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

(NOTE: Numbers in text refer to illustration opposite.)

OPERATION: KEY	OPERATION: DESCRIPTION OF OPERATION	REQUIREMENT OF THE REGULATIONS*: SECTION	REQUIREMENT OF THE REGULATIONS*: REQUIREMENT	DATA SHEET: SHEET TITLE	DATA SHEET: NO.
1	Diversions to convey overland flow around the edges (1) of the site both to minimize interference with mining, and to reduce contamination of stormwater have be constructed.	816.43	"Overland flow . . . and flow in ephemeral streams may be diverted away from the disturbed area by means of temporary or permanent diversions." Temporary diversions to be designed for a 2-year storm.	Stream diversions: Overland flow and ephemeral streams.	6:4
2-4 5,6	Flow from these diversions pass through three sedimentation ponds (2,3,4) prior to discharge from permit area (5,6). These ponds must be constructed before disturbance of the site.	816.42(a)(1) 816.46(a)(1)	"All surface drainage from the disturbed area . . . passed through a sedimentation pond." "Sedimentation ponds shall . . . be constructed before any disturbance of the . . . area to be drained into the pond."	Sedimentation Ponds	6:3
7 8	Topsoil is being removed by scraper (7) and stockpiled (8). Topsoil beneath the spoil dump (14) was also removed.	816.21 816.22 816.23	Topsoil: General Requirements. Topsoil: Removal. Topsoil: Storage.	Clearance of vegetation and removal and storage of topsoil	6:6
9 10	Unconsolidated (drift) overburden is being removed by scraper (9). Subsoil is being stockpiled (10) and the rest is being used to cover consolidated overburden on the spoil dump (14).	816.22(d)	"The B horizon and portions of the C horizon . . . shall be segregated and replaced as subspoil if the regulatory authority determines that . . . [it] is necessary."		
11 12	Drilling rig (11) drills consolidated overburden which is then shot. Dwelling with a water supply well (12).	816.62	A resident or owner of a dwelling within ½ mile of the permit area may request a preblasting survey to be carried out.		
13 14	Shovel digs first box-cut (13). Spoil is transported by dump truck to spoil dump (14). This is graded with maximum slopes of 1v:2h and covered with subsoil.	816.101	Box-cut spoils will largely have to be transported to the final cut. However, the RA in this case is permitting some of the box-cut spoils to be placed permanently and the left-hand slope of the spoil dump has been topsoiled and planted.	Temporary Spoil.	6:7
15	A hydroseeder (15) applies seed and fertilizer to the temporary spoil mound (14) and to the stockpiles of topsoil and subsoil (8,10).	816.23(b)	"Stockpiled materials shall be . . . protected from wind and water erosion. . ." Protection is usually accomplished by seeding with a cover crop of annual and perennial species.	Cover Crops.	7:11
16	Dragline assembly (16) is in progress. Construction of office and maintenance yard is complete.	816.150- 816.155	These Sections contain performance standards for Class I roads which will apply to the area here and to the access to the public road.	Haul Roads.	6:2
17	The stream has been diverted permanently (17). The channel has been graded and and constructed to reflect its natural character. The design standards for permanent diversions are more stringent than for temporary diversions, but the latter must be restored.	816.44(a) 816.44(b)(2) 816.44(d)	Flow from perennial streams . . . may be diverted only with the approval of the RA. Permanent diversions must be designed to carry flow from a 100 yr/24 hr precipitation event. The natural riparian vegetation and other natural characteristics of the stream should be restored.	Stream diversions: Perennial and intermittent streams.	6:5
18 19	Logging and destumping (18) are in progress along the old stream channel. Slash from clearance is being chipped (19) for use as mulch.	816.22(a)	This Section requires that "vegetative cover that would interfere with the use of the topsoil is cleared from the areas to be disturbed."	Clearance of vegetation and removal and storage of topsoil.	6:6
20	Note that much of the permit area is still in agricultural production (20), in this case a crop of mulch hay being harvested under contract for use during restoration. A feature of area mining is that it allows the minimum area of the site to be disturbed at any one time. The new Regulations emphasize the importance of minimizing the area disturbed and of contemporaneous reclamation.	816.22(f)(1) 816.45(b)(1)	"The size of the area from which topsoil is removed at any one time shall be limited." . . . Disturbing the smallest practicable area at any one time during the mining operation."	Mobilization and mining operations: General.	6:1
21	The operator has planted trees (21) on some areas of the site which will not be affected by mining.		This action is not required by the Regulations.	Revegetation: Trees and Shrubs.	7:13


AREA MINING - SINGLE SEAM
PHASE 2
MINING OPERATIONS AND CONTEMPORANEOUS RECLAMATION
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AREA MINING - SINGLE SEAM PHASE 2

MINING OPERATIONS AND CONTEMPORANEOUS RECLAMATION

Section 816.100 (Contemporaneous Reclamation) of the Regulations requries that "reclamation efforts, including. . .backfilling, grading, topsoil replacement and revegetation of all land that is disturbed by surface mining activities shall occur as contemporaneously as practicable with mining operations." The reclamation plan[780.18], required as part of the application process, must contain "a detailed timetable for the completion of each major step in the reclamation plan."

Section 816.101 requires that in area strip mining "rough backfilling and grading shall be completed within 180 days following coal removal and shall not be more than four spoil ridges behind the pit being worked. . ." In the illustrated example, the operator is ahead of this deadline.

Contemporaneous reclamation demands very careful allocation of machinery and preplanning, but the feasibility of contemporaneous reclamation in area mining is a feature which makes this form of mining more acceptable environmentally than most other forms of surface extraction. In the example shown, the operator has placed a temporary ramp across the pit to reduce the haul for scrapers carrying out contemporaneous stripping and replacement of unconsolidated overburden and topsoil.

Contemporaneous reclamation ensures that a minimum part of the permit area is disturbed at one time and therefore the hazards of erosion and water pollution are minimized. Note that in the illustration the land at the left of the site has already been regraded, topsoiled and revegetated. (Disturbance of the temporary spoil mound will occur at a later date.)

The temporary spoil mound and the stockpiles of topsoil and subsoil are protected from erosion by vegetation, and they will remain undisturbed until the backfilling of the final cut begins.

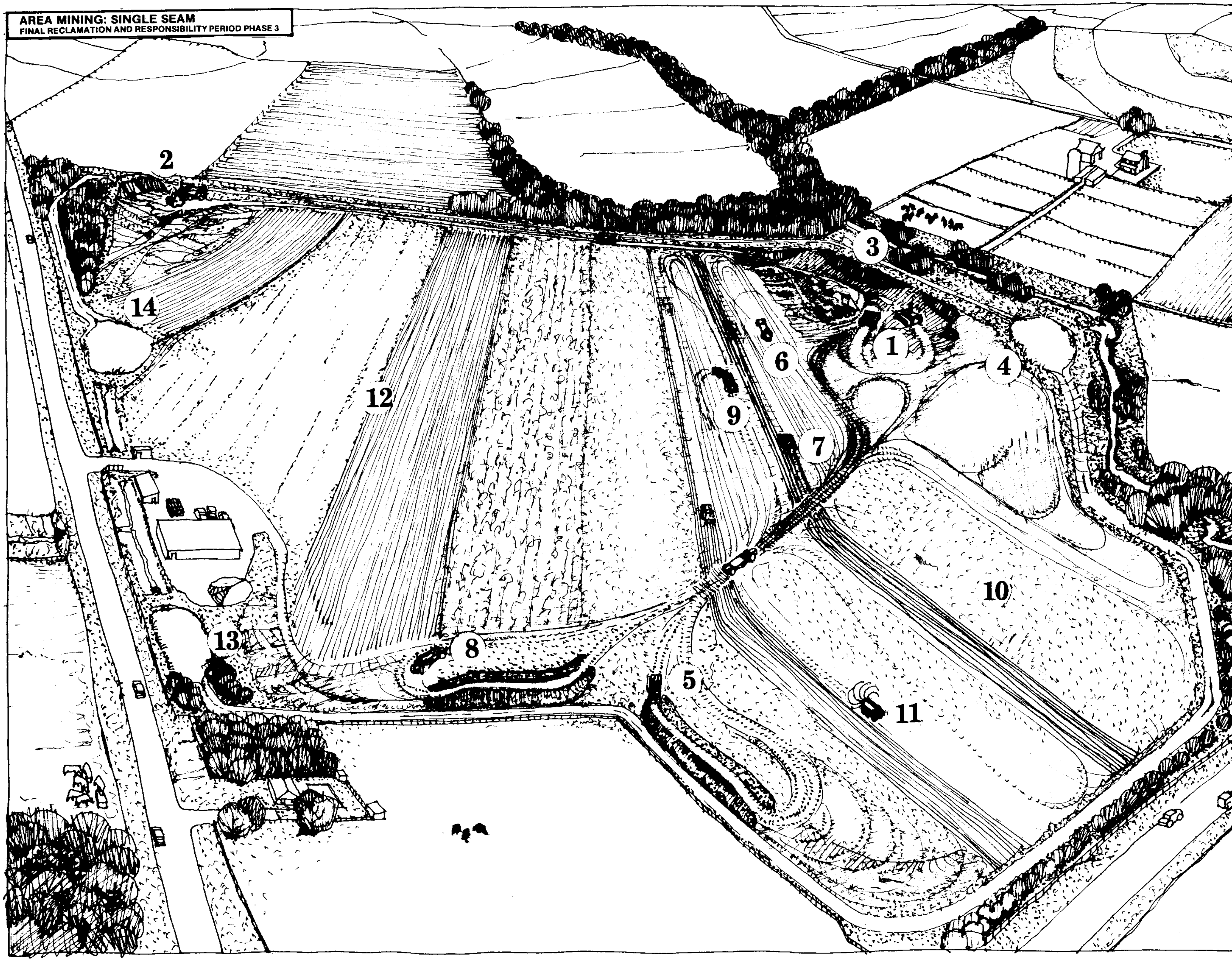
The diversions which carry overland flow from the site to the sedimentation ponds are kept mown in order that the resistance of the grass to erosion will not be reduced. One of the sedimentation ponds shown here is being dredged. This is required when sediment accumulates to 60% of the design sediment storage volume.

In order to clarify the method of working, some machines are shown more than once on this drawing. It is unlikely for instance that, on a site of this size, there would be 4 scrapers. Coaling may be done with a loader rather than a shovel as shown, and the operator will be able to find other unrealistic details in this example.

Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

(NOTE: Text includes references to illustration opposite.)

OPERATION KEY	OPERATION DESCRIPTION OF OPERATION	REQUIREMENT OF THE REGULATIONS* SECTION	REQUIREMENT	DATA SHEET SHEET TITLE	NO.
1 2	Scrapers remove topsoil (1) and redistribute immediately on the area being restored (2).	816.23(a)	"Topsoil . . . shall be stockpiled only when it is impractical to promptly redistribute . . . on regraded areas."	Removal and storage of topsoil	6:6
3 4	Scrapers remove subsoil and unconsolidated "drift" overburden (3) redistributing immediately (4) following rough grading of the cast spoil.	816.22(d) Part 823	The regulations do not require subsoil to be replaced separately unless the RA determines that it is necessary. In the case of prime farmland [Part 823] a minimum of 4' of soil material must be reconstructed.	Replacement of topsoil and cultivation	7:5
5	Drilling rig (5) bores blast holes, and shoots unconsolidated overburden.	816.61- 816.68	Preblasting surveys may be required. All blasting must be between sunrise and sunset and a blasting schedule must be published.		
6	Dragline (6) digs and casts overburden onto previously mined area.				
7 8	Shovel (7) digs coal which is removed by road trucks which are weighed and cleaned (8) prior to entering the public highway.	701.5 816.150- 816.176	Roads within the "immediate mining pit area" are not subject to the performance controls relating to haul raods in Part 816, but all others are.	Haul roads	6:2
9	Bulldozers carry out rough grading (9) of overburden followed by replacement of unconsolidated overburden by scrapers (4). Grading should approximate to general nature of pre-mining topography.	816.101(a)(3) 816.101(b)(1) 816.102(a)	"Rough grading shall be completed within 180 days following coal removal and shall not be more than four spoil ridges behind the pit being worked. . ." "All disturbed areas shall be returned to their approximate original contour." "Post-mining final graded slopes need not be uniform but shall approximate the general nature of the pre-mining topography.	Rough backfilling and grading	6:10
10	Crawler (10) sacrifies the area prior to the replacement of topsoil (2) to reduce compaction of regraded spoil. On sloping sites, regrading operations should be parallel to the contour.	816.24(a) 816.102(e)	"After final grading and before the replacement of topsoil . . . regraded land shall be scarified. . ." "All final grading, preparation of overburden before replacement of topsoil . . . shall be done along the contour. . ."	Final grading Replacement of topsoil and cultivation	7:3 7:5
11	Lime spreader (11) in operation and the necessary fertilizers are also spread.	816.25	"Nutrients and soil amendments in the amounts determined by soil tests shall be applied to the redistributed surface soil layer. . ."	Soil amendments: lime and fertilizer	7:6
12	Cultivation and seeding (12) takes place. These operations should be carefully timed and the seed mix chosen to ensure satisfactory growth. The area must be mulched unless the RA suspends the requirements.	816.111(b) 816.113 816.114(a)	"All revegetation shall be. . .carried out in a manner which encourages a prompt vegetative cover. . ." "Seeding. . .shall be conducted during the first normal period for favorable planting conditions. . ." "Suitable mulch. . .shall be used. . ."	Revegetation: general Revegetation: herbaceous species Chemical stabilizers Cover crops Mulches	7:12 7:14 7:14 7:10 7:11 7:9
12	A temporary ramp (13) across the working pit reduces the haul for scrapers involved in contemporaneous stripping and regrading. It will be mined through and then replaced by the dragline.	816.100	This facilitates the requirement of the performance controls for contemporaneous reclamation.		
14	Grass in the waterways is being mown (14) as are the embankments of the sedimentation ponds to ensure the erosion resistance of vegetation.	816.43	"Hydrologic balance: diversions and conveyance of overland flow. . ." This Section does not require diversions to be mown but this will help to prevent erosion.	Stream diversions: overland flow Grass waterways	6:4 6:4 7:4
15	Sedimentation pond is being cleaned out (15) because accumulations of sediment are reducing its effectiveness.	816.46(h)	"Sediment shall be removed from sedimentation ponds when the volume of sediment accumulates to 60% of the design storage volume.	Sedimentation ponds	6:3



AREA MINING: SINGLE SEAM
FINAL RECLAMATION AND RESPONSIBILITY PERIOD PHASE 3
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AREA MINING: SINGLE SEAM

FINAL RECLAMATION AND RESPONSIBILITY PERIOD PHASE 3

The Regulations require not only restoration of land to pre-mining productivity levels but also require that changes in quality and quantity of both surface water and groundwater are minimized [816.41].

Section 816.116 (b) (3) requires that the success of revegetation of areas to be used for cropland be judged in comparison to an approved reference area. Areas proposed for pasture [816.115] must have a grazing capacity equal to that of similar non-mined lands. The "period of extended responsibility" under the performance bond requirements of Subchapter J continues for a period of five years (in areas with more than 26" of rain which includes all areas covered by this Handbook). "Ground cover and productivity shall equal the approved standard for the last two consecutive years of the responsibility period" [816.116(b) (1) (i)].

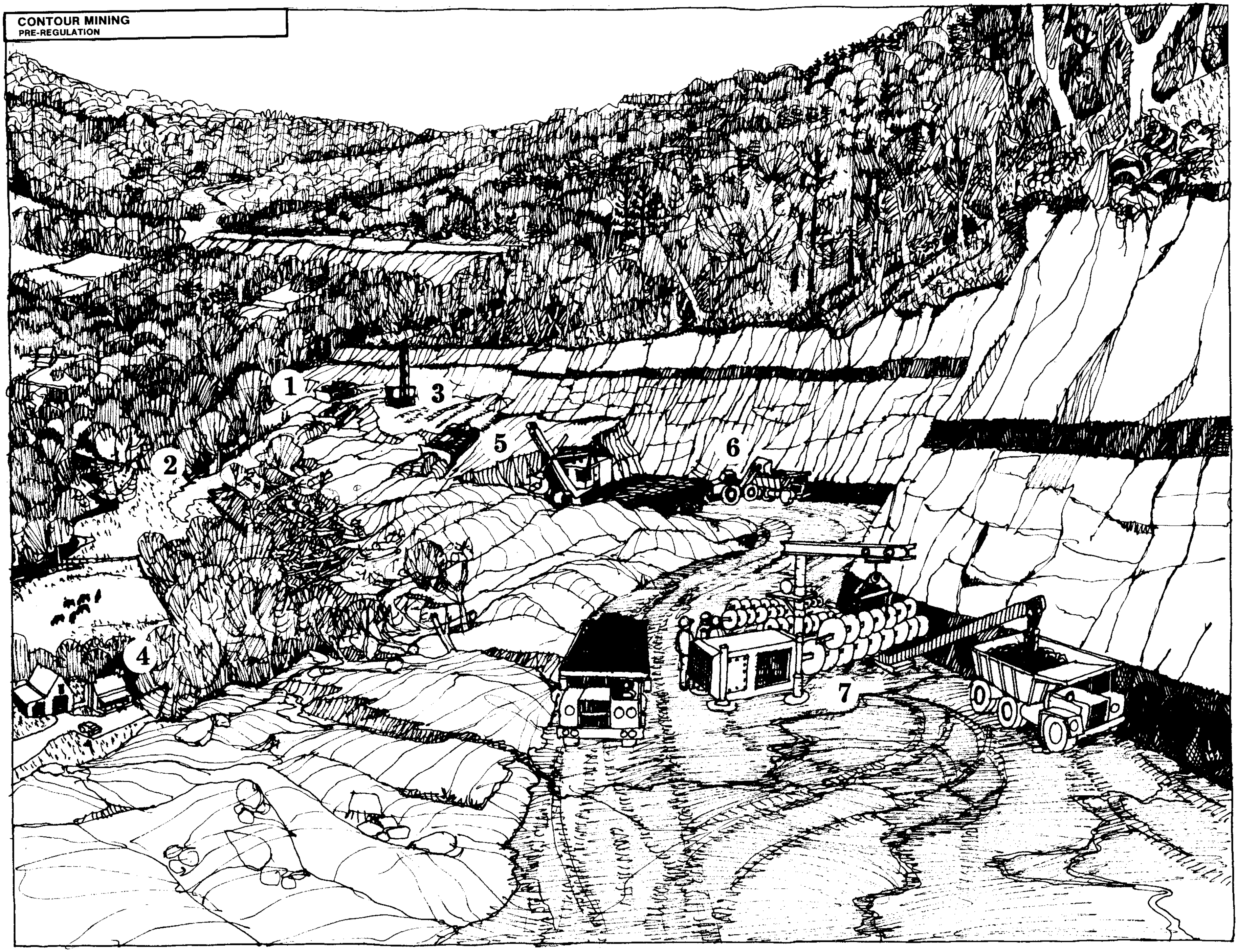
When permit areas are 40 acres or less, reference areas as a standard for revegetation success can be replaced by standards set out in Section 816.116(d), and then only with the approval of the RA. The responsibility period and success standards are longer and more stringent on prime farmland [Part 823].

Note that in the illustrated example, a 2-acre lake (1) has been proposed as a farm pond for livestock. Under Section 816.49(a) "permanent impoundments are prohibited unless authorized by the RA." The proposal, however, is quite compatible with the proposed post-mining uses and would probably be allowed. Unless approval for this variance is obtained from the RA, Section 816.101(b) (1) requires that "all spoil shall be transported, backfilled and graded to eliminate all highwalls, spoil piles and depressions." This, in effect, would disallow any of the box-cut spoil remaining on the site of the temporary dump as has been shown (the wooded slope at the left will remain and the remainder graded to a gentle slope). However, the RA has discretionary powers to establish the final provisions for the disposal of box-cut and it is felt that, in this example, transportation of box-cut spoil to the final cut is encouraged in order that the requirements of 816.101(b) (1) for elimination of highwalls, spoil piles and depressions be satisfied to a reasonable degree without requiring rehandling of **all** box-cut spoil.

Note that 816.102 specifies that slopes need not be uniform but in "general nature" should approximate to pre-mining topography. With a bulking factor less than the ratio of coal to overburden, the final grades must be lower than in pre-mining terrain. The important consideration is to make sure that surface drainage is feasible across the site which would make uneven lowering of the site necessary and occasionally changing convex slopes to concave thus insuring surface drainage.

**Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.*

OPERATION		REQUIREMENT OF THE REGULATIONS*		DATA SHEET	
KEY	DESCRIPTION OF OPERATION	SECTION	REQUIREMENT	SHEET TITLE	NO.
	(NOTE: Text includes references to illustration opposite.)				
1 2 3 4	Bulldozers carry out grading in the final void (1) which has been partially filled from the box-cut stock pile (2). Dump trucks (2) bring the loads of stockpiled overburden, partially back-filling the final void. The highwall, which is still just showing (3), will be completely eliminated. The depression (1) will remain in part to form a 2-acre lake for livestock also incorporating the sedimentation pond (4).	816.101(b)(1) 816.102(a) 816.49(a)	". . . all disturbed areas shall be returned to their approximate original contour. All spoil shall be transported, backfilled, compacted. . . and graded to eliminate all highwalls, spoil piles and depressions." "Post-mining final graded slopes need not be uniform but shall approximate the general nature of the pre-mining topography." Stockpiling and transportation of box-cut spoil to the final cut is encouraged. Permanent impoundments are prohibited unless authorized by the RA.	Rough backfilling and grading. Temporary spoil	6:10 6:7
5 6	Scraper removes stockpiled subsoil (5) for spreading on the backfilled cut (6). The area of this stockpile will require soil amendments, cultivation and seeding.	816.23(b)	Stockpiled materials shall not be disturbed until "required for redistribution on a regraded area."	Rough backfilling grading	6:10
7	A ripper pulled by a crawler tractor (7) scarifies the regraded area to reduce the compaction of regraded spoil prior to the replacement of topsoil (9). On sloping sites all regrading operations must be carried out parallel to the contour.	816.24(a) 816.102(e)	"After final grading and before the replacement of topsoil . . . regraded land shall be scarified . . ." "All final grading, preparation of overburden before replacement of topsoil . . . shall be done along the contour . . ."	Final grading	7:3
8,9	Scraper returns to topsoil stockpile (8) after spreading (9). After removal, stockpile area must be cultivated and seeded. In the case of prime farmland refer to Part 823.	816.24(b) Part 823	"Topsoil . . . shall be redistributed in a manner that achieves an approximate uniform, stable thickness consistent with the approved post-mining land uses . . . prevents excess compaction. . . and protects topsoil from . . . erosion . . ." Topsoil requirements on prime farmland.	Replacement of topsoil and cultivation	7:5
10	After final grading and topsoiling, this area (10) was seeded with a **temporary** cover crop as the season was not correct for seeding the permanent species. It is now being cultivated and lime and fertilizer spread before seeding perennial species.	816.114(c)	"Annual grasses and grains may be used alone . . . or in conjunction with another mulch when the RA determines that they will provide adequate soil erosion control and will later be replaced by perennial species . . ."	Cover crops Soil amendments; lime and fertilizer	7:11 7:6
11	Lime and nutrients have been applied in this area (11) which is being cultivated and seeded. The area must be mulched after seeding unless the RA suspends the requirement.	816.113 816.114(a)	"Seeding . . . shall be conducted during the first normal period for favorable planting conditions after final preparation." "Suitable mulch . . . shall be used . . . The regulatory authority may . . . suspend the requirement for mulch, if . . ." (see Regulations)	Soil amendments . . . Revegetation: Herbaceous species Mulches Chemical stabilizers	7:6 7:14 7:9 7:10
12	These areas (12) are being managed for grazing and cropland. "The period of extended responsibility" [816.116(b)] lasts for 5 years and begins "when ground cover equals the approved standard after the last year of augmented seeding, fertilizing. . .or other work. . ." Note that the 5-year responsibility period is applicable where annual precipitation is more than 26" (i.e., all areas covered by this Handbook). Elsewhere the period is 10 years.	816.115 816.116(b)(3)	When the approved use is pasture land, the grazing capacity must be approximately equal to that of "similar non-mined lands." This stand must be met for at least 2 years of the 5-year responsibility period. For areas to be used for cropland, success of revegetation will be judged by comparison with an approved reference area. Crop production must be equal to or greater than that of the approved standard for the last 2 growing seasons of the responsibility period.	Revegetation: General Revegetation: Herbaceous species	7:12 7:14
13,14	Sedimentation ponds (4,13,14) are still in position as all reclamation in areas drained by them has not been completed.	816.46(u)	Sedimentation ponds shall not be removed until the disturbed area has been restored and the revegetation requirements of Sections 816.111-816.117 are met.	Sedimentation ponds	6:3


CONTOUR MINING
PRE-REGULATION
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CONTOUR MINING

PRE-REGULATION

In the eighteenth century coal was discovered outcropping in the hills of Virginia. Settlers began to dig into these outcrops, removing the coal until the amount of overburden above the coal became too great. Then drift tunnels were cut into the seams. Overburden and debris from these operations were pushed over the downslope.

With mechanization, it was possible to remove much more overburden from above the coal seam before it became uneconomic. All this spoil, together with trees, vegetation and debris was pushed onto the downslope. These spoil banks eroded, depositing huge volumes of sediment in the streams. The overburden lying directly above the coal was usually dumped on the top of these spoil banks, and, because this often contained pyrite and other acid-forming minerals, the drainage from these banks was frequently highly acidic.

Spoil dumped onto steep outslopes was very unstable and landslips were common. The high rainfall and the method of dumping resulted in unconsolidated spoil with a very low shear strength. The shear stress was high in the steep terrain. Slips of abandoned spoil banks resulted in exposure of unweathered spoil which tended to prolong the problem of acid mine drainage, and to delay the natural colonization of vegetation.

Auger mining helps to increase the recovery of coal when it is no longer economic to strip overburden from the seam. However, though augering increases the recovery of coal, it has a low percent recovery rate and effectively makes it impossible to extract nearby coal by deep mine operations in the future. Unplugged auger holes are a serious source of acid mine drainage. Sometimes auger holes penetrated flooded, abandoned deep mines releasing large quantities of polluted water.

When coaling was complete the mine was abandoned and natural succession began. However, the spoil banks on the downslopes were steep and continued to erode exposing more acid-forming minerals to weathering. Hence revegetation has been very slow and surface waters in Appalachia continue to carry heavy sediment loads and large amounts of acid mine drainage.

The new Regulations for mining in steep terrain specifically forbid placement of spoil, temporarily or permanently, on the downslope. "Steep slopes" are defined in the Regulations as those slopes of 20 degrees or more and are subject to the special performance controls of Part 826. However, operations in steep terrain are also subject to the provisions of the performance standards of Part 816. These performance standards make it necessary to clear vegetation from all areas to be affected by mining, to retain all spoil and debris on the bench, to eliminate the highwall and to regrade the site to the approximate original contour, and to revegetate the area. In effect, this makes it necessary to employ some type of haul-back mining. This substantially increases the amount of equipment needed which may be difficult for small mine operations. It also makes operational planning essential, if the requirements for contemporaneous reclamation are to be met.

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OPERATION

(NOTE: Text includes references to illustration opposite.)

KEY	DESCRIPTION
1	Bulldozers push trees, vegetation, topsoil, subsoil, and unconsolidated overburden over the downslope (1).
2	The field (2) has been affected by a landslip.
3	Drilling rig (3) bores blast holes and shoots consolidated overburden.
4	This farm (4), within ½ mile of the permit area, gets water from a shallow well.
5	Bulldozer works together with shovel (5) removing the remainder of the overburden and exposing the coal. Spoil is pushed onto the downslope.
6	Front-end loader digs coal and loads truck (6) which uses a coaling road located on the previously mined bench.
7	Auger operation (7) in progress removing additional coal from the exposed outcrop.
8	Abandonment (8 is not shown)

PROBLEMS

— Mixing of topsoil, organic debris, subsoil, and overburden makes topsoil utilization impossible. Destruction of trees and vegetation on the downslope makes it highly erodible and sedimentation problems are serious.

— Spoil dumps on the downslope are often unstable and landslips are common.

— In most of Appalachia there is little groundwater available and that which is available is usually very localized. Fracturing of overburden due to blasting, and excavation and augering can change the availability of groundwater and affect base-flow in streams.

— The quality of groundwater can also be affected, usually by acid contamination.

— More spoil is dumped on the downslope, worsening both the instability problems and the destruction of vegetation.

— Erosion of the highwall, bench, and spoil on the downslope causes sedimentation problems.

— Acid-forming spoils dumped on the top of spoil banks cause acid runoff.

— Pyrite, in and close to the coal seam, is exposed to weathering, causing serious acid mine runoff.

— Runoff from the bench gathers naturally and cuts deep gullies as it pours over the outslopes.

— Auger operations do increase the recovery of coal, where the resource cannot be extracted by the other methods. But the rate of recovery achieved by augering is very low and the auger holes prevent future extraction by other methods. Augering has also, in the past, led to a worsening in acid mine drainage.

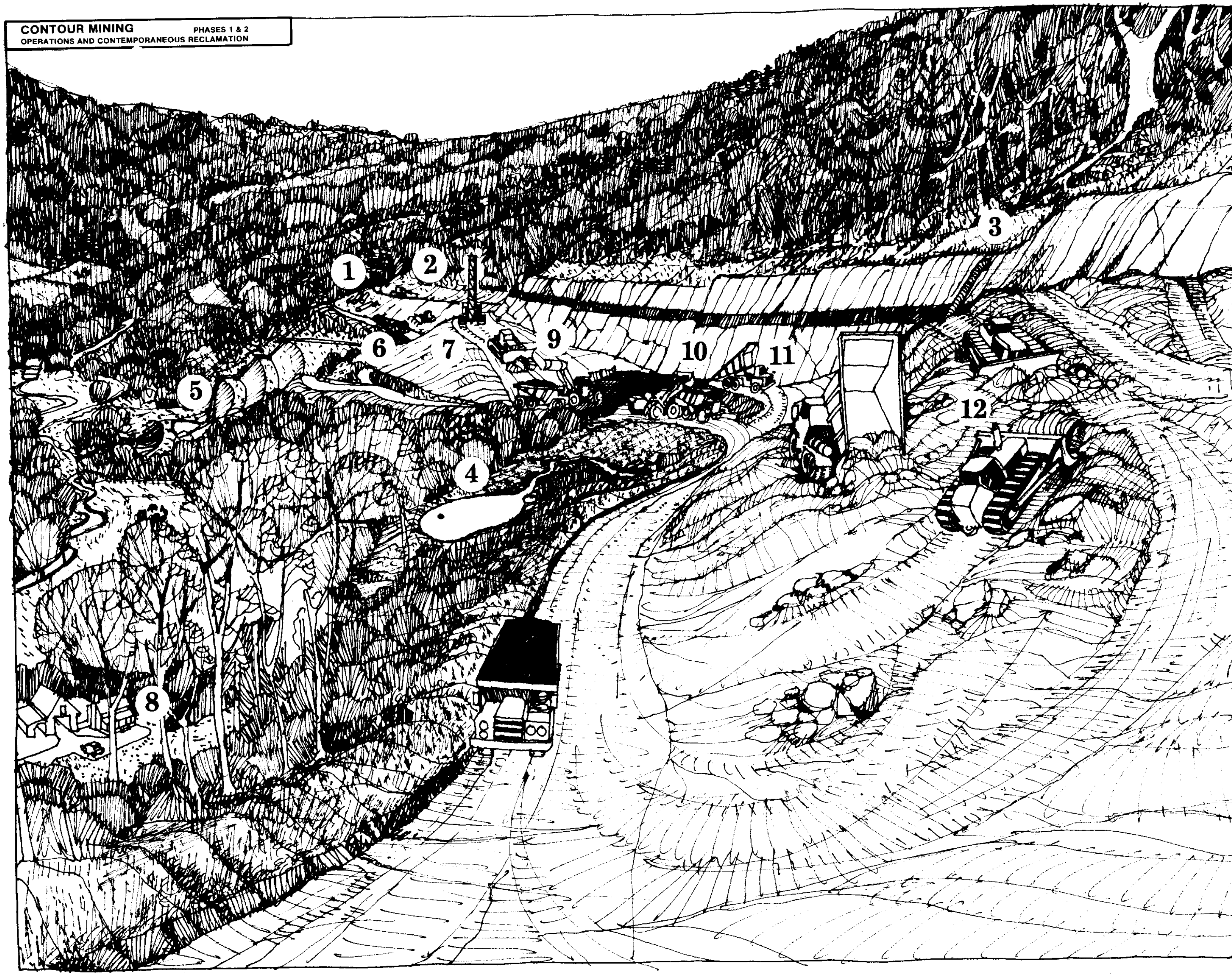
— This is due to increasing the oxidation of pyrite by admitting oxygen into the seam and also to releasing contaminated water from the seams and abandoned underground workings. In future the requirement for contemporaneous reclamation will make programming of augering very difficult for small operations.

— Abandoned, underdrained surface mines continue to produce acid and sediment-rich drainage for many years following coal extraction.

— Problems have been well documented particularly in Appalachia (see Chapter 2). Most of the water-related problems are due to erosion of steep, unstable spoil banks which continually exposes new spoil to weathering resulting in acid drainage and sedimentation, and preventing colonization of vegetation which would eventually provide effective protection against further erosion.

REQUIREMENTS OF THE REGULATIONS*

SECTION	REQUIREMENT
Part 826	This Part contains special performance standards for mining on steep slopes (20 degrees or more). This Part forbids placement of any spoil, waste or debris on the downslope.
826.12(e)	"Woody materials shall not be buried . . ."
816.22(a)	"Topsoil shall be removed after vegetative cover . . . is cleared."
826.12(b)	". . . the minimum static factor of safety for the stability of all portions of the reclaimed land is at least 1.3."
816.62	". . . a resident or owner of a dwelling . . . within one-half mile" of a permit area may request a pre-blasting survey.
816.52(a)	"When surface mining activities may affect the ground water systems ... ground water levels and ground water quality shall be periodically monitored."
816.54	The operator must "replace the water supply" where interruption of supply or contamination has resulted from mining.
826.12(a)	The operator "shall prevent the following materials from being placed or allowed to remain on th downslope: (A) spoil; (b) waste materials . . . (C) debris . . . (D) abandoned . . . equipment."
816.42(a)(1)	"All surface drainage from the disturbed area . . . shall be passed through a sedimentation pond . . ."
816.48	Acid pollution of surface water or ground water shall be avoided by identifying and burying acid-forming materials (within 30 days after it is first exposed) and preventing water coming into contact with acid-forming materials.
816.42(a)(7)	Discharges of water from areas disturbed by surface mining which are not within the pH range of 6.0-9.0 must be treated using an automatic neutralization process, unless a manual system is approved by the RA.
819.11(a)	"Any auger mining...shall be conducted to maximize recoverability of mineral reserves..."
819.11(b)	"No auger hole shall be made closer than 500 feet in horizontal distance to any abandoned or active underground mine workings..."
819.11(c)	"...each auger hole...shall be plugged so as to prevent the discharge of water from the hole and access of air to the coal..."
819.11(c)(1)	"Each auger hole discharging water containing . . . acid-forming material shall be plugged within 72 hours after completion..."
819.11(c)(2)	Holes not discharging water must be sealed within 30 days.
816.101(a)(1)	"Rough backfilling and grading shall follow coal removal by not more than 60 days or 1,500 linear feet."
826.12(b)	"The highwall shall be completely covered with compacted spoil and the disturbed area graded . . . including, but not limited to, the return of the site to the approximate original contour."
816.21-816.24	Topsoil must be stripped and replaced on all surface mining sites.
816.111(a)	Operators "shall establish on all affected land a diverse, effective, and permanent vegetative cover..."



CONTOUR MINING PHASES 1 & 2
OPERATIONS AND CONTEMPORANEOUS RECLAMATION

CONTOUR MINING — PHASES 1 & 2

OPERATIONS AND CONTEMPORANEOUS RECLAMATION

The crucial requirement of the Regulations which makes previous methods of contour surface mining obsolete is that no spoil is to be placed on the downslope, temporarily or permanently. This applies specifically to mines where slopes are in excess of 20 degrees (about 1:2.7 or 37%). In less steep terrain the conditions for mining require regrading to the approximate original contour, and elimination of the highwall. In addition, Section 816.102(a) (1) requires that all overburden and spoil be retained on the solid portion of existing and new benches.

A feasible way to carry out contour stripping in mountainous terrain without violating the conditions of the Regulations is the "Block Cut method" of dragline utilization and the "Haul-back method." In the latter a box cut is made, from which the spoil is placed permanently on an excess spoil disposal site. The following cuts may then proceed in one or both directions along the contour, the spoil from subsequent cuts being "hauled back" to previously worked-out cuts. This technique not only avoids spoil on the downslope but also satisfies the requirement for "contemporaneous reclamation," where, in the case of contour mining, rough backfilling and regrading must follow coaling by no more than sixty days or 1500 feet [816.101(a) (1)].

The problem of disposal of excess fill is covered in Sections 816.71-816.74. However, in Section 816.101(b) (1) the Regulations specifically require that "spoil shall be transported, backfilled. . ., and graded to eliminate all highwalls, spoil piles . . ." Exceptions are where spoil is not required to achieve the "approximate original contour" [816.71 (a)]. But, strictly, unless there is a high overburden: coal ratio and swell (bulking) factor, most of the box-cut spoil would be needed to fill the final cut. It is assumed that the term "approximate original contour" would permit some lowering of the original grade in vicinity of the final cut, providing there was sufficient spoil to eliminate the highwall and satisfy other grading requirements. It should be noted that in the Supplementary Information [816.101-816.105] that stockpiling and transportation of box-cut spoil to the final cut is encouraged. Obviously, operators would prefer to place box-cut spoil once and for all, and then to backfill the final cut by "borrowing" from adjacent cuts and this procedure has been used in this example.

In the past, mine operators have tended to prefer working methods which involved shifting overburden by pushing or casting rather than by loading and hauling. The latter is almost inevitably more expensive and involves much more careful operational planning to keep equipment fully utilized. It also requires more equipment which, for operators short of capital, may be a very serious problem. However, haulback methods can solve the environmental problems associated with contour mining.

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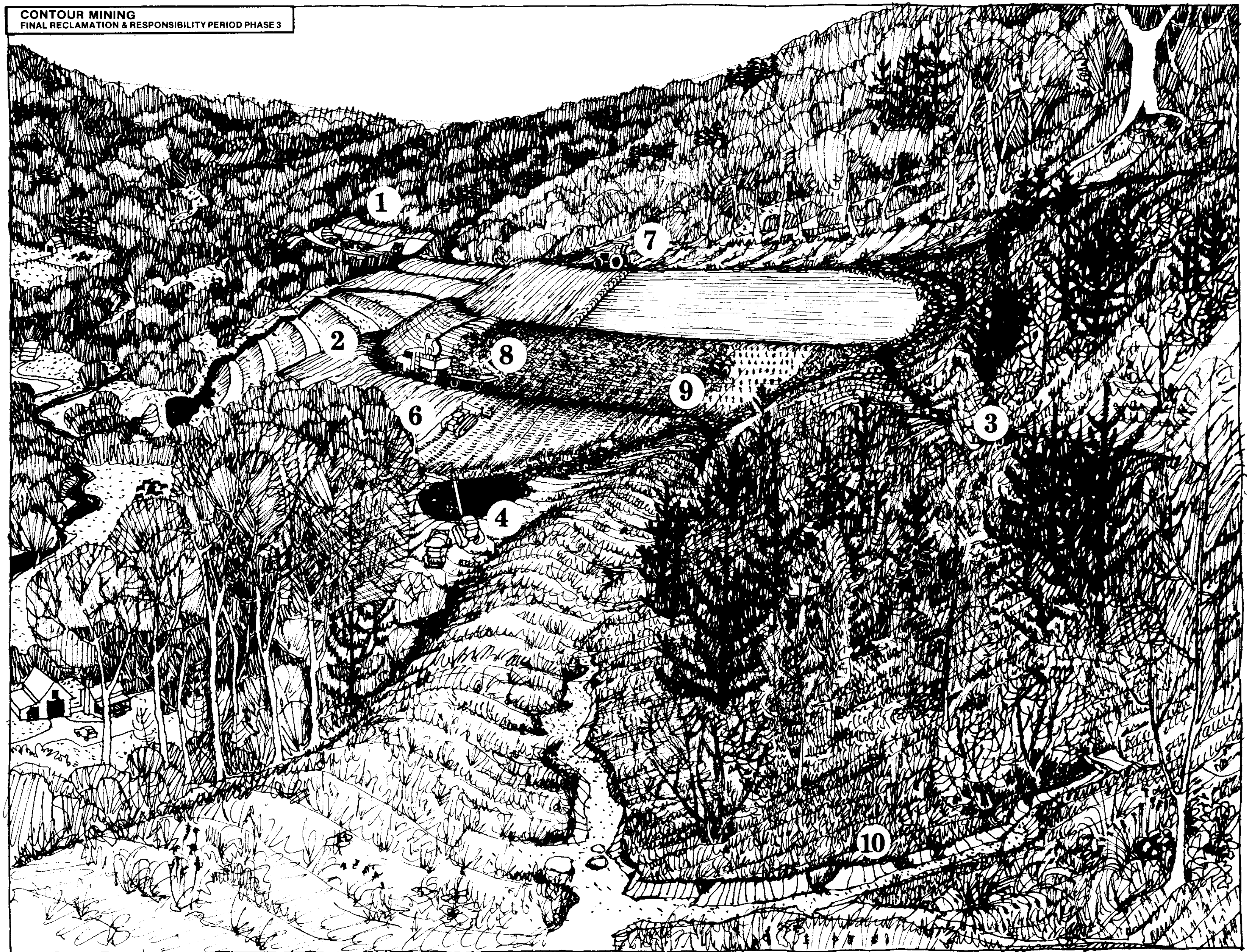
(NOTE: Text includes references to illustration opposite.)

OPERATION KEY	 DESCRIPTION OF OPERATION	REQUIREMENT OF THE REGULATIONS* SECTION	 REQUIREMENT	DATA SHEET SHEET TITLE	 NO.
1	Trees on areas which will be disturbed or affected by disposal of excess spoil are felled (1) and branches clipped for mulch.	816.22(a) 826.12(e)	"Topsoil shall be removed after vegetative cover that would interfere with the use of the topsoil is cleared. . ." "Woody materials may be chipped and distributed. . .as mulch.	Clearance of vegetation, removal of topsoil Mulches	6:6 7:9
2 3	Bulldozer creates runoff diversion (2) along upper edge of proposed highwall. The runoff must then be directed across the permit area in chutes (3) with protected outfalls.	Part 826 816.43	This Part forbids the disturbance of land above the highwall but the RA may grant a variance for reasons which include the control of runoff. "Overland flow. . .may be diverted away from disturbed areas. . ." if approved by the RA.	Stream diversions: Overland flow and ephemeral streams Grass waterways	6:4 7:4
4 5	Sedimentation ponds (4) have been installed at all points where drainage leaves the permit area, including the drainage from the Valley fill (5).	816.42(a)(1)	"All surface drainage from the disturbed area. . .shall be passed through a sedimentation pond. . .before leaving the permit area." Note the provisions in 816.42(a)(4) for overland flow which is diverted.	Sedimentation ponds	6:4
	Only three levels of the Valley fill (5) are completed. More fill will be placed on this disposal site as mining proceeds, due to the high bulking factor and the need to maintain working space in the pit.	816.71 816.72 816.73	"Spoil not required to achieve the approximate original contour" to be disposed of in accordance with Sections 816.71-816.74. Shown here is a "Valley fill" which drains to the edges of the fill mass. A Valley fill, unlike a Head-of-Hollow fill, need not fill the disposal site to the ridgeline.	Disposal of excess spoil: Head-of-Hollow and Valley fills	6:8
6	Topsoil is removed by a bulldozer. The dozer has also destumped the area to make topsoil removal possible and is pushing soil down where it is being loaded and hauled by a scraper (6). Often in steep terrain topsoil is thin and must be supplemented with consolidated material.	816.21- 816.25	The Regulations require a minimum of 6" of topsoil to be removed and redistributed immediately on regraded areas. Only if no areas are available for redistribution may topsoil be stored. If 6" of topsoil is not available, a 6" layer of topsoil and unconsolidated material below should be removed and redistributed.	Removal and storage of topsoil	6:6
7 8	Drilling rig (7) bores blast holes and shoots consolidated overburden. Pre-blasting survey of well (8).	816.62 816.52	A pre-blasting survey of the well (8) has been carried out. Ground water and surface water monitoring may be required.		
9 10	A bulldozer pushes unconsolidated overburden (9) to a front-end loader which loads it for backhaul directly to a mined out area (12). Front-end loader digs and loads coal (10).	816.99(a)	"An undisturbed natural barrier shall be provided beginning at the elevation of the lowest coal seam to be mined and extending. . .for such a distance as may be determined by the RA. . ." This barrier must remain undisturbed throughout operation.	Rough backfilling and grading; acid-forming material	6:10
11	Acid-forming overburden, identified in the overburden analysis is selectively placed in the bottom of the pit (11).	816.103(a)	". . . all exposed coal seams. . .and all acid-forming materials" shall be covered by "a minimum of 4' of the best available non-toxic and non-combustible material. . ."	Handling pit water: Acid mine drainage Acid-forming material	 6:9 6:10
12	Backfilling and rough grading in progress (12). Spoil hauled directly from above coal seam. Note that the highwall is still showing at this point.	816.101(a) 826.12(b)	The requirement for contemporaneous reclamation in contour mining is that rough backfilling and grading shall follow coal removal by not more than 60 days or 1500 ft. "The highwall shall be completely covered with compacted spoil and the disturbed area graded. . .including, but not limited to, the return of the site to the approximate original contour."	Rough backfilling and grading	6:10


CONTOUR MINING
FINAL RECLAMATION & RESPONSIBILITY PERIOD PHASE 3
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CONTOUR MINING
FINAL RECLAMATION & RESPONSIBILITY PERIOD PHASE 3

Shown here is the site illustrated on the two previous pages undergoing final reclamation and revegetation. In the far distance (1) mining operations are continuing. Notice that the Valley fill (2) has now been completed and has been revegetated.

It should be noted that terraces as shown here must have the approval of the RA and must be compatible with the approved post-mining land use. The sedimentation pond (4) is being cleaned out. The RA's approval for retaining this after reclamation has been obtained.

Grading of reclaimed land must be to "approximate original contour" and must eliminate the highwall, spoil piles and depressions [816.101(b) (1)]. Providing these conditions are met the operator has some flexibility in grading, provided that the slopes "approximate the general nature of pre-mining topography." The importance of good grading and revegetation in conservation of water resources by minimizing erosion is emphasized. Terraces may be approved by the RA to help achieve this [816.102(b)]. Improved access to forest land in steep terrain via roads located on the terraces would make more effective utilization of commercial forest land feasible.

For areas which are to be reclaimed for commercial forestry, woodland planting for wildlife, recreation, or non-commercial-forest uses, the success of revegetation is judged by comparison to a "reference area." An inventory of this area, including what is growing and in what numbers, must be carried out [816.117(c) (1)].

If the approved post-mining land use is commercial forestry, a five-year "period of responsibility" begins as soon as the area has been replanted and there are at least 450 trees and shrubs "alive and healthy" per acre for two growing seasons [817.117(a) (ii)]. For commercial forestry, 75% of these should be commercial tree species. At the time of request for bond release the stocking of trees and shrubs on the reclaimed area must be a least 90% of that on the reference area. In addition, the ground cover must be at least 70% of that on the reference area and must be adequate to control erosion.

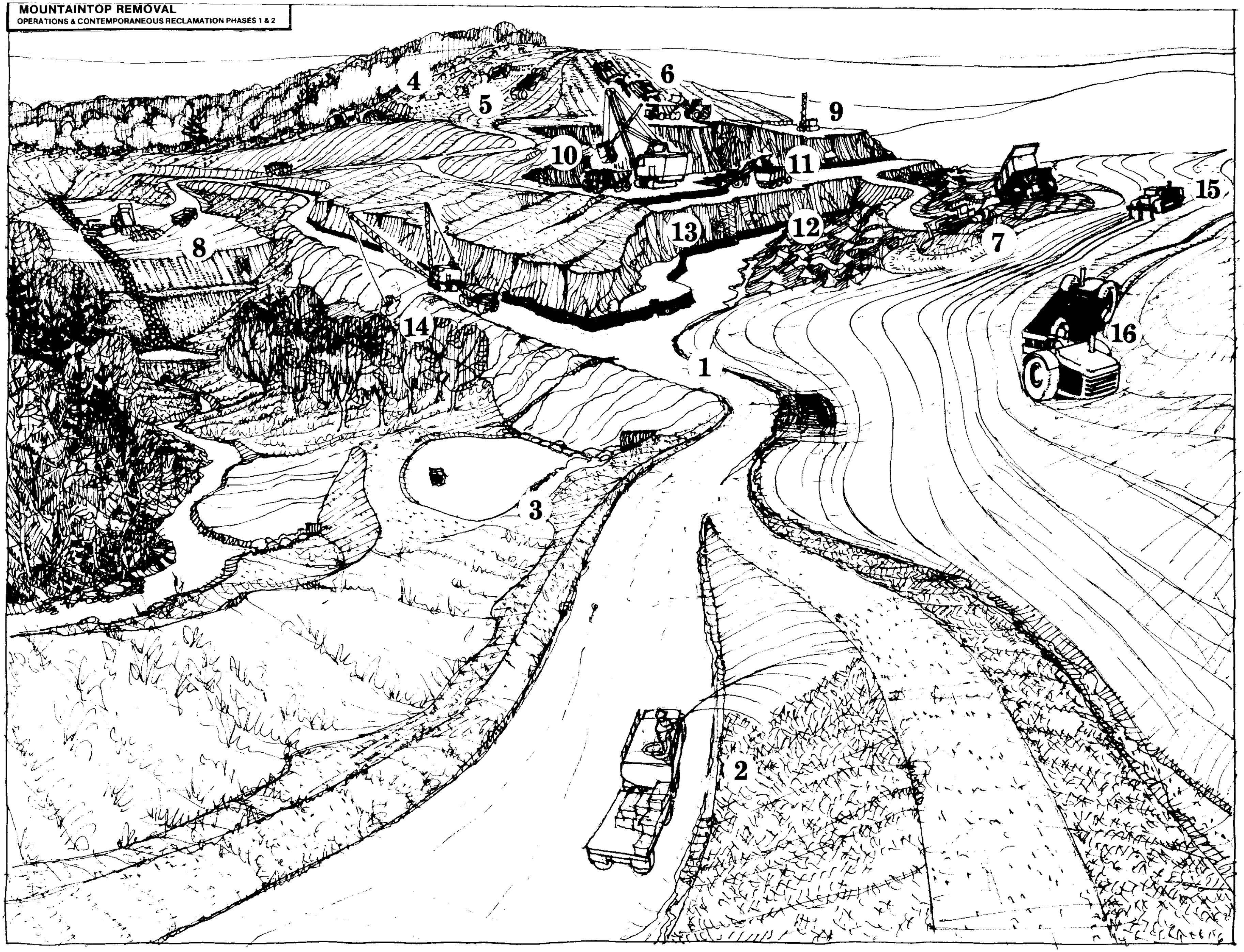
Section 816.117 also sets out requirements for revegetation of non-commercial forest land, for wildlife, recreation, etc. The five-year responsibility period begins when the stocking of trees and shrubs on the reclaimed area is 90% of that on the reference area. As is the case for commercial forest land, at the time of request for bond release, stocking of trees and shrubs shall be 90% of that on the reference area and ground cover must be at least 70% of that on the reference area.

Where permit area is less than 40 acres, the "reference area" need not be used if approved by the RA. At least 400 (600 on steep slopes) trees and shrubs must be maintained for five full consecutive years and ground cover which amounts to 70%.

**Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.*

(NOTE: Text includes references to illustration opposite.)

OPERATION: KEY	OPERATION: DESCRIPTION OF OPERATION	REQUIREMENT OF THE REGULATIONS*: SECTION	REQUIREMENT OF THE REGULATIONS*: REQUIREMENT	DATA SHEET: SHEET TITLE	DATA SHEET: NO.
1	In the far distance (1), mining operations are still in progress, followed by backfilling and rough grading.	816.101(a)	"Rough backfilling and grading shall follow coal removal by not more than 60 days or 1500 linear feet.	Rough backfilling and grading	6:10
2	The Valley fill (2) has been completed and revegetated. The sedimentation pond at the toe is still in place.	816.72	Performance standards for Valley fills include specifications for underdrains, terraces, etc. The vertical distance between terraces should not exceed 50 ft.	Disposal of excess spoil: Head-of-Hollow and Valley fills	6:8
3 4	The approval of the RA has been obtained for the use of terraces (3) in the restored land. The diversion above the highwall is the first terrace. These terraces have a gentle gradient to direct flow to a safe discharge point; in this case, the riprap channel leading to the sedimentation pond (4).	816.102(b)	"On approval by the RA ... cut-and-fill terraces may be allowed..." The width of the individual terrace bench shall not exceed 20 ft., unless ... approved by the RA as necessary for stability, erosion control, or roads included in the approved postmining land use plan." The outslope of terraces "shall not exceed 1v:2h" unless approved by RA.	Terraces Grass waterways	7:2 7:4
	The sedimentation pond (4) is being cleaned out. This must be done if sediment accumulates to 60% of the design sediment storage volume Sedimentation ponds must remain until the site is revegetated but permanent retention requires RA's approval.	816.46(h) 816.46(u)	"Sediment shall be removed ... when the volume of sediment accumulates to 60% of the design sediment storage volume." "Sedimentation ponds shall not be removed until . . . "revegetation requirements have been met. If the RA approves retention of a sedimentation pond it must meet the requirements for permanent impoundment. [816.49 and 816.56]	Sedimentation ponds	6:3
5	Final grading operations (5 is not shown) including scarification should be done along the contour, unless this is hazaradous to equipment operators.	816.102(e) 816.24(a)	"All final grading, preparation of overburden before replacement of topsoil . . . shall be done along the contour. . ." "After final grading . . . regraded land shall be scarified..."	Final grading	7:3
6	Topsoil (6) should be spread as part of a contemporaneous operation with topsoil removal. The dozer here is seen spreading topsoil. This slope is too steep for along the contour operation, but the cleat marks of the tracks help prevent erosion. Lime and fertilizer are applied and then the hillside is cultivated with a slope disc (7).	816.24(b)	Topsoil should be distributed to achieve "an approximate uniform, stable thickness." Topsoil should be protected from erosion after it is seeded and planted. "Nutrients and soil amendments in the amounts determined by soil tests shall be applied to the redistributed surface soil layer..."	Replacement of topsoil and cultivation. Soil amendments: lime and fertilizer.	7:5 7:6
		816.111- 816.117	Requirements for revegetation. The species used depend upon the approved postmining land use. However, generally they should be native species of the same type and variety as are found locally and they must be capable of controlling erosion.		
7 8	Seed, fertilizer, mulch and binder are often applied to steep slopes in one mix by a hydroseeder (8); or, a power mulcher may spray seeded slopes with mulch after seeding. If the season is not correct for permanent revegetation, a cover crop should be used.	816.113	"Seeding...shall be conducted during the first normal period for favorable planting conditions..."	Mulches Chemical stabilizers Cover crops	7:9 7:10 7:11
9	Hand planting (9) of tree and shrub species is being carried out. Direct seeding tree and shrub species with grass and herbaceous species has not been very successful. Competition from herbaceous species has resulted in poor performance of trees and shrubs. The performance standards emphasize that whatever stocking rate and ground cover is applicable, vegetation must be adequate to control erosion.	816.117(b)	Areas reclaimed for forestry must have a minimum stocking of 450 trees or shrubs/acre, and of these 75% shall be commercial tree species. When the stocking is equal to or greater than 450 trees/acre the five-year responsibility period begins.	Revegetation: general Revegetation: trees and shrubs	7:12 7:13
		816.116(d)	On permit areas of less than 40 acres, stocking of 400 trees or shrubs/acre (600 on steep slopes) must be achieved.	Revegetation: herbaceous species.	7:14
		816.117(c)	". . . for areas where woody plants are used for wildlife management, recreation, shelter belts, or forest uses other than commercial forest land...the stocking of trees...and ground cover...shall approximate the stocking and ground cover" on the approved reference area.		
10	The erosion gully (10) which has occurred here must be filled and reseeded if it is more than 9" deep [Section 816.106].	816.116	The requirements of performance standards with respect to the responsibility period vary according to the approved postmining land use. The period begins when the approved stocking rate and ground cover are met. The period ends after five years if stocking rate and ground cover meet standards specified for each postmining land use in Section 816.116.	Revegetation	7:12 -7:14



MOUNTAINTOP REMOVAL
OPERATIONS & CONTEMPORANEOUS RECLAMATION PHASES 1 & 2

MOUNTAINTOP REMOVAL

OPERATIONS & CONTEMPORANEOUS RECLAMATION PHASES 1 & 2

Part 824 of the Regulations states that the objectives of Mountaintop Removal are "to enhance coal recovery" and "to reclaim the land to equal or to higher post-mining use," and to protect environmental values.

In the example shown here, two coal seams with a parting of about 15' run right through the ridge. The outcrop of the lower of these seams was contour-mined several years ago. Hence, the performance standard to retain an outcrop barrier [824.11(a) (6)] does not apply. Excess spoil is being disposed of in the Head-of-Hollow fill on the left of the pictures. A Head-of-Hollow fill (which drains to a central rock chimney drain), rather than a Valley fill (which drains to the sides of the fill mass) is permissible in this example as the disposal site will be filled to the level of the adjacent ridgeline [816.73].

Although Mountaintop Removal operations are generally on a much larger scale than contour mining, it is easier to keep all drainage within the site and to limit the discharge to certain specified points. This makes the control of water pollution, particularly sedimentation and acid mine drainage, much more effective. Section 824.11(a) (8) requires that the restored land "drain inward from the outslope, except at specified points where it drains over the outslope in stable and protected channels."

In order to conduct Mountaintop Removal, a variance from the requirement of 816.101(b) (1) for restoring affected areas to their "approximate original contour" must be granted by the RA. Mountaintop Removal realizes an opportunity to create terrain which is suitable for urban and agricultural development in country which is steep and where development land is in short supply. A permit for Mountaintop Removal can only be given when "an industrial, commercial, agricultural, residential or public facility (including recreational facilities) use" is proposed and approved for the affected land [785.14].

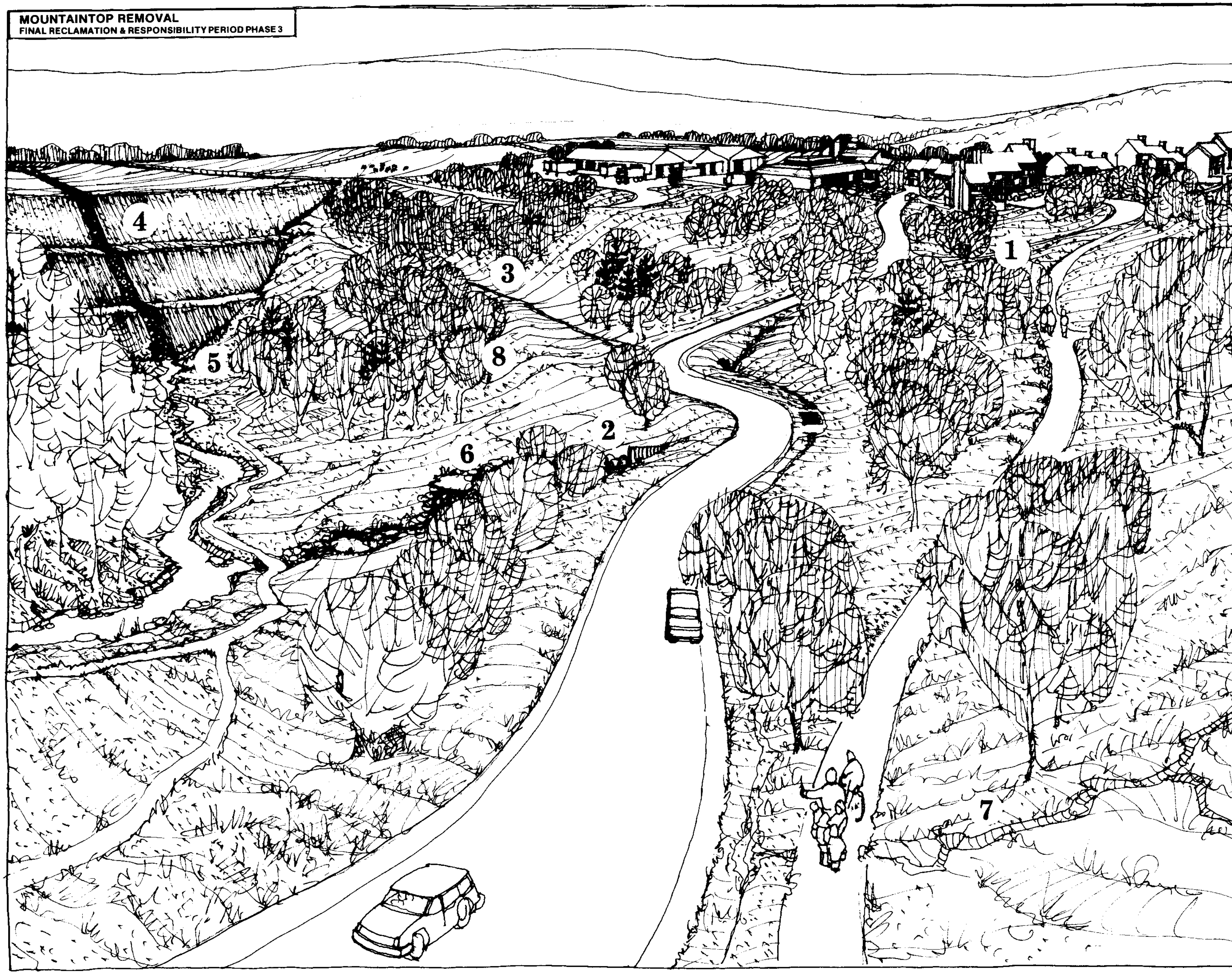
The amount of machinery and the scale of operation required for efficient Mountaintop Removal operations is large and consequently only a few small mine operators will have sufficient resources to carry out an operation of this type. However, we show here a fairly small operation. Some of the machinery is shown more than once in order to explain the working of the site more clearly. Note that the old bench from contour mining operations is adapted to intercept runoff from the reclaimed area of the site.

In this example we also show the reclamation of orphan land from a previous mining operation being carried out as part of this mining operation. In this case, after regrading spoil which had been dumped on the outslope, selected unconsolidated overburden is being used as a topsoil substitute.

Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

(NOTE: Text includes references to illustration opposite.)

OPERATION KEY	OPERATION DESCRIPTION OF OPERATION	REQUIREMENT OF THE REGULATIONS* SECTION	REQUIREMENT	DATA SHEET SHEET TITLE	NO.
1	The abandoned bench (1) from an old contour mining operation is modified to act as a runoff diversion during working of site. In some sections this bench is also used as a haul road.	824.11(a)(6) 816.150- 816.176	"An outcrop barrier of sufficient width" must be retained at the toe of the lowest coal seam, unless this was removed "prior to May 3, 1978. . ." Roads (Class I, Class II and Class III)	Operation - General Stream diversions: Overland flow Haul roads	6:1 6:4 6:2
2	Topsoil stockpiles (2) are mulched and seeded with a cover crop.	816.23(b)	Topsoil protection "shall be accomplished either by an effective cover of . . . plants or . . . other methods . . ."	Removal and storage of topsoil Cover crops	6:6 7:11
3	Sedimentation ponds (3) installed at all points where runoff leaves the permit area and at toe of Head-of-Hollow fill (8). Discharge points protected with riprap.	816.42(a)(1) 816.47	"All surface drainage from the disturbed area . . . shall be passed through a sedimentation pond. . ." "Discharge from sedimentation ponds...shall be controlled...riprap...where necessary..."	Sedimentation ponds	6:3
4 5	Logging teams (4) fell all timber on site in advance of earth-moving. All branches and other vegetataion used as mulch on reclaimed areas. Dozers destump and scraper removes (5) topsoil and subsoil to be spread on area being reclaimed.	816.22(a) 816.45(b)(1)	"Topsoil shall be removed after vegetative cover that would interfere with the use of the topsoil is cleared from the areas to be disturbed. . ." "The smallest practicable area" is disturbed at any one time during the mining operation.	Clearance of vegetation Removal and storage of topsoil	6:6
6 7 8	Dozers (6) push unconsolidated overburden down to the first bench where it is loaded into dump trucks and hauled to the area being backfilled and rough-graded (7) or for disposal in Head-of-Hollow fill (8).	816.22(e) 816.71 816.74	Selected unconsolidated overburden may be used as a topsoil substitute in certain circumstances. Performance controls covering the dispoal of excess spoil.	Disposal of excess spoil	6:7
9 10	Drilling rig (9) drills and shoots consolidated overburden which is loaded by shovel (10) and hauled to either Head-of-Hollow fill (8) or to reclamation area (7).	816.101(b)(1) 816.72(b)(1)	Only if a variance from the requirement to restore land to the "approximate original contour" is granted may spoil be disposed of in excess spoil disposal areas. Drainage of Head-of-Hollow fill.	Disposal of excess spoil	6:7
11	Coaling (11) of the upper seam with a front-end loader and trucks. All toxic-forming overburden is backfilled in the bottom of the cut (12).	824.11(a)(10)	"All waste and acid-forming materials . . . are covered with non-toxic spoil to prevent pollution and achieve the approved post-mining land use . . ."	Acid-forming material Handling pit water, acid mine drainage	6:10 6:9
12 13	The stripping of the parting between the upper and lower seams (13 is not shown). Contemporaneous reclamation and rough grading continues (7).	816.100 816.101	Overburden which is not being disposed of as excess spoil must be reclaimed as contemporaneously as possible. The period is not specified for Mountaintop Removal.	Rough backfilling and grading	6:10
14	Dragline is rough grading spoil (14) which had been dumped on the outslope during an old contour mining operation.	Part 872	Funds are provided to reclaim abandoned mine land.		
15	Excessive compaction of regraded spoil is being broken up with ripper (15). These operations must be carried out along the contour.	824.11(a)(7) 816.102(e)	Slope requirements for reclamation of Mountaintop Removal operations. "All final grading, preparation of overburden before replacement of topsoil . . . shall be done along the contour . . ."	Rough backfilling and grading Final grading	6:10 7:3
16	Scraper (16) replacing topsoil immediately following stripping (5). Replacement of topsoil should be carried out along contour.	816.23(a) 816.102(e)	Topsoil "shall be stockpiled only when it is impractical to promptly redistribute . . ." "Placement of topsoil shall be done along the contour to minimize subsequent erosion and instability."	Reclamation: General Final Grading Replacement of topsoil and cultivation	7:1 7:3 7:5
17	Reclamation operations involving spreading and incorporation of lime and fertilizer, cultivation, seeding, mulching and planting (17 not shown).	816.25 816.114 816.111 -816.117	"Nutrients and soil amendments . . . shall be applied to the redistributed surface soil layer..." Mulching and other soil stabilizing practices. Revegetation.	Soil amendments Mulches Chemical stabilizers Revegetation	7:6 7:9 7:10 7:12 -7:14



MOUNTAINTOP REMOVAL
FINAL RECLAMATION & RESPONSIBILITY PERIOD PHASE 3

MOUNTAINTOP REMOVAL

FINAL RECLAMATION & RESPONSIBILITY PERIOD PHASE 3

In order to be granted a variance from the requirement to restore land to the approximate original contour, necessary for a Mountaintop Removal operation, an applicant must plan to create terrain suitable for urban, agricultural or public facility development. Any proposal to create post-mining land uses which are different from existing uses must be consistent with the plans of the local planning agency and must also be accompanied by a feasibility study [816.133(c)]. The Regulations also specify that a proposed change of use must not result in unreasonable delays in reclamation. In this example mixed uses including residential, commercial, light industrial, warehousing and recreation are shown, either under construction or in use.

The Act requires that the final graded slopes be less than 1v:5h so as "to create a level plateau or gently rolling configuration." In steep mountainous terrain, ridges and mountains graded to level plateaus may destroy the character of the landscape. However, it is hoped that this example illustrates the way in which restored earthforms can be blended into the existing topography while still satisfying the conditions of Mountaintop Removal. One condition is that reclaimed land must be graded "to drain inward from the outslope except at specified points, where it drains over the outslope in stable and protected channels." This should not be interpreted to mean that the regraded sites should be a shallow concave area draining inwards to one point. The use of the term "inward" is to ensure that all drainage flows within the regraded area except at the specified points (as in the drawing).

Even if the land is proposed for urban development, the requirement of the Regulations regarding the replacement of topsoil still holds. Revegetation must also be carried out, sufficient to control erosion prior to construction. "For areas to be developed for industrial or residential use less than two years after regrading is completed, the ground cover of living plants shall not be less than required to control erosion." All other areas are subject to the standards of success for revegetation set out in 816.116 and a five-year period of responsibility during which the operator is responsible for managing the area. Standards for success will vary according to the proposed and approved postmining land use.

Buildings, roads, sewers, etc., constructed on regraded spoil may be subject to settlement damage. This hazard may be serious where overburden is largely unconsolidated material and where it is cast with a shovel or dragline (not the case in the illustrated example). Where there is a danger of settlement occurring, buildings should have a reinforced concrete pad foundation or construction should not take place until settlement has ceased.

Regulatory Program promulgated by the Office of Surface Mining and the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

OPERATION: KEY	OPERATION: DESCRIPTION OF OPERATION	REQUIREMENT OF THE REGULATIONS*: SECTION	REQUIREMENT OF THE REGULATIONS*: REQUIREMENT	DATA SHEET: SHEET TITLE	DATA SHEET: NO.
	(NOTE: Text includes references to illustration opposite.)				
	Though no period is specified in the Regulations for Mountaintop Removal, reclamation must be carried out as contemporaneously as possible.	816.100 816.101(a)	"Reclamation efforts. . .shall occur as contemporaneously as practicable with mining operations." A time limit for backfilling and rough grading would be specified by the RA for Mountaintop Removal.	Rough backfilling and grading Reclamation: General	6:10 7:1
1	Note the "gently rolling configuration" (1) of the regraded site. This avoids giving the appearance of a "sawn-off" mountain or ridgetop.	824.11(a)(7)	"The final graded slopes on the mined area [shall be] less than 1v:5h so as to create a level plateau or gently rolling configuration, and the outslopes of the plateau (shall not) exceed 1v:2h. . ."	Final grading Replacement of topsoil Soil amendments Mulches	7:3 7:5 7:6 7:9
2 3	Drainage from the regraded area must only drain off the site at specified points (2). Internal drainage within the site should be directed to these points in stable grass waterways (3).	824.11(a)(8)	The regraded area is to "drain inward from the outslope, except at specified points where it drains over the outslope in stable and protected channels."	Grass waterways	7:4
4	Note that the Head-of-Hollow fill (4) is now complete and that it fills the disposal site to the low point of the adjacent ridge.	816.73(a) 816.73(b)	"The fill shall be designed to completely fill the disposal site to the approximate elevation of the ridgeline." Design of rock-core chimney drain system.	Disposal of excess spoil	6:8
5,6	The two sedimentation ponds (5,6) have been removed. This must not be done until the site is restored and the revegetation requirements are met. The regraded channel contains rock plunge pools and riffles to prevent erosion of the channel.	816.46(u) 816.47	"Sedimentation ponds shall not be removed until the disturbed area has been restored, and the vegetation requirements of Section 816.111-816.117 are met. . ." "Discharge from. . .diversions shall be controlled by energy dissipators, riprap channels and other devices where necessary. . ."	Sedimentation ponds Grass waterways, chutes, flumes, etc.	6:3 7:4
7	The gully (7) shown here, if greater than 9" deep, should be filled and stabilized.	816.106	"When. . .gullies deeper than 9" form. . . (they) shall be filled, graded, or otherwise stabilized and the area reseeded or replanted. . ."		
8	The outslope (8) from the abandoned contour mining operation has been reclaimed as part of the operation. Some subsoil "borrowed" from the Mountaintop Removal operation was used to cover this slope which was then seeded and mulched.	816.116(b)(3)	"For previously mined areas. . ." the ground cover of living plants shall not be less than can be supported by the best available topsoil or other suitable material in the reaffected area. . ." The ground cover must be adequate to control erosion and not be less than that existing before mining.		
	The entire disturbed area, except water areas and roads, shall be vegetated. This applies also to land approved for urban development. Because there are several different post-mining land uses on this site, the requirements for revegetation differ. Generally vegetation of areas planned for urbanization within two years must be capable of effective erosion control. Areas designated for recreational open space will have a requirement for number of trees and shrubs and for ground cover. Areas planned for grazing must have a capacity equal to that of non-mined land.	816.111 816.112 816.113 816.97(d)(11) 816,116	The general requirements for revegetation. Use of introduced species requires approval. Revegetation to be carried out during first favorable period. "Where the primary land use is to be residential, public service, or industrial land use, intersperse reclaimed lands with greenbelts utilizing species of grass, shrubs and trees useful as food and cover for birds and small animals. . ." The standards for success of revegetation are judged by comparison to a "reference area." When the ground cover and productivity of plants on the revegetated area equals that of the reference area for two consecutive years during a five-year "responsibility period," the operator can request bond release.	Revegetation: General Revegetation: Trees and Shrubs Revegetation: Herbaceous species Post-mining land uses	7:12 7:13 7:14 8
	Note that the "period of extended responsibility" under the performance bond requirement of the Regulations applies even where urban development is approved for the post-mining land-use. The period runs for 5 years for all areas covered in this Handbook.	816.116(b) 816.116(b)(3)	There are different standards for previously mined land and for areas to be developed for urban uses within two years.		

CHAPTER 5

PRE-MINING SURVEYS, EXPLORATION AND PLANNING

The Regulations of the Surface Mining Control and Reclamation Act (1977) contain specific pre-mining planning requirements which are part of the application and permit process [Parts 779, 780, and 785]. However, besides requiring preplanning, the Regulations dictate stringent performance standards [Subchapter K] containing contemporaneous reclamation requirements and other measures which make preplanning essential if the operation is to meet the requirements. Because the requirements of the Act were recognized by Congress to place a financial burden on the SMO, "provisions were made for the RA to pay a qualified laboratory to make certain hydrologic and geologic analyses" required by the Regulations (Section 507(c) of the Act). The small operator is still required to meet these Regulations.

The Regulations differentiate between exploration operations involving the removal of less than 250 tons of coal [776.11] and those involving the removal of more than 250 tons of coal [776.12]. Operators removing less than 250 tons in an area to be explored need only file a written notice of their intention to explore [776.11(a)] but their actual operations are subject to exploration performance standards [Part 815]. If the exploration is successful the operator must follow the normal application procedure to obtain a permit to extract the coal.

Premining surveys should seek to maximize the amount of information gained during each stage of exploration and subsequently at each stage of the operation. "For instance it should be possible to justify follow-up investigations based on the few bore holes made while looking for a coal prospect" (1). EPA (1978) suggests that drill holes should be maintained as observation points in case mining is feasible. The exploration holes should be plugged only if it is decided that mining is not feasible or when the necessary data has been obtained from them. Even then some should be maintained as observation wells to monitor groundwater during mining operations. Thus the cost of premining surveys can be minimized by coordinating the requirements with exploration efforts. Parizek also emphasizes that a manual of practice to guide premining planning cannot be written with a series of hard and fast rules for each proposed mine no matter what the hydrological and geochemical setting. Rather he suggests the planners and developers of modern surface mines must be fully aware of the principles of geology, hydrology, and geochemistry and they must carefully apply these principles during premining planning. Parizek calls for innovation and creativity both in the design of mines and remedial programs associated with mine reclamation (1).

PERFORMANCE STANDARDS FOR EXPLORATION

The performance standards for exploration require that unique habitats for fish or wildlife should not be disturbed [816.15(a)]. The standards also require that vehicular traffic should be minimized and restricted to graded and surfaced roads during periods when excessive damage to vegetation would occur [815.15(c)(1)]. Depending on whether new roads in the exploration area are used more or less than 6 months, they need to comply with 816.150-816.166 *or* 816.170-816.176. Existing roads used during exploration shall, after exploration activities are completed, be reclaimed so that the requirements in 816.150-816.166 are met. All areas disturbed by exploration shall be revegetated with a cover sufficient to stabilize the soil surface in regards to erosion. Requirements for handling and disposal of acid-forming toxic-forming materials in 816.48 and 816.103 must be met. Also the requirements for casing and sealing bore holes in 816.13, 816.14 and 816.15 must be met.

PLANNING

If compliance with the Act is first approached with the procedure of interpreting the Regulations one by one, individually, the process becomes very complex. Table 7 serves to capsulize this stage of premining planning in order to communicate more easily what needs to be done. The context in which this Table was prepared is that premining planning is an essential and critical stage of the surface mining process because, given that certain environmental criteria are required by law, this stage allows the SMO to comply as effortlessly and as economically as possible. The aspects of planning as they are presented in the Table are, roughly, in the order in which they should be approached so that the broadest areas are covered first. In the actual planning process the SMO will jump back and forth between stages in order to tie it all together.

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TABLE 7

ASPECTS OF PLANNING *(In chronological order)* *A narrative description of each aspect needs to be included in the Permit Application.*	**INFORMATION NEEDED*** *(To carry out premining planning)* *This column introduces the process of Data Gathering and the process of Data Presentation, which are required in the Surface Mining Permit Application process.*	**COMMENTS** *This column points out the benefits which result from compliance with the Regulations, thereby providing some incentive for the SMO.*
SITE INFORMATION Mine location Size Breakdown of Area to be Disturbed Estimated Duration of Activities	Primarily information from existing maps (e.g. topography, geology) [General review of these sections: 779.24, 779.25, 780.14]; Criteria for designating lands as unsuitable [Part 762]; Sequence and timing of activities [779.12(a)]; Cultural and Historic Resources [779.12(b), 780.31]; Land-use [770.22(a)(1)], especially prime farmland investigation [779.27(a), 785.17]; General information on Hydrology and Geology [779.13(b)(1)], Climate [779.18(a)] and Vegetation [779.19], and Fish and Wildlife Resources [779.20].	Getting an overview of all the environmental data at the outset enables the SMO to anticipate problems which are likely to occur and to plan his operation to meet the requirements. SMO will discover if there are any areas which he will not be allowed to mine. Enables SMO to have a more certain schedule, to be more efficient in his overall operation, to plan for his next job. A disadvantage of advanced planning is that the SMO will not be as flexible in responding to the severe fluctuations in demand on the spot market. Discovering all the information about the factors which affect degree of environmental degradation enables the SMO to sequence and time his activities so that his costs of reclamation are not excessive.
MINING TYPE TO BE PRACTICED Area Contour Mountaintop Removal Auger Experimental	Detailed analysis of Geology [779.14], including Groundwater [779.15] and the Coal Seam [779.22(b), 780.11(a), 779.25(c)]; Detailed review of Sections 779.24, 779.25, and 780.14. Study the requirements for Permits for special categories of mining [Part 785].	SMO will have clarity in scheduling activities; after this choice is made he can be more specific about the "breakdown of area to be disturbed" and the "estimated duration of activities." SMO can see *what* equipment is needed *where* and *when*. This information also will show whether the SMO must apply for a permit for a special category of mining. This stage is an opportunity for the SMO to plan to reclaim any abandoned surface-mine land in the area and to apply for grants for that. Also, careful attention needs to be given to any abandoned underground mines in the area so that they are not accidentally broken into.
POST-MINING LAND-USE	Analysis of productivity of existing soils [779.21(a)(4)]; Details of Land-use [779.22]; State and Local Land-use Plans [780.23(a)(4)]; A description of alternative uses and the supporting details of proposed use [780.23].	Waste-land will be eliminated as an end product. The SMO will have land that has a marketable value. There is the potential that the restored land may be more productive than before mining. After this choice is made, all operations can be planned to efficiently provide for the land-use. Compatibility with the local community and long-term community needs.
SITE PREPARATION Erosion Control Vegetation Clearing Topsoil Conservation Other Premining Activities	Slopes analysis [779.25(k)]; Surface water information [779.16]; Alternative sources of water supply [779.17]; Degree of soil erodibility [779.21]; Water resources protection measures [780.11(b), 780.14(b)]; Details of Climate [779.18], Vegetation [779.19], and Fish and Wildlife [779.20].	Enables SMO, with little effort as possible to preserve water quality and to control erosion and sedimentation. Enables SMO to plan for the use of vegetation debris for mulch for soil preparation for revegetation and to conserve topsoil. Improves public relations through the appreciation of clean streams and the overall aesthetic quality.
OVERBURDEN REMOVAL Blasting Handling Overburden Overburden Placement	Physical properties of each stratum within overburden [779.14(b)(1)] and Chemical Analyses; Details of blasting procedures [780.13]; Dust control practices [780.15]; Overall Hydrologic balance protection [780.21]; Earthworks [780.18 (b)(3), 780.18(b)(4)]; Disposal plan for excess spoil [780.35].	Maintains SMO's position in public eye through care for environmental quality. Minimizes earthmoving/regrading to produce reclaimed land. Minimizes costs. Minimizes costs in preventing acid-mine drainage. Accelerates time in which land is again productive. This planning opens up the possibility for the burial of Solid Wastes within the regraded surface-mined land.
COAL RECOVERY	Extent of Coal [779.22(b),779.25(c)]; Outline Coal Seam [779.25(d)]; Mining [780.11(a)]; Maximize Use and Conservation [780.18(b)(6)].	SMO can estimate quantity and quality of coal deposit so that he is prepared for the spot market. SMO can maximize the amount of coal mined with least disturbance.
HAULAGE Road Construction Road Maintenance	Description of surface drainage system [779.16 (a)]; Public road location [779.24(h)]; Relocation or use of public roads [780.33]; Road construction [780.37].	Maximizes SMO's ability to control erosion and sedimentation from roads. Enables SMO to incorporate the time it takes to load and haul coal into his sequence plan; and to do this with the least amount of disruption of public transportation arteries.
RECLAMATION AND REVEGETATION	Biotic inventory and assessment of ecological criteria [779.19, 779.20]; Backfilling and regrading plan [780.18(b)(3)]; Revegetation plan [780.18(b)(5)]; Plan for drainage control structures [780.25, 780.29].	Enables SMO to comply with Regulations requiring contemporaneous reclamation. Enables SMO to plan for treating of reclaimed land with sewage effluent and/or sludge from local populations. Insure the immediate success of revegetation.

*This is not a complete list of the requirements for Permit Application [See Subchapter G].

APPENDIX

I. Summary of Main Requirements of Performance Standards Concerning the Control of Erosion and Sedimentation

Topic of Corrective Measure	Activity Required	Section of Regulations
Minimization of Disturbed Area	Disturb smallest practicable area at any one time.	816.45(b)(1)
	For roads, do not clear vegetation for more than necessary width.	816.153(a)(3)
	Reclaim as contemporaneously as practicable.	816.100
	Limit the topsoil removal area.	816.22(f)
	Immediately redistribute topsoil wherever practicable.	816.23(a)
	Backfill and grade within the specified period.	816.101(a)
	Seed and plant as contemporaneously as practicable.	816.113
Buffer Strips	Do not disturb land within 100 feet of a perennial stream or a stream with a "biological community."	816.57(a)
	Mark the buffer zone.	816.11(3)
	Avoid disturbance to habitats of high value for fish and wildlife.	816.97(d)(4)
Diversion of Water around Mine Area	Divert runoff away from disturbed areas.	816.45(b)(4)
	Divert shallow groundwater flow and ephemeral streams.	816.43
	Divert perennial and intermittent streams.	816.44
Internalization of Drainage	Pass all surface drainage from disturbed area through a sedimentation pond.	816.42(a)(1)
	Retain sediment within disturbed area.	816.45(b)(3)
	Use straw dikes, riprap, mulches, etc. to reduce overland flow velocity, reduce run-off volume, or trap sediment.	816.45(b)(6)
Roads (Class I)	Control or minimize erosion and siltation during all stages of operation.	816.150(a)
	Locate to minimize erosion.	816.151(a)
	Prohibit stream fords.	816.151(c)
	Provide temporary erosion-control measures on road cuts.	816.152(c)
	Provide adequate drainage.	816.153
	With all transportation facilities, have concern for control of erosion.	816.180
Sedimentation Ponds	Construct sedimentation ponds before beginning any surface mining activities in the drainage area.	816.42(a)(5)
	Design and construct to provide a minimum sediment storage volume.	816.46(b)
	Design and construct to provide the required detention time.	816.46(c)
	Remove sediment as required.	816.46(h)
	Provide discharge structure to minimize disturbance.	816.47
	Clean ditches and spillways.	816.49(g)
	Stabilize embankment and surrounding area.	816.49(e)
	Do not remove pond until area has been restored.	816.46(u)
	Rehabilitate pond before abandoning permit area.	816.56
Stabilization of Slopes	Selectively place topsoil stockpiles to provide stability.	816.23(b)
	Do not locate diversions so as to increase the potential for land slides.	816.43(d)
	During blasting, assure that no slides are imminent.	816.65(d)(1)
	Locate disposal areas for excess spoil on the most moderately sloping and naturally stable areas available.	816.71(e)
	Where slope exceeds 1v:2.8h, construct keyway cuts to stabilize fill.	816.71(i)
	Stabilize slopes on Valley Fills.	816.72
	Stabilize slopes on Head-of-Hollow Fills.	816.73
	Provide an undisturbed natural barrier at the elevation of lowest coal seam to prevent slides.	816.99(a)
	Prevent placement of materials on the downslope for steep slopes.	826.12(a)
	Regrade or stabilize rills and gullies.	816.106
Land Forms	Shape land to minimize water pollution.	816.41(d)(2)(i)
	Eliminate all highwalls, spoil piles, and depressions.	816.101(b)
	Construct cut-and-fill terraces if approved by RA.	816.102(b)
	Perform final grading, placement of topsoil, etc. along the contour.	816.102(e)
Revegetation	Select substitutes or supplements if available topsoil is insufficient for vegetation.	816.22(e)
	Scarify regraded spoil to promote root penetration.	816.24(a)
	Apply nutrients and soil amendments as needed.	816.25
	Protect topsoil from erosion before and after it is seeded and planted.	816.24(b)
	Seed and plant to achieve a permanent vegetative cover.	816.111(b)
	Substitute introduced species for native species only if approved.	816.112
	Provide revegetation according to the standards for success.	816.116

II. Summary of Main Requirements of Performance Standards Concerning the Minimization of Changes in Water Quantity.

Topic of Corrective Measure	Activity Required	Section of Regulations
Runoff Volume and Velocity	Limit area of removal of vegetative cover at any one time.	816.22(f)
	Minimize changes in water quantity (hydrologic balance).	816.41(b)
	On steep slopes, consider effects on entire watershed.	826.15(b)
	Provide temporary vegetation as soon as practicable.	816.41(d)(2)(iii)
	Use straw dikes, mulches, etc. to reduce velocity and volume of runoff.	816.45(b)(6)
	Stabilize diversions with vegetation.	816.43(b)
	Prohibit impoundments.	816.49(a)(5)
	Do not discharge surface water into underground mine workings.	816.55
	Backfill and grade to conserve soil moisture.	816.102(b)
	Locate roads to minimize flooding downstream.	816.151(d)
	Place excess spoil so as to avoid interference with natural drainage.	816.71(f)
Stream Conditions	Minimize changes in location of surface water drainage channels.	816.41(b)
	When permanent diversions are constructed or stream channels restored:	
	- enhance natural riparian vegetation.	816.44(d)(1)
	- restore natural meandering shape.	816.44(d)(2)
	- include aquatic habitats.	816.44(d)(3)
	Provide stream buffer zones.	816.57
	Monitor surface water to establish the quantity of runoff.	816.52(b)
Required Design Storms	Construct permanent diversions to pass safely the peak runoff from an event with a 10-year recurrence interval.	816.43(b)
	Construct stream channel diversions to pass safely the peak runoff of a 10 yr-24 hr event for temporary diversions, a 100 yr-24 hr even for permanent diversions.	816.44(b)(2)
	Construct sedimentation ponds to provide detention time for runoff from a 10 yr-24 hr event.	816.46(c)
	Provide spillways for ponds to safely discharge runoff from a 25 yr-24 hr event.	816.46(i)
	If embankment of pond is more than 20 feet in height, provide spillway for 100 yr-24 hr event.	816.46(q)(1)
	Divert runoff of a 100 yr-24 hr event away from Valley fills.	816.72(d)
	Divert runoff of a 100 yr-24 hr event away from Head-of-Hollow fills.	816.73(c)
	Provide adequate drainage structures on roads to safely pass peak runoff from a 10 yr-24 hr event.	816.153
Groundwater Recharge Capacity	Provide a rate of recharge after mining that approximates the premining recharge rate.	816.51
	Monitor infiltration rate.	816.52(a)
	Conduct blasting so as to not alter the course of groundwater.	816.65(h)
	Maintain base flow in streams to avoid adverse impact on fish.	816.97
Water Supply	Assure that water impoundments not result in diminution of quantity of water available for surrounding population.	816.49(a)(4)
	Maintain groundwater level.	816.52(a)
	Replace water supply for landowner whose source has been contaminated through mining.	816.54
	Conduct pre-blasting survey to assess the water supply.	816.62(b)
	Do not blast within the given minimum distance from water supply wells or supply lines.	816.65(f)
	In order to provide for postmining land use, ensure that suficient water will be available.	816.133(c)(9)
	Transfer a monitoring well for further use as a water supply well only with approval of RA.	816.53

III. Summary of Main Requirements of Performance Standards Concerning the Minimization of Changes in Water Quality.

Topic of Corrective Measure	Activity Required	Section of Regulations
Identification of Acid-Forming Overburden	During the process of preparing the surface mining permit application:	
	- collect test borings or core samples of each stratum and analyze them.	779.14(b)(1)
	- use chemical analyses to identify those horizons which contain potential acid-forming material.	779.14(b)(1)(iv)
	- analyze coal seam to determine sulfur, pyrite, and marcasite content.	779.14(b)(1)(v)
Placement of Acid-Forming Spoil	Selectively place and seal acid-forming material.	816.41(d)(2)(vii)
	Bury acid-forming spoil as soon as practicable.	816.48
	Cover acid-forming material with a minimum of 4 feet of nontoxic spoil.	816.103(a)(1)
	Place backfilled materials so as to minimize contamination of groundwater.	816.50(a)
	Place spoil in a manner to ensure that runoff will not degrade surface or groundwaters.	816.71(a)(1)
	Place backfilled materials so as to minimize adverse effects on groundwater.	816.101(b)(2)
	Do not bury acid-forming materials close to a drainage course.	816.103(a)(4)
	If necessary, treat these materials to neutralize toxicity.	816.103(a)(2)
	Do not use acid-forming material in road surfacing.	816.154(b)
Control Water Flow to Prevent Contact With Acid-Forming Materials	Use changes in flow of drainage in preference to the use of water treatment facilities.	816.41(d)(1)
	Direct overland flow from disturbed areas to prevent contact with acid-forming material.	816.43
	Use measures, as required by RA, to avoid any runoff contact with acid-forming material.	816.48(b)
	Prevent leaching of acid-forming materials into surface or groundwaters.	816.103(b)
	Construct an underdrain system to prevent infiltration of water into spoil.	816.71(l)
Acid Mine Drainage	Treat water discharged from disturbed areas to meet the required effluent limitations.	816.42(a)(7)
	Provide automatic lime feeder or other automatic neutralization process to raise pH above 6.0.	816.42(c)
	Control mine excavations to avoid harm resulting from discharge of acid mine drainage.	816.50(b)
	Monitor groundwater quality.	816.52(a)
	Monitor surface water quality.	816.52(b)
	For postmining land use, ensure that quality of impounded water shall be suitable on a permanent basis.	816.49(a)(1)

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CHAPTER 6

MOBILIZATION AND MINING OPERATIONS

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PROBLEM & PURPOSE

Many of the performance standards of the new Regulations are designed to prevent erosion and, subsequently, sedimentation. The problems of erosion and sedimentation on surface coal mining sites were described and quantified in Chapter 2. Preventing erosion and sedimentation solves or helps to solve three of the basic problems associated with surface mining.

1. Sediment in surface waters is a direct result of erosion and results in serious degradation of stream health and a reduction in the capacity of streams to handle flood flows and many other problems (9). Sedimentation will be reduced by erosion control measures.

2. Exposure of acid or toxic-forming spoil. A problem on abandoned mine sites was the continual exposure of acid-forming or toxic-forming spoil as a result of erosion of unstable slopes. Stabilization of slopes, topsoiling and revegetation coupled with effective erosion control measures will prevent the exposure of new acid-forming spoils to the atmosphere and hence result in improved control of acid mine drainage.

3. Revegetation. Erosion results in the loss of soil and hence reduces the ability of the site to support a vigorous vegetation cover. Reestablishment of an effective vegetation cover is one of the principles of effective erosion control and is emphasized in the new regulations.

"The universal soil loss equation" can be used to estimate the rate of erosion from surface mine sites. This equation was developed by the U.S. Department of Agriculture for use on agricultural land but gives a fairly accurate estimate for soil loss from any activities involving the removal of vegetation and the disturbance of the land surface. The use of this equation is described in the U.S. Department of Agriculture's Handbook No. 282 (1965).

$$A = RKLSP$$

Where:

A = Soil loss (tons/acre)
R = Rainfall factor (reflects intensity of rainfall)
K = Erodibility factor (reflects soil characteristics affecting erodibility)
L = Length of slope factor (reflects accumulation of runoff on long slopes)
S = Steepness of slope factor (reflects increased runoff velocity on steep slopes)
C = Cropping and management factor (reflects cover, plant residues, mulching, etc.)
P = Erosion control practice factor

In some cases, the universal soil loss equation has been found to give unsatisfactory estimates of soil loss on surface mine sites. For instance, on long slopes of dumped spoil, it was found that runoff and erosion did not necessarily increase as was expected as it accumulated and gained momentum flowing down a slope. It has been suggested that this is because the coarser material, when dumped, tends to segregate on the lower part of the slope, and this increases the infiltration and consequently reduces the runoff at this point. However, for spoil which is selectively placed, consolidated and topsoiled, the universal soil loss equation gives a reasonable estimate and will probably remain in use until a more precise technique can be developed.

DISCUSSION & DESIGN GUIDELINES

Eight major principles in the control of erosion and sedimentation on surface mine sites are discussed here. For a detailed tabulation of the main requirements of the new Regulations [Part 816] relating to erosion and sedimentation control see Table I of the Appendix following Chapter 5.

1. Minimizing the area which is disturbed at any one time. As soon as protective vegetation is removed from the site, erosion will begin and will not stop until an effective vegetation cover is reestablished. Minimizing the disturbed area is addressed in Section 816.45(b)(1). The requirement of Part 780 that the operational plan indicate the phasing of operations and reclamation on surface mine sites is also in part designed to make sure that the minimum area is disturbed at any one time in the planned surface mining operation. Regulations require temporary protection of spoil piles and topsoil stockpiles that must remain in position for a long time.

2. Maintaining buffer strips of undisturbed land between the mine area and streams and bodies of surface water. The requirement of the regulations is that no land within 100 feet of perennial streams shall be disturbed without specific approval.

3. Diversion of clean water around the disturbed area. The regulations contain provisions for the diversion of both permanent and ephemeral streams around the planned operational area. The purpose is to prevent clean water picking up sediment and other pollutants when passing over the disturbed site. Careful attention to drainage is essential before any mining operations begin (5).

4. "Internalization" of drainage within the disturbed area. The regulations require sediment ponds at all points at which surface water drains from the site, and therefore, it is in the interest of the mine operator to try to internalize the drainage from the disturbed area and to minimize the points at which it flows from the site. Some practices such as dumping spoil on the downslope make it very difficult indeed to control surface water drainage and therefore this practice has been outlawed in the Regulations. It is much more difficult for an operator in hilly or mountainous terrain to internalize drainage than for an operator using the area mining method. Operators may find it especially difficult to control sediment caused by the erosion of excess spoil disposal sites. However, studies of Head-of-Hollow filling techniques have shown a significant reduction in the amount of sediment generation (Curtis, 1974). Haul roads (Sheet 6:2) also pose a difficult problem largely because of the difficulty of keeping drainage within the disturbed area, and long haul roads can involve the operator in heavy expenditures on sediment control measures.

5. Slope stability. Placement and compaction of spoil in such a way as to avoid instability, slides and slips is clearly very important in erosion and sediment control. The continued erosion from abandoned surface mine sites is caused partly by instability due to slips and steep slopes where fresh spoil is continually exposed to erosion and where effective vegetation cover cannot get established. Many of the performance standards in Part 816 are designed directly or indirectly to prevent these problems.

6. Sedimentation ponds. Section 816.42(a)(1) "All surface drainage from the disturbed area, including disturbed areas after being graded, seeded or planted shall be passed through a sedimentation pond or a series of sedimentation ponds before leaving the permit area." Sedimentation ponds are required at appropriate locations before any mining activities start and they must be retained until after revegetation is complete [816.46(u)]. Generally the approach is to prevent erosion occurring whenever possible, but to trap sediment from erosion which does occur, in sedimentation ponds before drainage leaves the site. Section 816.46 contains specific

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

details on the design of sedimentation ponds including the sediment storage volume required, the detention time and discharge structures. For further details on the design and construction of sediment ponds see Sheet 6:3. In the past, the performance of sedimentation ponds has been erratic, but this has been very largely due to poor construction, poor maintenance, failure to remove accumulated sediments and also the failure to remove the pond after the site has been revegetated.

7. Landforms. The amount of erosion will vary with both steepness and length of regraded slopes. Even if land is to be restored to the "approximate original contour" there are measures which can be taken to reduce slope length (terracing, diversions) on regraded areas [816.102] and cultivation techniques to improve infiltration and to reduce the runoff (see Sheet 7:3).

8. Revegetation. Performance standards requiring prompt revegetation are designed to reduce erosion and sedimentation and other standards are designed to ensure the quick establishment of effective vegetation. These include the requirement to remove and replace topsoil, to break up excessive compaction [816.24], and to apply soil amendments, etc. Only after effective vegetation has been established may sedimentation ponds and other control measures be removed. Note that suggestions that earthmoving operations should be programmed to occur during periods of low rainfall are not realistic on surface mining sites. However it should be realistic to program reclamation operations to fit in with seasonal requirements for revegetation (or temporary cover).

Hydroseeding to Attain Prompt Revegetation

Breaking Up Excessive Compaction

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PROBLEM & PURPOSE

As much as 10% of the total area affected by surface mining is devoted to coal haulage roads (1). Haul roads extend beyond the actual mine area and they tend to intercept clean runoff and contaminate it with sediment. In the past, poor construction practices of haul roads and attempts to bed down the roads after completion of mining operations led to serious and prolonged erosion and sediment problems from these sources. In many respects, coal haulage roads are similar to logging roads in mountainous regions. Experiments at Coweeta Hydrologic Laboratory near Franklin, NC showed that the erosion from lumbering operations in Appalachia was mostly due to erosion from logging roads and skidding operations (6).

Mine haulage costs often represent up to 50% of the total mining costs in surface mining and hence the construction and maintenance of good haulage roads is critical to the economics of a surface mine. The quality of a road also depends very largely upon how well drained it is, but there is also an important relationship between the operating speed and the safety of operation. "The benefits to be derived from safe haulage road design and construction quite often lie unseen as the intangible factors of reduced accidents and injuries. However, in many cases, the incorporation of correct design principles can increase mine productivity "(9).

Some erosion and sedimentation from haul roads will occur on the run sites, even on the well-managed sites. There are 4 sources of sediment from roads: the road surface, the cut slope, the roadside ditches, and the fill slope (13).

APPLICABILITY

Applicable to all mining operations. Roads within the mining pit area are not subject to the performance standards in Sections 816.150-816.176. But all other roads within the permit area are.

RELEVANT SECTIONS OF THE REGULATIONS

Section 780.37 requires that each application contains a detailed description of all roads to be constructed within the proposed permit area. It should be noted that the term "road" does not include roadways within the immediate mining pit area (Definitions, 701.5).

The drainage from roads within the pit is covered by performance standards dealing with drainage water and the control of sediment from the pit. The stringency of performance standards for roads outside the pit area is due to 1) the high rates of erosion and sedimentation caused by dirt roads in constant use by heavy vehicles and a high runoff from these roads due to extensive consolidation; and 2) the difficulty of treating runoff from a road because the runoff tends to be dispersed over a wide area.

It should be noted that Section 816.42(a) requires that surface drainage from all disturbed areas be passed through a sedimentation pond, but that "disturbed areas" in this section does not include roadways if they are installed in accordance with the performance controls and the upstream area is not otherwise disturbed by mining activities.

This sheet covers Sections 816.150-816.176 which apply to roads. This handbook contains general guidelines only and designers should check each case for conformance to the regulations. There are three classes of roads covered by the regulations, these are:

Class I - These are roads used for the transportation of coal. Generally, these roads remain in place for the whole working life of the site and the design criteria for their construction are the most stringent.

Class II - These are roads other than Class I roads which are to be used for 6 months or longer.

Class III - These are roads other than Class I roads which are to be used for 6 months or less. (These definitions can be found in Part 701.5.)

The performance standards for all classes of roads emphasize the importance of the design, location, construction, maintenance and reclamation of roads to minimize erosion and sedimentation problems. All classes of roads have to be removed and restored after mining operations unless approved for post-mining land use or for controlling erosion [816.150(c)]. Class I roads have to be designed by a registered professional engineer. In the case of Class II roads, a qualified engineer need only be used if alternative specifications for the road design other than those specified in the performance standards are to be used. A registered professional engineer need not be used by mine operators for the design of Class III roads.

DISCUSSION & DESIGN GUIDELINES

Some of the design criteria described on this sheet are not specific requirements of the performance controls. The following references are suggested for basic design guidelines for haul roads: (9), (7) and (10).

I. LOCATION [815.151, 816.161 AND 816.171]

The performance standards require roads to be located so as to minimize erosion, sedimentation, and downstream flooding as a result of the construction. Generally, fords are prohibited for stream crossings by haul roads. If roads can be located along ridgelines, stream crossings will be minimized and the amount of overland flow intercepted by the road will also be minimal. Though this won't be possible in most cases, careful location to avoid seeps, wet areas and to minimize stream crossings can save a lot of money.

II. HORIZONTAL AND VERTICAL ALINEMENT

Horizontal and vertical alinement are important factors in insuring safe operating speeds and stopping distances.

The small operator should understand the relationship between grade steepness and haulage costs. Sometimes longer slopes covering the same vertical distance can give substantial improvement in truck performance. Curves just before or after a grade can reduce truck performance also.

Horizontal and vertical alinement are important factors in insuring safe operating speeds and stopping distances. Skelly and Loy's report gives the design for horizontal and vertical alinement of haul roads including stopping distances for various weights of vehicles (Figure 1). The maximum grades as required in the new Regulations are similar to most of the state regulations pre-1977 and are shown in Table 1. Slopes of less than 3% should be avoided, if possible as they will not drain adequately.

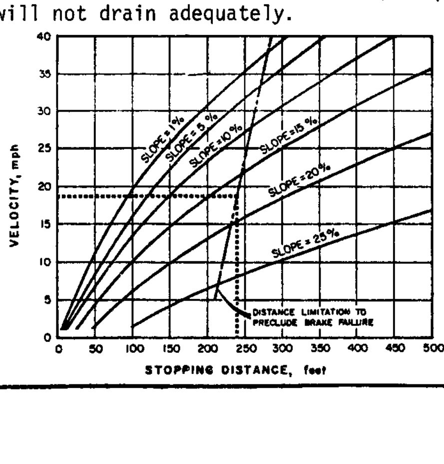


Figure 1. Stopping distance characteristics of vehicles of less than 100,000 pounds GVW.

TABLE 1

MAXIMUM GRADES FOR HAUL ROADS

Road Class	Overall Grade %	Pitch Grade %	Permissable Length of Pitch Grade
Class 1	10	15	300 (Maximum length within 100 feet)
Class 2	10	15	300 (length)
Class 3	10	20	1,000 (consecutively)

Source: Regulations

III. TRANSVERSE GEOMETRY

The transverse geometry, the cross section of the road are of great importance especially in ensuring good drainage of the road and stable construction.

The Regulations specify the width of haul roads required. Skelly and Loy's report gives the following design guide for vehicles up to 100,000 pounds gvw. The width for 1-lane (23 ft.) and 2-lane (40 ft.) haul roads on curves are shown in Table 2.

TABLE 2

RECOMMENDED WIDTHS FOR HAUL ROADS

Curve Radius (Ft.*)	One-Lane Haul Way	Two-Lane Haul Way
25	27	48
50	25	44
100	24	42
200	23	41
tangent	23	40

Source: (9)

*On the inner edge of the pavement.

If the area upstream of the haul road is also disturbed, all runoff from the road must be passed through a sediment basin [816.42]. Therefore it is clearly best to try to concentrate road drainage at a few selected points. This will mean the use of roadside ditches, usually located on the upslope side of the road, with a reverse fall on the whole roadbed so that all drainage flows to the ditch (Fig. 2). This will mean a culvert under the road at each sag in the vertical profile.

In steep terrain where most haul roads will be on cut and fill, a downslope ditch would have to be located on fill (Fig. 3) and would be liable to washout unless lined. The reverse fall also prevents overland flow from upslope areas flowing onto the road. Cross-slope to give rapid drainage of surface water should be ¼-½"/ft (10). However in flatter terrain such an arrangement or a cambered road with a ditch on both sides is possible when road is in total cut

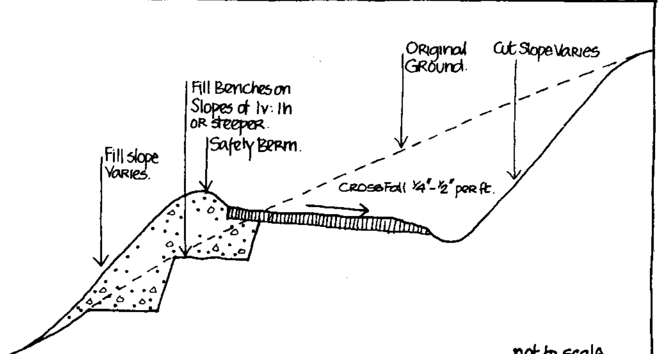


Figure 2

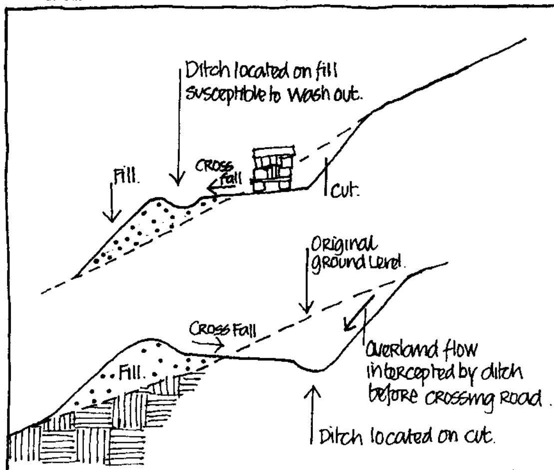


Figure 3

Curves on haul roads should normally be superelevated (banked) for greater safe-operating speeds. Superelevations will normally be banked into the slope of the land at crests and away at sags which allows most drainage to be handled in upslope ditches as suggested above. The Regulations do not specify superelevations, but Skelly and Loy's report gives criteria for calculating superelevations necessary on high-speed haul roads.

The Regulations specify maximum slopes for cuttings and embankments on haul roads for Class I and II roads. These are shown in Tables 3 and 4.

TABLE 3

MAXIMUM CUT SLOPES FOR HAUL ROADS

Road Class	Unconsolidated Material	Rock
Class I	1v:1.5h	1v:0.25h
Class II	1v:1.5h	1v:0.25h
Class III	no standards specified	

TABLE 4

MAXIMUM SLOPES FOR EMBANKMENTS IN HAUL ROADS

Road Class	Unconsolidated Fill	Rock
Class I	1v:2h	1v:1.35h
Class II	1v:1.5h	1v:1.35h
Class III	no standards specified	

Topsoiling and temporary erosion control measures are required for Class I and II roads in the performance standards for slopes of 1v:1.5h or flatter (i.e. those slopes not in rock or constructed of rock fill).

IV. DRAINAGE [816.153, 816.163 AND 816.173]

On Class I roads the drainage system must be designed for a 10-yr, 24-hr precipitation event. Sedimentation control for all classes of roads must comply with Sections 816.42 and 816.45 requiring that all runoff from "disturbed areas" be passed through sedimentation ponds; however, Section 816.42(a)(4) notes that "disturbed areas" do not include those areas in which only roads are installed if the area upstream of the road is not "otherwise disturbed." Natural drainage channels may not be altered without the approval of the RA and may not be altered at all in the case of Class III roads. Drainage structures are required for all stream crossings.

4:1 Ditches are required for Class I road (on both sides of a throughcut and on the inside shoulder of a cut-and-fill section). Ditches are not necessarily required for Class II roads where ditches, surface dips and natural drainageways may be used. Where ditches are provided a cross fall of ½" per foot will be adequate to drain the surface of all roads. Ditches themselves may be 'V' shaped or trapezoidal but 'V' shaped ditches are easier to construct without specialized equipment. Erosion is likely in ditches with a grade of over 4%, in which case they may require protection with riprap or other lining (Table 5). Avoid constructing ditches on fill.

TABLE 5

ROADSIDE DITCH LINING

Grade	Lining
0-3%	None required.
3-5%	Seed with erosion resistant grass and protect with jute matting or similar.
Over 5%	Riprap to at least 6" above max depth of flow.

Source: (9)

As an alternative to lining ditches, where the grade is too steep it can be reduced by constructing checkdams along the length of the ditch. These checkdams may be constructed of logs, riprap, or gabions, although logs are probably the cheapest on most forested sites. An example of a log checkdam is shown in Figure 4 (7).

Smooth channel linings or conduits will speed up the flow of water in the ditch and an energy dissipator should be installed at the discharge point. Fig. 5 shows a dumped rock energy dissipator to check erosion (9).

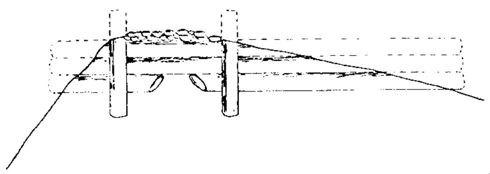


Figure 4

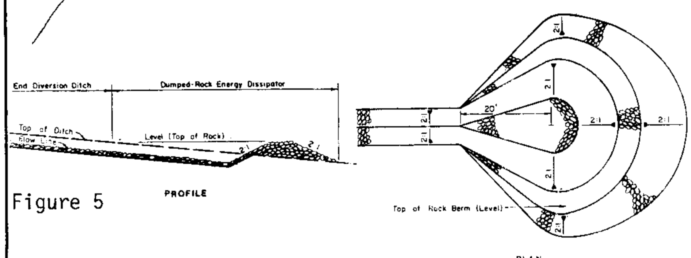


Figure 5

4:2 Culverts. The maximum spacings for culverts on haul roads required in the performance controls [816.153.(c)(v)] are shown in Table 6.

TABLE 6

MAXIMUM SPACING FOR CULVERTS ON HAUL ROADS

Grade %	Class I Road Maximum Spacing	Class II Road Maximum Spacing	Class III Road Maximum Spacing
0-3	1,000	1,000	unspecified
3-6	800	600	unspecified
6-10	500	400	unspecified
10 & greater	300	200	unspecified

Source: (Regulations)

Culverts should generally have a 2-4% grade to prevent clogging. The Regulations require protection of the culvert at both upstream and the discharge end to prevent erosion and scour. A riprap apron or energy disipator at the discharge end of the culvert will prevent the formation of a scour pool.

The Regulations require that a 10 yr/24 hr precipitation event be used for the design of all culverts on Class I and II roads where the end area of the culvert is 35 ft^2 or less. Where the end area is greater than 35 ft^2 a 20 yr/24 hr precipitation event should be used for the design. For both Class I and II roads the culverts should be covered in at least 1 ft of fill. Temporary culverts may be used on Class III roads. Temporary culverts for Class III roads should be designed for a 1 yr/6 hr precipitation event. These culverts can be constructed of timber. Details of timber culverts are shown in Figures 6 and 7 which are commonly referred to as open-top culverts. Figure 6 consisting of two logs held apart and parallel by 2" planks spiked at each end of the logs, and the second type (Figure 7) is made up of 3" timbers assembled in a trough shape with spacers of 1" pipe bolted across along the upper edge at about 4' intervals for rigidity (7). A photograph of an open-top log culvert is shown in Fig. 8.

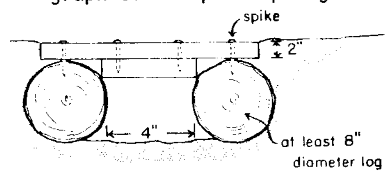


Figure 6

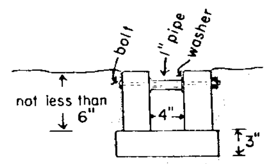


Figure 7

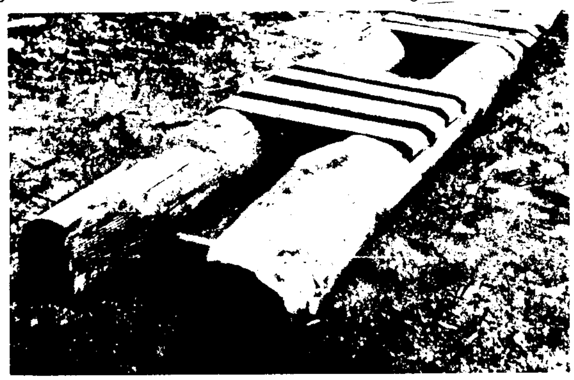


Figure 8

Weigle recommends the spacing for open-top culverts in Table 7 (spacing is not specified in the Regulations for culverts on Class III roads).

TABLE 7

SPACING OF OPEN-TOP CULVERTS

Road Grade (Percent)	Spacing (Feet)
2-5	300-800
6-10	200-300
11-15	100-200

Note: Spacing must be based on local conditions and the type of soil and the amount of watershed cover present in the area.

Source: (7)

4:3 Drainage Dips. Drainage dips are permitted in the Regulations for Class II roads. Broad-based drainage dips may be used to divert runoff across the roadbed without damage (but not in the case of permanent or ephemeral streams). These are normally 20' long with a 3% reverse grade in the roadbed. The spacing of these dips is recommended to be 400' divided by slope percent plus 100' giving the spacing in Table 8.

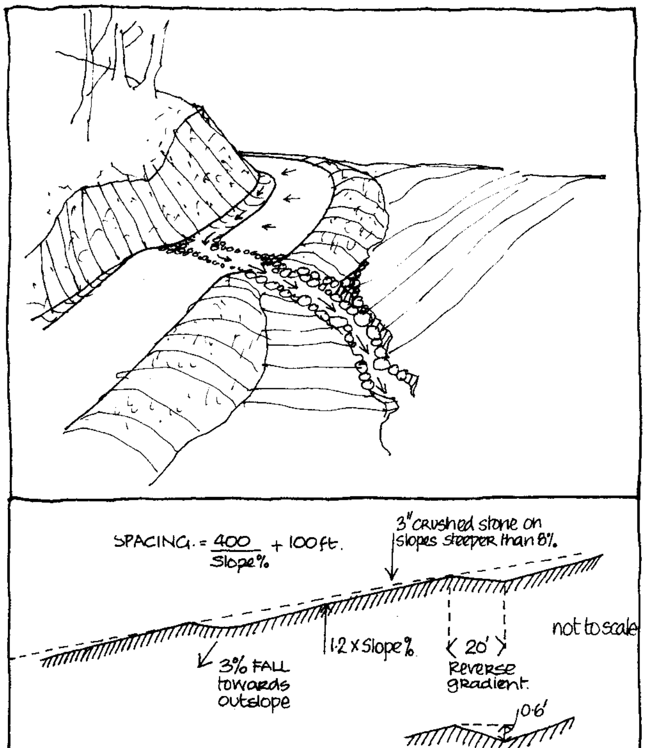
TABLE 8

RECOMMENDED SPACING FOR DRAINAGE DIPS

Road Grade (%)	Spacing (ft)
2-4	300-200
5-7	180-160
8-10	150-140

Source: (6)

Broad-based dips are cheaper to maintain and more permanent than wooden culverts but require a skilled bulldozer operator for construction. Fig. 9 shows the design factors for a drainage dip.



Source: Kochenderier 1970 Figure 9

4:4 Berms. Berms have been used widely in haul roads as a safety feature, particularly, in hilly areas where there is a danger of vehicles running over the outslope. The configuration and the design of berms is discussed in Skelly and Loy's report (9). The height of the berm is the critical factor and this must be equal to or greater than the rolling radius of the vehicle's tire. The use of berms will also help in reducing the problem of runoff flowing over embankments.

V. CONSTRUCTION

5:1 Clearance. The Regulations require clearing vegetation from the roadbed and the removal of topsoil for all classes of haul roads before construction. It is sometimes suggested that any trees and vegetation should be wind-rowed at the base of fill slopes (7). The Regulations do not forbid this practice but it may cause instability if buried by the fill. It is preferable to chip the cleared slash and use it for erosion control on cut slopes and embankments as required in 816.152 (c)(3), 816.152(d)(15), 816.162(c)(2) and 816.162(d)(14).

5:2 Topsoil removal from the roadbed is required in the performance standards for all classes of road.

5:3 Sub-base. The maintenance of a good surface is dependent upon a properly designed and constructed sub-base. The Regulations do not actually specify sub-base standards. The required thickness of sub-base is usually based on the California bearing ratio and Skelly and Loy's report gives guidelines for calculating the required thickness.

Plastic filter cloths are frequently used below haul roads to prevent the pumping action of truck tires pushing stone aggregates into the roadbed, resulting in reduced traction and muddy conditions, which will also increase sediment generation from the road. There are a number of different makes of these plastic filter cloths, one is shown during installation in Figure 10 (8). Monsanto, who manufactures 'Bidim' fabric, emphasizes that roadbeds incorporating filter fabric dry out more rapidly after rainfall. Wheel loads are spread over a greater area when a filter fabric is used.

5:4 Surfacing. Surfacing is important not only in minimizing delays during adverse weather conditions and minimizing haulage time but is also an important factor in road safety. The surfacing will also affect erosion of the road surface and sediment problems which result.

Road surfacing of granite, crushed rock, asphalt, etc., is required for both Class I and Class II roads, but for Class III roads it is simply specified that the surface should be adequate for the use of the road.

Figure 10

Asphalt surfacing is expensive, a 4" surface costing about $5/yd^2 for labor, equipment and material at 1978 prices (11). Asphalt surfaces may also become extremely slick when wet, especially if there is mud on the road. Crushed stone is far more commonly used on haul roads. Stone aggregate should not contain more than 10% fines to prevent muddy conditions after freezing and thawing. Sometimes operators supplying power plants with coal may arrange to haul back cinders as a road surfacing material.

VI. BEDDING DOWN AND RESTORATION
[816.156, 816.166 AND 816.176]

The regulations require as part of the restoration performance standards that all bridges and culverts be removed from haul roads. Ditch relief culverts should generally be replaced by water bars. These should also angle downgrade at 30 degrees at the spacing shown in Table 9. They may be a ditch or a berm (of earth or crushed stone). Earth berms are useless once they are

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

rutted so traffic must be kept off closed roads by erecting a barricade across them. For Class 1 roads, the rounding of cut and fill slopes to blend with the surrounding topography (but not regrading to the approximate original contour) is required. The standards for the restoration of Class II and Class III roads are similar, and in all cases, roadbeds are to be topsoiled and revegetated in accordance with 816.111-816.116.

TABLE 9

WATER BAR SPACING RECOMMENDATIONS

Road Grade (%)	Spacing (ft)
2	250
5	135
10	80
15	60
20	45

Source: (7)

REFERENCE

(1) Grim, E.C. and Hill, R.D., Oct 1974, "Environmental Protection in Surface Mining of Coal," EPA-607/2-74-093.

(2) Cowhert, et al., 1974, "Devel. of Emission Factors for Fugitive Dust Sources," EPA, Res. Tri. Park, NC 27709.

(3) Kimball, L.R., 1975, "Slope Stability, Vol. 1, Report and Field Book," Department of Natural Resources and Environmental Protection, Frankfort, KY.

(4) Packer, P.E., 1967, "Criteria for Designing and Locating Logging Roads to Control Sediment," Forest Sci. 13(1).

(5) Curtis, W.R., 1973, "Effects of Strip Mining on the Hydrology of Small Mountain Watersheds in Appalachia," from Hutnick, R.J. and Davis, G. (Eds.), "Ecology and Reclamation of Devastated Land - Vol. 1," Gordon and Breech, New York.

(6) Kochenderfer, J.N., 1970, "Erosion Control on Logging Roads in the Appalachians," USDA Forest Service Research Paper, NE 158, Upper Darby, PA.

(7) Weigle, W.K., 1964, "Designing Coal-Haul Roads for Good Drainage," Central States Forest Experimental Station, Berea, KY.

(8) Advance Construction Specialties Co., Memphis, TN 38101.

(9) Kaufman, W.W., Ault, J.C., (Skelley and Loy, Engineers and Consultants), 1976, "Design of Surface Mine Haulage Roads, A Manual," Bureau of Mines, Pittsburgh, PA.

(10) Chironis, E.P., (Ed.), Jan 1978, "How to Build Better Haul Roads," Coal Age, pp. 122-128.

(11) Chironis, N.P., (Ed.), June 1974, Paved Haul Road, 10-Wheel Trucks Boost Output of West Virginia Form," Coal Age, pp. 94-95.

(12) Davis, H., Dec 1976, "Jones & Brague has been Rocognized for Excellence of its Recla.," Coal Age, pp. 94-97.

(13) Grier, W.F., 1976, "Demonstration of Coal-Mine-Haul-Road Sediment Control Techniques," EPA 600/2-76-196.

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GROUP	MOBILIZATION AND MINING OPERATIONS	HANDBOOK FOR SMALL MINE OPERATORS	6
MEASURES	SEDIMENTATION PONDS		3

PROBLEM & PURPOSE

Runoff water from surface mine sites often carries a heavy sediment load which can cause severe damage in receiving streams. If the water is impounded in small ponds, much of the sediment will settle out. The amount of sediment which will settle depends upon the period during which the water is detained in the pond and also upon the size of the particle. Large heavy particles settle rapidly but small particles may take days to settle. In some cases settlement can be speeded by adding 'flocculants' to the water, but usually careful location, design and management of ponds is sufficient to meet the effluent limitations in Section 816.42.

APPLICABILITY

All surface mine sites must meet the effluent limitations in Section 816.42 and "appropriate sediment control measures must be designed, constructed and maintained" [816.45(a)]. It will generally be easier for operations in flat or rolling terrain to meet sediment limitations because, in these areas, runoff is more controllable and 'internalized' within the permit area. Operators in steep terrain will have more difficulty in meeting limitations on suspended solids.

REVELANT SECTIONS OF THE REGULATIONS

Section 780.25 of the Regulations requires that "each application shall include a general plan for each proposed sediment pond." Section 816.42 requires that all surface drainage from disturbed areas including disturbed areas that have been graded, seeded or planted, shall be passed through a sedimentation pond or series of sedimentation ponds before leaving the permit area. The sedimentation ponds must remain in place until the disturbed area has been restored and the vegetation requirements of Sections 816.111-816.117 are met, and the quality of the untreated drainage from the disturbed area meets applicable State and Federal water quality standards.

Discharges from the area must not exceed certain effluent limitations [816.42(a)(7)]. Maximum allowable total suspended solids is 70 mg per liter, but the average daily value for 30 consecutive days must not exceed 35 mg/l. These limitations do not apply if the discharge results from a 10 yr/24 hr precipitation event or larger. Note that the effluent standards for suspended solids are the same as those recommended by EPA in 1976 "Effluent Guidelines and Standards."

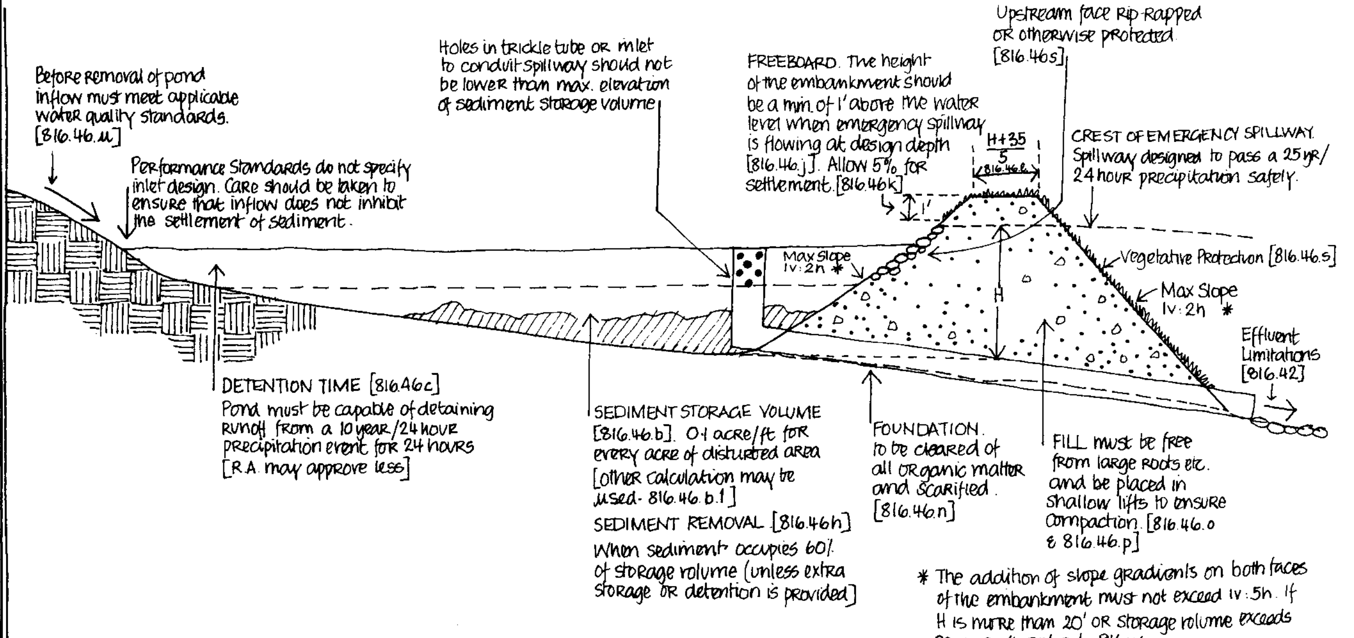
The design standards for sedimentation ponds (see Figure 1) are quite specific. Other types of sediment control impoundment can be constructed upstream of the required sedimentation pond but this does not relieve the operator of responsibility for meeting the requirement for a sediment pond of the standard design. The RA does have the discretion however of reducing the required storage volume of the sediment pond if it can be demonstrated that sediment removed by other measures is equal to the reduction in sediment storage volume [816.46(b)].

DISCUSSION & DESIGN GUIDELINES

"Each pond shall be designed and inspected during construction by a registered professional engineer." [816.*6(f)]. It should be noted that even when sedimentation ponds are constructed according to the specifications in this Part, that the operator is still subject to the effluent limitations as contained in Section 816.42[816.46(f)].

The design of the sediment ponds is not based on a precise method and includes considerable safety factors built into the design. While it is possible to determine the settlement velocity and other factors important in the design of sediment ponds, it is not possible to translate these factors into precise design criteria because of the many variables which affect the performance of a sedimentation pond.

The main requirements for the design of a sedimentation pond included in the Regulations are shown on Figure 1 which shows a schematic section through a pond and the embankment. When a sedimentation pond has an embankment which is more than 20' in height or a storage volume greater than 20 acre-ft., additional design requirements are specified in Section 816.46(q). These larger ponds must be designed to pass a 100 yr/24 hr precipitation event without damage.



REQUIREMENTS FOR THE DESIGN OF SEDIMENT PONDS.

Figure 1

NOT TO SCALE.

I. LOCATION

The main economic criterion for the construction of a sedimentation pond will be to minimize earthmoving. This demands careful location which is made considerably easier by the availability of a good topographic map during the pre-mining planning process. Sediment ponds can be used individually or in series [816.46(a)]. They must be constructed before any disturbance takes place, and they may not be constructed in the course of perennial streams unless approved by the RA.

II. DETENTION TIME

The total volume of the pond will depend partly on the sediment storage volume and also upon the detention time. The detention time is calculated using a 10 yr/24 hr precipitation event and is the average time that the design flow is detained in the pond. Sedimentation ponds must provide a theoretical detention time of not less than 24 hours. In certain circumstances [816.46 (c)(1)], the RA may approve a detention time of less than 24 hours but not less than 10 hours. Approval of a shorter detention time depends upon the designer being able to demonstrate an improved sediment removal efficiency due to the pond design, and that the pond is capable of achieving and maintaining effluent limitations. The RA may also approve detention times of less than 10 hours in cases where a chemical treatment process is to be used, if it can be demonstrated that this will be harmless to fish and wildlife and will achieve and maintain effluent limitations.

The design of sediment ponds should in theory be based on the size of the particles which are to be trapped, their settling velocity and hence the detention time required. The settling velocity is a function of the density, size and shape of the particle and also the viscosity of the fluid. Table 1 shows how long it will take particles, with a specific gravity of 2.65, to settle in still water at 10°C.

TABLE 1

SETTLING TIME FOR PARTICLES IN FLUID
(S.G. 2.65, at 10°C)

Diameter (mm)		Time Required to Settle 1'
1.0	coarse sand	3 seconds
0.1	fine sand	38 seconds
0.01	silt	33 minutes
0.001	bacteria	35 hours
0.0001	clay	230 days

Source: (3)

From Table 1, it will be appreciated that very fine colloidal particles may take considerably longer to settle than the 1 day detention time required in the performance standards. However, irrespective of the requirements of the performance standards, effluent limitations apply, and if these are exceeded, the operator may be required to take additional measures to reduce the concentration of suspended solids. In these cases, when drainage water contains a high percentage of very fine colloidal particles it may be necessary to add a flocculating agent to speed the rate of settlement. There are a number of these available and the operator should consult a qualified engineer.

III. SEDIMENT STORAGE VOLUME

There are two methods by which sediment storage volume may be calculated. The first, which is rather complicated, involves the use of the "Universal Soil Loss Equation (see Sheet 6:1), Gully Erosion Rates and the Sediment Delivery Ratio converted to sediment volume." The second method, which is much simpler, requires a sediment storage volume of 0.1 acre-ft. for each acre of disturbed area within the upstream drainage area. The RA may approve a storage volume of less than 0.1 acre-ft. under certain conditions [816.46(b)(2)]. These conditions require the operator to demonstrate that sediment is removed by other sediment control measures equal to the reduction in sediment storage volume. There are a number of measures which the mine operator may take upstream of the sedimentation pond including other detention ponding devices employing less elaborate dams and spillways than those required for the main sedimentation pond. An effective sediment control impoundment, for instance, to remove larger sediments can be constructed without a trickle tube using a permeable rock dam with a plastic filter cloth. There are a number of these plastic filter cloths available. Figure 2 shows a hypothetical section through a rock sediment control dam across a small drainage channel.

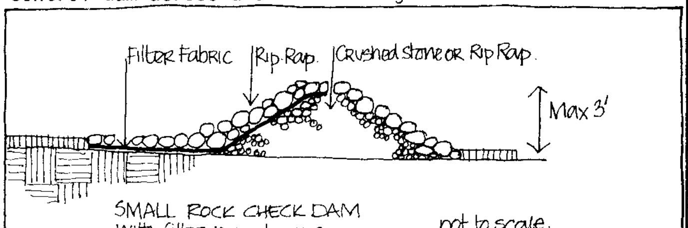


Figure 2

Other small sediment control impounding devices using gabions, log dams, etc., may be used above the main sedimentation pond. Gabions have been used fairly widely in the surface mining industry and in some cases have been used for fairly large dams. The photograph (Figure 3) shows a gabion type structure also used for silt control in Fayette County, WV (Source: 1).

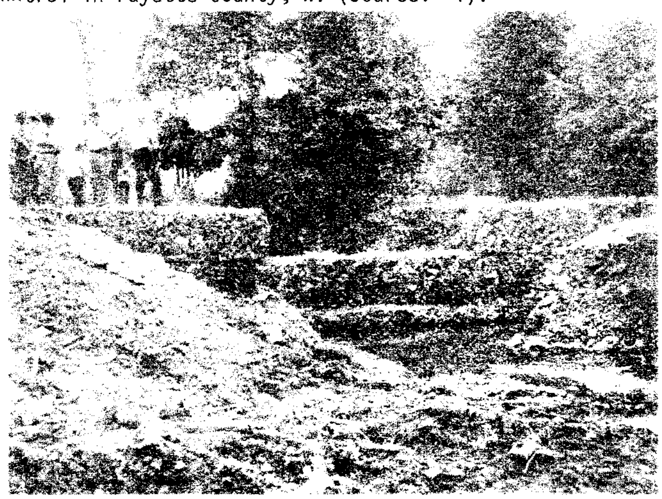


Figure 3

The Northeast Forest Experimental Station at Berea, Kentucky, conducted experiments early in the 1970's to estimate the sediment generation by land disturbed by surface mining. In the experimental watershed, which contained 63 acres of land affected by surface mining, the sediment pond trapped 0.82 acre-ft. of sediment which was equivalent to 0.54" over the whole disturbed areas. Partly on the basis of these experiments, the Forest Service and the Soil Conservation Service predicted a 0.20 acre-ft. sediment yield per acre of disturbed acreage. This production included a safety factor and this was subsequently used in Kentucky's surface mine regulations. (6)

IV. DEWATERING

"A non-clogging dewatering device" (e.g. a trickle tube with a trash rack or conduit spillway) shall be located so that its lower elevation is below the maximum elevation of the sediment of the sediment storage volume. [816.46(d)] Figure 4 shows a simple trickle tube arrangement with a trash rack.

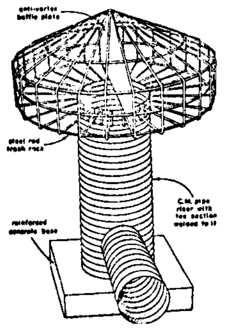


Figure 4

V. SEDIMENT REMOVAL

Sediment must be removed when the volume of sediment accumulates to 60% of the design sediment storage volume [816.46(h)]. This applies unless the sedimentation pond has been designed and constructed with additional sediment or water storage capacity and approved by the RA. Sediment removal is most easily accomplished using a dragline or a clam-shell. Many small operators will have access to neither of these pieces of equipment although a long-arm backhoe may be available in these cases. It may be more economic to construct the sediment basin with a larger storage volume as is permissible in Section 816.46(h) in order to reduce the need for sediment removal.

VI. DAM, EMBANKMENT

[816.46(i)-(p)] The minimum elevation of the top of the settled embankment must be 1 ft. above the water surface in the pond when the emergency spillway is flowing at the design depth. A minimum of 5% allowance for settlement in the height of the dam must be allowed during construction. The minimum top width of the embankment shall not be less than the quotient of (H + 35) divided by 5 where H is the height in feet of the embankment as measured from the upstream toe of the embankment. The maximum slopes of the upstream or downstream sides of the embankment should not exceed 1v:2h but the addition of the gradients for both embankments should not exceed 1v:5h. During construction, the foundation of the embankment should be cleared of all organic matter and the entire foundation area scarified. The fill material should be free of large roots and other vegetative material and built up in horizontal lifts so as to achieve good compaction. The entire embankment should be stabilized after construction with a vegetative cover, and the active upstream face of the embankment rip-rapped or otherwise stabilized [816.46(s)].

VII. INLET DESIGN

Inlet design is an important factor in the design of sediment ponds. The performance controls do not specify the design of inlets for sedimentation ponds. However in section 816.46(c)(1) it is stated that the RA may approve a detention time of less than 24 hours (but not less than 10 hours) if an improvement in "sediment removal efficiency" can be demonstrated by "inflow and outflow facility locations, baffles to decrease inflow velocity and short circuiting...." If water enters at one point at a high velocity, sediments already settled in the pond are likely to be disturbed and settlement is poor. Multiple inlets, baffles, or spreading devices to reduce inlet velocity are recommended. Small modifications to the inlet design and consequently the pattern of flow of polluted water through the pond may significantly alter the percentage of suspended solids removed.

VIII. EMERGENCY SPILLWAY

The combination of principal and emergency spillways must be capable of passing a 25 yr/24 hr precipitation event without damage to the pond. The elevation of the crest of the emergency spillway must be 1 ft above the crest of the principal spillway, and the emergency spillway must be capable of passing the design flow without damage.

IX. REMOVAL OF PONDS

Sedimentation ponds may not be removed until the disturbed area has been restored and revegetated. The drainage entering the pond must meet applicable State and Federal water quality requirements for the receiving stream. In certain cases, the RA may approve retention of a sedimentation pond in which case it must meet the requirements for permanent impoundments of Sections 816.49 and 816.56. Where the RA has approved permanent retention of sedimentation pond, 816.56 requires that operators renovate the pond to meet the criteria specified for permanent impoundments [816.49(a)].

REFERENCE

(1) Hamilton, L.W., Sep 1974, "Reclamation in Steep Slope Surface Mining," Mining Congress Journal.
(2) Carthage Mills, Erosion Control Division, "Filter Handbook," 124 W. 66th St., Cincinnati, OH.
(3) Hill, R.D., 1976, "Sedimentation Ponds, A Critical Review," US EPA, Cincinnati, OH.
(4) Janiak, H., 1975, "Progress in Methodology of Lignite Mine Waters Purification," Central Research and Design Institute for Opencast Mining, Wroclaw, Poland.
(5) McCarthy, R.E., June 1973, "Surface Mine Siltation Control," Mining Congress Journal.
(6) Curtis, W.R., Oct 22-24, "Sediment Yield for Strip-Mined Watersheds in Eastern Kentucky," 2nd Research and Applied Technology Symposium on Mined-Land Reclamation, National Coal Association, Louisville, KY.
(7) Hill, R.D., May 1975, "Sediment Control and Surface Mining," Polish-US Symposium, Environmental Protection in Open-Pit Mining, Denver, CO.
(8) U.S. Environmental Protection Agency, October 1976, "Erosion and Sediment Control - Surface Mining in the Eastern U.S. - Planning," EPA Technology Transfer Seminar Publication, EPA 625/3-76-006.
(9) U.S. Environmental Protection Agency, October 1976, "Erosion and Sediment Control - Surface Mining in the Eastern U.S. - Design," EPA Technology Transfer Seminar Publication, EPA 625/3-76-006.

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PROBLEM & PURPOSE

It is usually in the interest of the mine operator to divert clean runoff and streamflow from areas upslope or upstream of the mine site before it becomes contaminated with sediment and polluted water on the mine site itself. These diversions intercept runoff and streamflow and convey it around the mine working area to a receiving watercourse, downstream. This can result in considerable savings for the operator because all surface drainage from disturbed areas must be passed through a sedimentation pond [816.42]. The size of this sedimentation pond has to be sufficient to hold the flow from upstream for a 24 hour period [816.46(c)]. If much of this upstream flow can be diverted, then the size requirement for the pond will be that much less. The diversion itself is not part of the "disturbed area" and therefore flow through it need not be passed through a sedimentation pond [816.42(a)(4)]. Diverting overland flow before it enters the mine area will also help the operator in keeping the working area and the pit dry and the operations running smoothly. In cases where the overburden contains acid-forming materials, diversions around the workings are especially important to reduce the possibility of AMD and the possible need to treat the discharge water.

APPLICABILITY

These measures apply to all surface mining sites. They are especially important where there is a large area upslope of the mine site from which overland flow or streamflow, which then passes over the mine site, originates. In these cases the required size of sedimentation ponds would be very large unless the flow is diverted. The measures are also especially important in steep terrain where erosion problems are most serious, where it is difficult to keep polluted water within the mine site, and where confined pit conditons make a dry working area important for smooth operations.

REVELANT SECTIONS OF THE REGULATIONS

The Regulations distinguish between 3 types of stream. [Definitions, 701.5]

(i) Ephemeral streams. These carry water only immediately after rain or during snowmelt, otherwise they are almost dry.

(ii) Intermittent streams do not carry water the whole year but they drain at least one square mile, receive some flow from groundwater as well as runoff and are also below the local water table for part of their length for some of the year.

(iii) Perennial streams, flow the whole year round, receiving flow from both runoff and groundwater.

The requirements of the performance standards for ephemeral stream diversions [816.43] are less stringent than those for perennial and intermittent streams [816.44]. Temporary or permanent diversion channels may be used to divert overland flow, or flow in ephemeral streams, away from disturbed areas in order "to minimize erosion, to reduce the volume to be treated and to prevent or remove water from contact with acid-forming or toxic-forming materials" [816.43] but these diversions do need the approval of the RA. Plans of stream channel and other diversions to be constructed within the proposed permit areas are required under Section 780.29.

Section 816.43 contains the various performance standards for design and construction of diversions of overland flow and ephemeral streams, and they are also discussed below. It should be noted that in Section 816.42(a)(4) it states that "for the purposes of this Section only 'disturbed area' shall not include those areas in which only diversion ditches....are installed in accordance with this Part." This means that if the diversions are constructed to the standards in 816.43 and approved by the RA, the flow in the diversions need not be passed through a sedimentation pond, and the diversion will also reduce the size of sedimentation ponds which are required. However. Section 816.43(c) requires that all diversions be designed, constructed and maintained in a manner which prevents additional contributions of suspended solids to stream flow and to runoff outside the permit area.

DISCUSSION & DESIGN GUIDELINES

I. LOCATION

Locating a diversion for maximum effectiveness requires a good topographic map. No areas upslope of the diversion may be disturbed otherwise flow in the diversion would have to be passed through a sedimentation pond. The Regulations specify also that no diversion should be located so as to increase the potential for land slides [816.43(d)]. This is particularly important when locating diversion ditches around the upslope side of Head-of-Hollow or Valley fills, in which case these diversions should be constructed on solid ground.

II. DESIGN CAPACITY

Temporary diversions must be designed to pass safely a peak runoff from a precipitation event with a 2 yr recurrence interval. For permanent diversions the recurrence interval must be 10 years. Diversions must have channels which are capable of passing the design velocity without causing erosion.

The capacity of the channel is based on caluclation of the peak discharge. This is calculated in the normal way using the rational formula:

$$Q = CiA$$

Where:

- Q = discharge in cfs;
- C = runoff coefficient;
- i = intensity of rainfall;
- A = drainage area in acres.

The Soil Conservation Service's "Engineering Field Manual for Conservation Practices" gives several examples of methods of calculating the channel size for diversion channels.

III. CROSS SECTION

Waterways may be built in parabolic, trapezoidal or V-shaped cross sections. The parabolic cross sections have generally proved to be the most satisfactory. Waterways with a trapezoidal cross section, however, are easier to construct. Maintenance of grassed waterways by mowing is absolutely essential to insure the maximum erosion resistance of the grass. To enable frequent high-speed mowing to take place, side slopes of trapezoidal sections should not exceed 1v:3h.

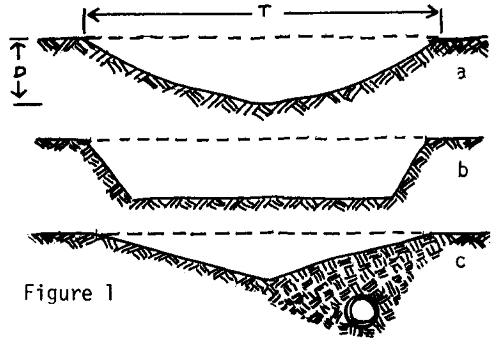


Figure 1

The performance standards require a freeboard of no less than 0.3 feet. [816.43(f)(2)].

IV. CHANNEL LINING: VEGETATIVE

The regulations require that "channel lining shall be designed using standard engineering practices to pass safely the design velocities." [816.43(f)(1)].

Grass-lined diversion channels are generally the most economical. There is also considerable expertise in the design of grass channels to minimize erosion. The USDA Soil Conservation Service's "Engineering Field Manual for Conservation Practices" gives an excellent guide for the design of grass diversion channels. This includes the method for estimating the "retardance" for various types of vegetation. Grass channels must be capable of withstanding the abrasive action of water without damage. Generally grass channels have slopes of between 1 and 10 percent. The permissible velocities for various types of grass and soil erodibility are shown on Table 1. Note that the range is between 2-6 fps with velocities of 7-8 fps used only where the sward is of the highest quality.

Table 1. PERMISSIBLE VELOCITIES FOR CHANNELS LINED WITH VEGETATION

Cover	Slope range 2/ (percent)	Permissible velocity 1/ Erosion resistant soils (fps)	Easily eroded soils (fps)
Bermuda grass	0-5	8	6
	5-10	7	5
	over 10	6	4
Bahia Buffalo grass Kentucky bluegrass Smooth brome Blue grama Tall fescue	0-5	7	5
	5-10	6	4
	over 10	5	3
Grass mixtures	2/ 0-5	5	4
Reed canarygrass	5-10	4	3
Lespedeza sericea Weeping lovegrass Yellow bluestem Redtop Alfalfa Red fescue	3/ 0-5	3.5	2.5
Common lespedeza 4/ Sudangrass 4/	5/ 0-5	3.5	2.5

1/ Use velocities exceeding 5 fps only where good covers and proper maintenance can be obtained.

2/ Do not use on slopes steeper than 10% except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

3/ Do not use on slopes steeper than 5% except for vegetated side slopes in combination with a stone, concrete or highly resistant vegetative center section.

4/ Annuals--use on mild slopes or as temporary protection until permanent covers are established.

5/ Use on slopes steeper than 5% is not recommended.

Rapid stabilization of grass diversion channels following grading is obviously essential to minimize erosion. Hydroseeding and mulching will help considerably but in critical areas other forms of stabilization may be appropriate. A variety of jute, paper, and plastic nettings are on the market and can be used to stabilize grassed waterways at the time of seeding. In larger channels where several widths of netting are required these should overlap by 2 inches and the overlap be stapled 4 to 10 inches apart. The ends of the rolls should also be overlapped and the top ends buried in trenches 4 inches deep. After laying these nets, they should be rolled well to insure good contact with the soil.

V. REINFORCING VEGETATIVE LININGS

The erosion resistance of a grass waterway can be increased in difficult cases by reinforcing the sward with nylon netting or by introducing fiberglass erosion checks at regular intervals. Erosion checks are usually constructed of fiberglass matting which is installed across the waterway. They prevent the formation of gullies and aid in the establishment of vegetation. Preferably they should be installed at any changes in gradient and downstream from the confluence of two diversions. Installation involves excavating a 1 foot deep trench and installing a vertical membrane of fiberglass. It is secured with staples, backfilled, compacted and the excess fiberglass trimmed off flush with the surface (Figure 2).

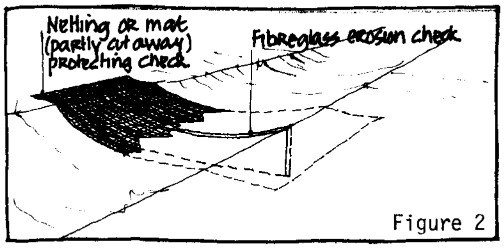


Figure 2

VI. STRAW BALE AND BRUSHWOOD EROSION CHECKS (ABOVE GROUND)

In cases where a grass channel is eroding or to help stabilize a grass channel various types of above-ground erosion checks can be used.

On channels over 9 feet wide, straw bale checks as shown in Figure 3 may be used. Bales are staked down with 2 x 2'6" wooden or metal stakes and tied down with nylon or wire. Riprap is placed to form an apron downstream of the check for a minimum distance of 4 feet and at the edge of the channel on both sides. On channels of less than 9 feet in width the small checks shown in Figure 4 may be used without an apron. They should be spaced about 40 feet apart. Checks must be removed prior to final restoration

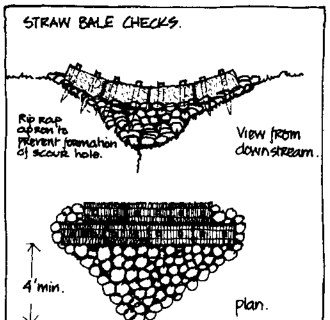


Figure 3

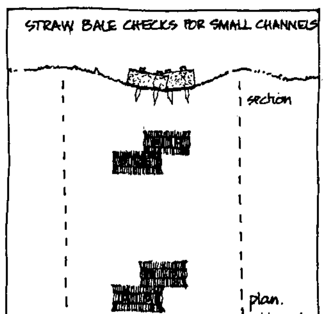


Figure 4

Where a longer life erosion check is required a three foot cyclone fence is nailed on the upstream side of 4" x 4" wooden stakes across the channel. Straw bales are placed on the upstream side as shown. These are wired together and to the fence. Riprap is placed as for straw bale checks and in some cases, the straw bales may be covered with crushed stone. This installation must also be removed prior to restoration. When straw is not available but when there are large quantities of brushwood on site, brushwood bundles approximately 18 inches in diameter can be made up on site with #9 wire and laid in staggered formation upstream of the fence and wired to the fence. Riprap is placed as before. Wooden stakes (usually 4 inch diameter poles) may also be used in various conformations to provide erosion checks alone or with straw or brushwood. These alternatives are shown in Fig. 5 and Fig. 6.

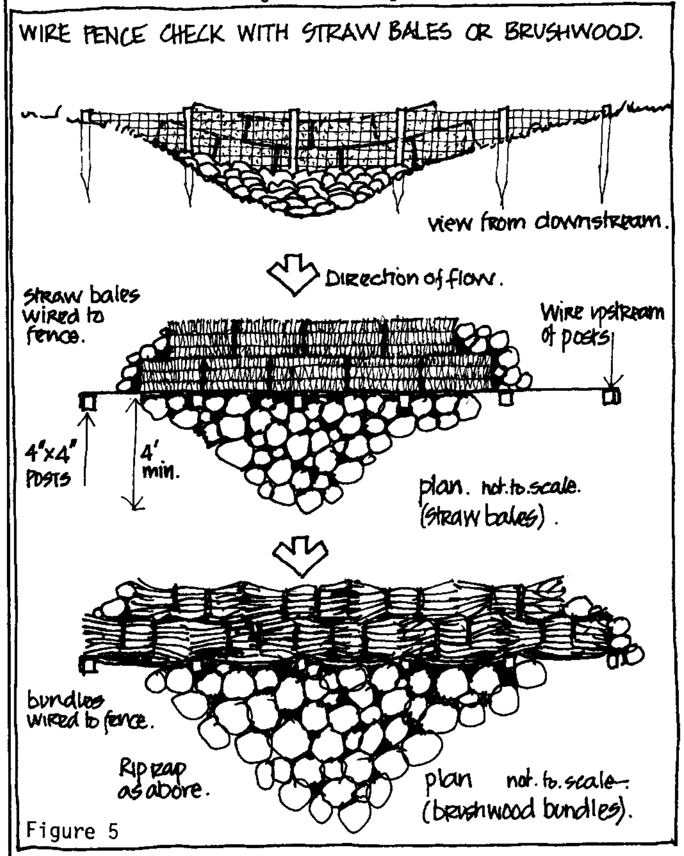


Figure 5

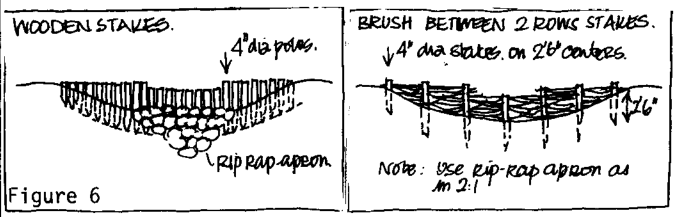


Figure 6

VII. CHANNEL LINING - NON-VEGETATIVE

Temporary diversion channels may be stabilized with asphalt concrete, riprap or other non-vegetative lining, but non-vegetative linings may be used for permanent diversions only with the approval of the RA. In the case of a diversion which has permanent wetness in the bottom, grass will not give good protection. In these cases it is questionable that it is an 'ephemeral' and not an intermittent stream. To prevent erosion a stone center drain or underdrain should be installed. Alternatives are shown in Figures 7 and 8.

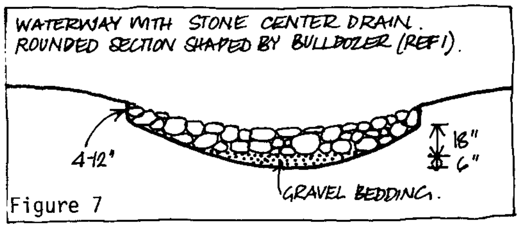


Figure 7

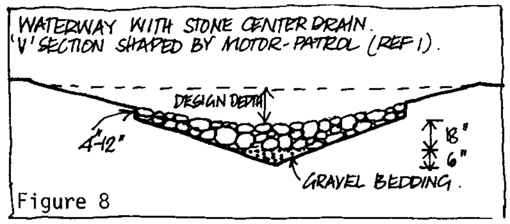


Figure 8

VIII. DROP STRUCTURES AND CHECK DAMS, ENERGY DISSIPATORS

These counteract gully erosion in waterways by reducing the effective gradient of the channel. They should be used when the flow velocity exceeds that for which vegetation can provide effective protection. These may be preferable to the use of a concrete, asphalt or riprap lining, particularly for permanent channels when such linings require the approval of the RA. Selection of the type of drop structure or check dam and the materials to be used will depend on flow velocity, cost, performance and aesthetic aspects. Materials may consist of timber, rock, gabions, concrete, brush or sod. To prevent undercutting the toe all structures should be keyed well into the existing ground surface. The approval of the RA should be obtained for the use of these structures on permanent diversions. Figures 9, 10, and 11 show alternative spillways for diversion channels. It should be noted that section 816.43(f)(3) requires that energy dissipators shall be installed where diversions meet a natural stream if the velocity in the diversion exceeds that in the stream. See Sheet 6:2 for details of a dumped rock energy dissipator.

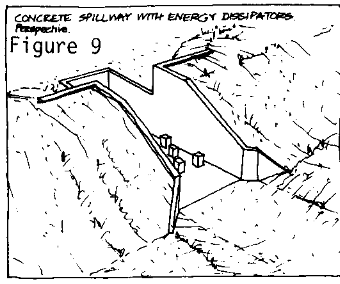


Figure 9

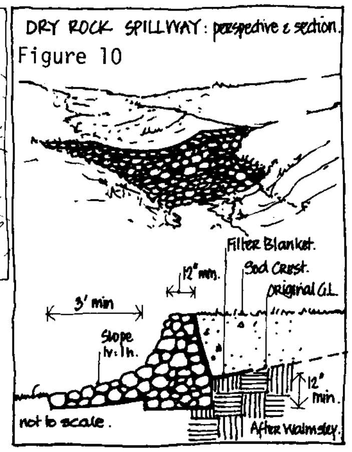
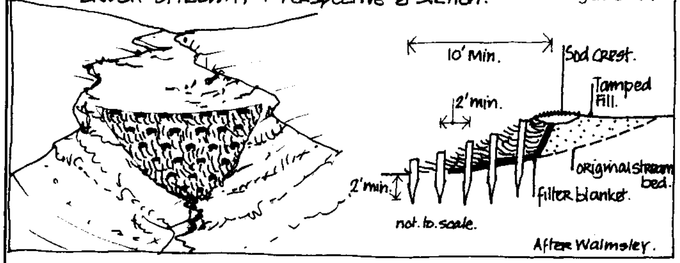


Figure 10

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

BRUSH SPILLWAY : Perspective & Section. Figure 11



IX. REMOVAL

Section 816.43(e) of the Regulations requires that after operations are complete, temporary diversions must be removed and the affected land regraded, topsoiled and revegetated in the same way as other disturbed areas of the site.

REFERENCE

(1) USDA Soil Conservation Service, 1975, "Engineering Field Manual for Conservation Practices."
(2) USDA, 1970, "Controlling Erosion and Construction Sites," Soil Conservation Serv., Agric. Infor. Bulletin 347.
(3) EPA, 1972, "Guidelines for Erosion and Sediment Control Planning and Implementation."
(4) Pennsylvania Department of Environmental Resources, Sep 1972, "Soil Erosion and Sediment Control Manual."
(5) Skelly and Loy, Engineers-Consultants, Oct 1973, "Processes, Procedures, and Methods to Control Pollution from Mining Activities," EPA 430/9-73-011.

PROBLEM & PURPOSE

It may be desirable to divert stream channels either temporarily or permanently for any of the following reasons:

1. To allow the existing channel to be mined through, enabling the extraction of coal beneath and rationalization of the mining operation.
2. To divert unpolluted stream flow around the mine working, so avoiding contamination with sediment or by contact with acid-forming materials while passing over the working area.
3. Diversion of flow from upstream areas reduces the required capacity of sedimentation ponds as only the drainage from the disturbed areas will flow through the pond.
4. Diversion of streams away from the working area reduces the problem of pit dewatering, and other problems of handling drainage water on a surface mine site.

APPLICABILITY

These measures apply to all surface mining sites. Diversion of streams which cross the proposed coal extraction area is particularly important for certain types of mining - e.g. area mining which relies on moving the cut steadily across the site without any obstructions. Where overburden is thick any obstructions on the surface (streams, roads, etc.) which are not diverted or relocated will result in the sterilization of a large area of coal because of the batter of the high wall when mining around obstructions.

Diversion of streams to reduce the amount of flow which must be passed through sedimentation ponds is very important on sites where there is a large area of undisturbed land above the mine site, and in hill terrain where it will be difficult to confine drainage water to the permit area. In the case of contour mining, diversions may have to cross the extraction area in temporary pipes or chutes.

The diversion of streams to reduce the problem of dewatering the working area and the pit will be most important in cases where the pit is confined and where much equipment is working in the bottom of the pit. It is also very important on sites where the overburden contains large amounts of acid-forming materials. It should be noted that diversions must be approved by the RA but that the RA may also require diversions to be installed.

REVELANT SECTIONS OF THE REGULATIONS

Sheet 6:4 described the performance control and design guidelines for the diversion of ephemeral streams and overland flow. This sheet considers the diversion of streams with perennial or intermittent flow. Both perennial and intermittent streams may be diverted [816.44] but the diversions must be approved by the RA. The application must contain plans of all proposed stream channel diversions within the proposed permit area under Section 780.29.

The performance standards make no distinction between the design requirements for permanent and intermittent stream diversions. But a distinction is made in the design of permanent versus temporary diversions. It should be noted here that Section 816.42 requires that all surface drainage from disturbed areas is passed through a sedimentation pond but Section 816.42(a)(4) specifically excludes diversion ditches. From this definition it is not clear whether "diversion ditches" include stream channel diversions. Sections of the Regulations which deal specifically with the design and construction of stream diversions are discussed below.

DISCUSSION & DESIGN GUIDELINES

I. CAPACITY

The combination of channel bank and floodplain configurations for temporary diversions must be adequate to pass safely the peak runoff from a 10-yr/24-hr precipitation event, while the combination of channel bank and floodplain configurations for a permanent diversion must be adequate to pass safely the peak runoff from a 100-yr/24-hr precipitation event. In both cases the capacity of the channel must be at least equal to the capacity of the unmodified stream channel immediately upstream and downstream of the diversion. The performance standards require that the longitudinal profile of the stream channel and the floodplain be designed and constructed to remain stable and to prevent additional contributions of suspended solids to stream flow or runoff outside the permit areas.

II. CROSS SECTION AND CHANNEL LINING

The required treatment of the channel differs between permanent and temporary diversions. Some of the principles described on sheet 6:4 of using grass and other vegetation to stabilize diversions also apply to that part of these diversions which is not permanently wet. Section 816.44(b)(1) requires that any erosion control structures, such as channel linings, retention basins, artificial channel roughness structures, should only be used with the approval of the RA and it is noted that these structures will be approved for permanent diversions only where they are stable and will only require infrequent maintenance. However 816.44(d) requires that the longitudinal profile and cross-section of a restored or permanent stream diversion should include aquatic habitats (usually a pattern of riffles, pools and drops rather than uniform depths) that approximate premining stream characteristics. It also requires that the stream be restored to its "natural meandering shape" with an environmentally acceptable gradient. The Section requires the operator to restore and enhance, where practicable, the natural riparian vegetation on the bank of the stream.

III. BANK CONFIGURATION AND STABILIZATION

A "natural meandering" stream is usually cutting the bank on the outside of bends (the bank here being steep) and depositing on the inside of the bend where the bank is shallow. When creating a meandering profile with variations in the depth of water, it is desirable to copy this natural situation. Steep banks can be constructed using various techniques and should usually rely on planting of natural riparian vegetation to provide permanent stabilization. The lower riparian zone in the Northeast and Middle Atlantic States has a natural growth of willow, alder, button bush, small maples, sweet gum and swamp rose. These vegetation types can be used to stabilize streambanks. The most commonly used of these is willow, because of its capability to develop roots from cuttings and it throws up suckers readily. Willows can be planted either as individual cuttings or bound together in various forms, e.g. willow mattresses or bundles or rolls (Figures 1 and 2).

Willow rolls (which may also contain reeds) are usually 1'-1'6" in diameter and are constructed of wire netting. A trench 1'6" wide and deep is dug along the bank with a row of stakes on the channel side. Wire netting is stretched across the trench and about 4" coarse gravel dumped onto it forcing it into the trench. On this should be placed layers of sod, willow shoots and reed clumps, until the upper edges of the wire will just meet. The upper edge of the roll should not be more than 2" above water level for a reed roll and 1' above water level for a willow roll.

Willow bundles or 'fascines' have a diameter of 3"-12" and contain willow shoots and sod and are tightly bound around with wire. On cut banks packed fascine crib-work

(Figure 3) can be employed or single fascines or willow rolls can be used (Figure 2). The packed fascine crib-work consists of layers of bundles, secured by stakes. The spaces between the bundles are filled with dirt and another layer is added on top. Another technique is the use of willow mattresses made from 4'-6' willow switches. These are held down by stakes and braided or wired together and covered lightly with dirt. These techniques can be adapted to the local conditions, vegetation and expertise available.

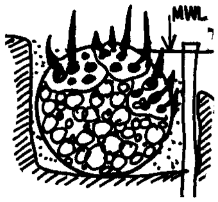


Figure 1. Willow roll formed of tightly bound bundle of willow shoots, sod and coarse gravel, in wire mesh roll.

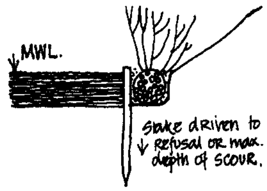


Figure 2. Willow roll staked against cut bank and throwing out new shoots.

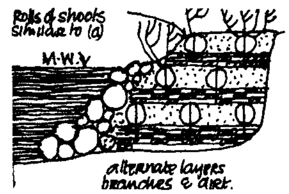


Figure 3. Crib-work of willow rolls or bundles backfilled with soil and coarse gravel.

IV. THE CREATION OF STILL SHALLOWS OR REED BEDS

Most natural stream channels contain still shallow areas and beds of reeds that are important to the biological community. These will gradually develop in a restored stream but the development can be hastened by artificial means. Reed or willow berms can be constructed by throwing up a riprap and earth embankment to just below the mean water level which is then planted with reed roots and/or willow cuttings as shown in Figure 4. These would be constructed in a wide section of the restored channel.

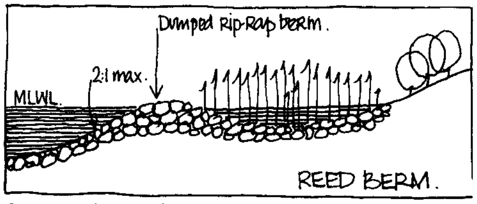


Figure 4. Reed or willow berms creating areas of still shallow water in a diversion channel.

V. THE CREATION OF RIFFLES AND POOLS

Most natural stream channels will include riffles and natural jetties which result in variation in the depth of water. The recreation of a natural stream habitat can be accelerated by the creation of certified jetties and riffles. These must be carefully stabilized with natural vegetation to insure their permanence. Various combinations of gabions, gabion mattresses, riprap, timber and natural materials can be used in the construction of jetties and riffles. Figure 6 shows a simple willow jetty constructed of riprap, crushed rock and soil.

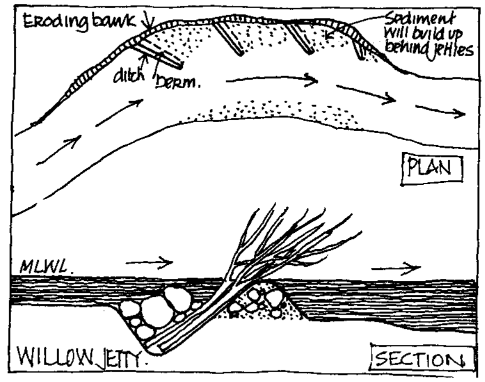


Figure 5. Willow jetties used here to stabilize an eroding stream bank will cause variation in water depth.

VI. REMOVAL

Temporary diversions must be removed and the affected area regraded and revegetated to the same standards as other disturbed areas of the site. If the removal of the diversion will cause downstream sedimentation ponds or other treatment facilities to be overtopped or fail, they must be modified or removed.

REFERENCE

(1) Tourbier, J. and Westmacott, R., 1974, "Water Resources Protection Measures in Land Development - A Handbook," University of Delaware, Water Resources Center, Newark, DE.

PROBLEM & PURPOSE

It has been shown that one of the most important factors in reestablishing vegetation on restored mine sites is replacing the topsoil. The removal, storage and replacement of topsoil are therefore emphasized in the performance controls of the new Regulations. Because much of the land planned for coal extraction, particularly in Appalachia is forested, the clearance of vegetation and grubbing of stumps is necessary before topsoil can be removed.

In some areas, including most of Appalachia, topsoil is thin. The Regulations do not specify the thickness of soil which must be restored but in areas where topsoil is thin, 6" of soil material, including whatever topsoil is present and the remainder unconsolidated material beneath has to be removed and treated as topsoil [816.22(c)].

In situations where existing topsoil is thin the overburden analysis, for which small operators can receive assistance under the Small Operators Assistance Program, may reveal suitable topsoil substitutes which may be approved by the RA. The operator will probably find that the selective handling required to place this material on top of regraded areas pays off in greatly improved establishment of vegetation.

APPLICABILITY

Applicable to all surface mining sites. There are special performance standards for topsoil removal and reconstruction on prime farmland (Part 823). On sites which have been forested, removal of topsoil with a scraper may not be possible. In these situations, especially on steep terrain, a tracked front-end loader may have to be used to grub stumps and remove topsoil. But this operation requires loading the topsoil for haulage to the distribution site, whereas a scraper can dig, load, haul and redistribute all in one operation, as well as maintain its own haul road. Therefore, these operations can be costly on heavily forested sites in steep terrain. The Regulations also contain a requirement that the minimum practicable area is disturbed at one time (disturbance includes removal of vegetation and topsoil) [816.45(b)(1)]. Requirements of the Regulations, that reclamation should be as contemporaneous as possible and that topsoil should only be stockpiled if immediate redistribution is not practical, make it imperative that vegetation removal and topsoil removal are planned and phased very carefully with other operations on all sites

REVELANT SECTIONS OF THE REGULATIONS

I. CLEARANCE OF VEGETATION

Few specific references are made to the clearance of vegetation in the Regulations. The clearance of vegetation is required specifically in the Regulations only to enable topsoil to be stripped [816.22]. This has the following implications:

1. The clearance of vegetation will have to include grubbing of tree roots to enable topsoil to be removed.
2. Section 816.45(b)(1) requires that the smallest practicable area is disturbed at any one time during the mining operation. Section 816.23(a) requires the topsoil to be stored only when it is impracticable to redistribute promptly and this is in the operator's interest to avoid double handling. Therefore, the topsoil should be removed in a phased sequence, and this should also apply to vegetation clearance and grubbing. The "disturbed area" as defined in 701.5 includes areas from which vegetation has been cleared. Section 816.42 which requires that runoff from disturbed areas must pass through a sedimentation pond also applies to areas cleared of vegetation. The clearance of vegetation should be phased with topsoil removal to disturb the smallest practicable area of the site at any one time.
3. The performance standards do not specify what the operator should do with the cleared vegetation. Many operators in the past found in satisfactory to windrow vegetation below areas of fill as a sediment control measure. However, these windrows tend to interfere with other requirements of the Regulations and the operator would be advised to chip all cleared slash (chips can be used for mulch) and to burn any unsaleable logs which cannot be used on-site for erosion control structures, etc.
4. Other specific references in the performance standards to the clearance of vegetation include restricting the clearance of vegetation for road construction to the width necessary for road and ditch construction only [816.153(a)(3)].

II. TOPSOIL REMOVAL

Section 779.21 (Soil Resources Information) requires that the applicant submits a soil survey which must include:

1. A map delineating different soils;
2. Soil identification;
3. Soil description; and
4. Present and potential productivity of existing soils.

Where the applicant wishes to use selected overburden material as a topsoil substitute he must also submit the results of certain analyses required under Section 816.22(e). The RA may approve the use of selected overburden as a substitute for topsoil if it is determined that the substitute material is equal to or more suitable for sustaining vegetation than the topsoil which is available. The determination will depend on the results of chemical and physical analyses of overburden and topsoil, which must be carried out by a certified laboratory approved by the RA. The details of the tests required are included in Section 816.22(e). They include determination of pH, alkalinity, phosphorus, potassium, texture and may also include other analyses. Under the Small Operator Assistance Program, the RA will pay for these overburden analyses by a certified lab.

The application must include: 1. a narrative explaining the topsoil handling and storage [780.11(b)(2)]; and 2. topsoil storage areas must be indicated on the operations plan [780.(b)(5)]. It is also required that this plan be prepared by or under the direction of a professional qualified engineer [780.14(c)].

The performance standards contain very specific requirements for removing, storing and distributing topsoil [816.21-816.25]. Some of these are discussed in the next section below. Topsoiling has been shown to be one of the most effective means of establishing vegetation on restored mined sites. However most of the potential mine land in Appalachia has shallow infertile soils and much of it is also steeply sloping. Topsoil in this area is often thin and it may be necessary for operators to carry out an overburden analysis to check whether there are suitable topsoil substitutes in the overburden. The performance standards for topsoil handling contain specific requirements for the use of topsoil substitutes [816.22(e)]. It should be noted that there are special provisions for the removal and handling of topsoil in the case of mining operations on prime farmland. These may be found in Part 823 (Special Permanent Program Performance Standards - Operations in Prime Farmland). One of the most stringent requirements of this Part is that the minimum depth of soil "to be reconstructed for

REVELANT SECTIONS OF THE REGULATIONS (CONTINUED)

prime farmland shall be 48 inches." For further details on application requirements and performance standards for mining on prime farmland, the operator should refer to Part 823.

DISCUSSION & DESIGN GUIDELINES

I. REMOVAL OF VEGETATION

It is in the interest of the operator to dispose of saleable timber but the actual clearance technique will depend on terrain, the equipment available and various other factors. The practice of windrowing slash and debris around the site is generally not advisable particularly where these may be buried in spoil heaps and cause instability. It is preferable that all slash be chipped, and the chips used for mulch on the restored area. Disposal of stumps, which are difficult to burn, should be in a designated disposal site in the permit area [816.89]. An example of efficient utilization of cleared vegetation is the Jones and Brague Mining Company who chip the vegetation on their sites and ship it to a Masonite plant at Towanda, PA. The company uses a chipper manufactured by Morbark Industries which accepts trunks up to 22" in diameter. (2)

II. TOPSOIL REMOVAL

Section 816.22 specifies that topsoil should be removed prior to any disturbance of the site other than clearance of vegetation. Disturbance includes drilling, blasting or any form of mining. Topsoil must be removed in a separate layer. When topsoil is less than 6" thick, a 6" layer of material including whatever topsoil is available should be removed and treated as topsoil. If the total unconsolidated material is less than 6", whatever is available should be removed and treated as topsoil [816.22(c)]. In some cases the RA may decide that to ensure soil productivity consistent with the approved post-mining land use, it is necessary to remove and redistribute the subsoil separately from the topsoil. But unless the RA determines this, it is not required.

Where topsoil substitutes are to be used (this has already been discussed earlier on the sheet), the substitute material shall be removed and segregated (and stored, if immediate redistribution is not feasible, in the same way as topsoil).

The operator may have to limit either the size of the area in which topsoil is removed or the timing of redistribution if either operation results in serious erosion or if wet conditions are resulting in damage to topsoil, uneven distribution, or are causing erosion [816.22(f)].

The difficulty of using scrapers for topsoil removal have already been mentioned, particularly where a comparatively long haul is required and immediate redistribution is possible on a regraded area. (Figure 1)

III. TOPSOIL STORAGE

Topsoil, subsoil (if required), and any topsoil substitute should only be stockpiled where it is impractical to redistribute it promptly on regraded areas [816.23(a)]. Stockpiles must be placed on a stable area and protected from erosion either by water or

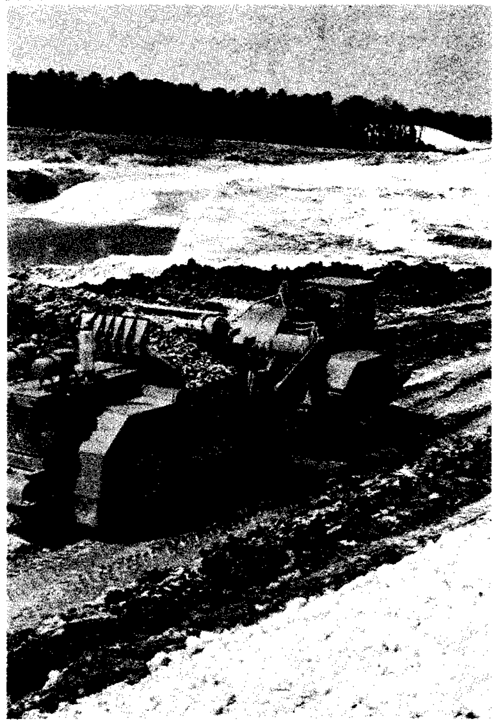


Figure 1

wind. This is best achieved in most cases with a quick-growing cover crop which should be seeded or planted during first "normal period" after placing the stockpile (see Sheet 7:11) [816.23(b)(1)]. The performance standards require that the stockpiles should not be removed until the topsoil is required for redistribution on a regraded area. Topsoil removal, segregation, storage and redistribution is also specifically required for certain operations by the performance standards, including the construction of stream diversions [816.43(f)(5)], the disposal of excess spoil [816.71(c)], and the construction of roads Classes I, II, and III [816.152(e), 816.162(e), 816.172(e)].

The regulations do not specify any design for topsoil stockpiles. Sometimes it is recommended that topsoil is not piled in excess of 8'-10' deep, and should preferably be placed in fairly narrow banks. This enables aerobic bacteria in the soil to survive. Some operators have found it useful to use topsoil stockpiles on the edge of the site to screen the operation from the public road or nearby residences. This is commonly practiced by contractors on N.C.B. sites in Great Britain.

REFERENCE

(1) Plass, W.T., Mar-Apr 1978, "Reclamation of Coal Mined Land in Appalachia," Journal of Soil & Water Conservation.
(2) Davis, H., Dec 1978, "Jones & Brague has been Recognized for Excellence of its Reclamation," Coal Age, pp. 94-97.
(3) Smith, R.M., Summer 1973, "Choosing Topsoil to Fit the Needs," Green Lands Quarterly, WV Surface Mining and Reclamation Association.

PROBLEM & PURPOSE

In surface mining operations, it is necessary to find somewhere to put the spoil from the initial cut to provide the working space in the pit. If the swell or bulking factor of the overburden exceeds the volume of coal to be taken out, more spoil may have to be removed from the pit as mining progresses to maintain working space in the pit. Therefore, at the end of the mining operation there will tend to be a final void and somewhere else on the site a dump or dumps of spoil. This spoil can, of course, be used to fill the final void but this requires double handling. Most operators therefore would prefer to place the box-cut spoils permanently and not have to transport it back to fill the pit. However, the requirements of the Regulations do require the elimination of all highwalls, spoil piles and depressions and that all disturbed areas be returned to their "approximate original contour" [816.101(b)]

APPLICABILITY

Applicable to all surface coal mine operations, but the problem of temporary spoil dumps is most serious in the following situations:

1. Open pit mines where overburden is thick. In order to provide sufficient working space in deep pits, the amount of spoil removed from the pit is very large and this must be stockpiled close to the pit for ease of backfilling. In these cases the problem is made worse if the bulking factor is large, making it necessary to take spoil out of the pit continuously to maintain its size.
2. Sites in steep terrain often have few suitable locations for temporary spoil dumps which will not cause serious instability, landslips and erosion. Often the only suitable locations involve the operator in long costly hauls.
3. Sites where the overburden contains large quantities of acid-forming materials. In these cases the performance controls require that material is buried within 30 days after it is first exposed. This means that careful selection of overburden materials from the box-cut spoils is necessary.

RELEVANT SECTIONS OF THE REGULATIONS

The Regulations are clear that sites must be returned to "approximate original contour," and that "spoil shall be transported, backfilled, compacted and graded to eliminate all highwalls, spoil piles and depressions" [816.101(b)(1)]. Although there may be a certain amount of freedom in interpreting the "approximate original contour" requirement, leaving the final cut open and restoring spoil dumps is clearly not sufficient to meet the requirements of the performance standards.

In the supplementary information to the Regulations it is stated that stockpiling and transportation of box-cut spoils to the final cut is encouraged. The use of the word "encouraged" appears to conflict with the specific requirements of the performance standards to eliminate all spoil dumps. It has been anticipated that if the post-mining graded slopes "approximate the general nature of the pre-mining topography" [816.102(a)] that a slight depression in the area of the final cut and a slight rise in the area of the temporary spoil dump would be allowed, provided that the other requirements of the performance standards are met.

Box-cut spoil requires expensive double handling. In some cases it may be appropriate, in the proposed post-mining use of the land, to have a water impoundment or other area of low terrain on the location of the final cut but this will require specific approval of the RA and may prolong the application process [816.49].

On sites with a high swell or bulking factor and thick overburden [816.105] the operator is not any worse off, as spoil in excess of that required to achieve approximate original contour at restoration may be disposed or permanently [816.71-816.74]. In fact, this may be an advantage in that the original box-cut spoil may be disposed of permanently and restored close to the cut and any temporary spoil piles which are needed, placed near the final cut so reducing handling costs.

Although there is not a Section of the performance standards dealing specifically with temporary spoil and the treatment of temporary spoil dumps, specific reference is made in the permit application requirements in Part 780 (Permit application - Minimum requirements for reclamation and operations plan). This must include [780.11(b)] "a narrative explaining the construction... and removal of overburden storage areas and structures." This must be accompanied by maps and plans [780.14(b)(5)] of each spoil storage area and it is specified [780.14(c)] that these maps or plans be prepared by or under the direction of a qualified registered professional engineer. It should also be noted that this refers to "storage areas", which implies the temporary nature of the piles. Permanent disposal of excess spoil is dealt with separately in this Section [780.14(b)(11) and 780.14(c)(2)] and specifically in the performance standards in Sections 816.71 - 816.74.

The amount of latitude that the RA will permit in interpreting the "approximate original contour" requirements of the performance standards will become clearer as time goes on. It appears, however, that temporary stockpiling of spoil is one of the operations for which premining planning is required as part of the application procedure, but to which only general performance standards apply, leaving it up to the discretion of the RA to determine to what extent it is necessary to the operator to "transport box-cut spoil to the final cut" to achieve the "approximate original contour." Nevertheless it is quite clear in the performance standards that grading must "eliminate all highwalls, spoil piles and depressions" [816.101(b)(1)].

DISCUSSION & DESIGN GUIDELINES

I. PLACEMENT OF TEMPORARY SPOIL PILES

Temporary spoil piles should be placed to avoid problems of instability. The operator will wish to place temporary spoil dumps so as to minimize handling costs. For instance this might involve placement close to the final pit so that the spoil can be pushed into the pit rather than a load/haul operation. With these considerations in mind, the operator should avoid steep areas (if the slope is in excess of 1v:2.8h special measures may be required to stabilize the spoil mass) and also wet areas containing seeps or springs which may result in instability.

Topsoil must be removed from areas on which temporary spoil piles are to be placed, in the same manner as for all other areas of the site to be disturbed [816.22(b)].

II. THE PROTECTION OF TEMPORARY SPOIL PILES FROM EROSION

It is emphasized that temporary spoil piles, as part of the permit area, are subject to the various requirements of the performance standards which require removal of topsoil from the disposal area and the control of sediment. All surface drainage from the disturbed area (which includes temporary spoil piles)...shall be passed through a sedimentation pond. As temporary spoil heaps may remain in position for the whole life of a surface mine site. It is important that they should be placed on a stable site, graded to a stable slope and be protected from erosion by a vegetative cover crop. (see Sheet 7:11) In order to achieve this some topsoil may be required. Large temporary spoil piles with long slopes are especially vulnerable to erosion and should be terraced (see Sheet 7:2).

Generally, the design and configuration of these terraces should be similar to those for excess spoil disposal facilities (Sheet 6:8). However, as all temporary spoil heaps must be designed by or under the supervision of a registered professional engineer, guidelines for large spoil heaps are not included on this sheet.

III. STABILITY OF TEMPORARY SPOIL PILES IN STEEP TERRAIN

The requirement that temporary spoil piles be designed by a professional engineer will reduce problems of instability [780.14(b)]. However, some general notes are included here on the principal causes of slides. They are based largely on a report by the State of Kentucky, Department of Natural Resources and Environmental Protection (1). Slides will tend to occur when there is a high shear stress and a low shear strength and will be a result of 4 main practices.

1. The removal of lateral support may be caused by the action of streams, weathering (wetting, drying, swelling, shrinking), frost action or subsidence.
2. The removal of underlying support may be caused by the undercutting of streams, frost action or underground mining.
3. Surcharge may result from excess fill on the pile or be due to heavy rain or snow resulting in saturation.
4. Lateral pressure due to water or ice may also cause instability.

Kimball (1) suggests that the sequence of events for the initiation of slides in stacked spoil is:

a. stacking too much spoil on an unstable site in a loose and generally wet condition;
b. initial slumping of the spoil caused by overloading or failure in spoil material;
c. a sudden downpour of rain, resulting in small slides and then:
   i. piling additional spoil on the slip plain of smaller slides;
   ii. development of tension cracks;
   iii. percolation of surface water into tension cracks, leading to the vertical displacement along cracks;
   iv. slumping due to decrease in shear strength along the slip plain results in major slides.

From the above, it is apparent that the principles in ensuring the stability of temporary spoil piles include the following:

1. Selection of a stable, gently sloping site;
2. Removal of topsoil and any organic matter from the disposal site and if necessary a key cut;
3. Spoil material should not be placed when too wet;
4. Placement should be carried out in such a way to ensure good compaction;
5. Attention should be paid to drainage of the pile particularly the diversion of surface water around the base of the pile.

IV. ACID AND TOXIC-FORMING SPOIL IN TEMPORARY SPOIL PILES

If spoil is acid or toxic-forming, as identified and analyzed in the geology description [779.14], it should not be stockpiled but should be buried within 30 days after it is first exposed on the mine site as required in Section 816.48(c).

Temporary storage of acid-forming or toxic-forming spoil may be approved by the RA if it is not feasible to bury or treat within 30 days and if it will not result in any water pollution risks; however, this too must be buried at the earliest possible opportunity.

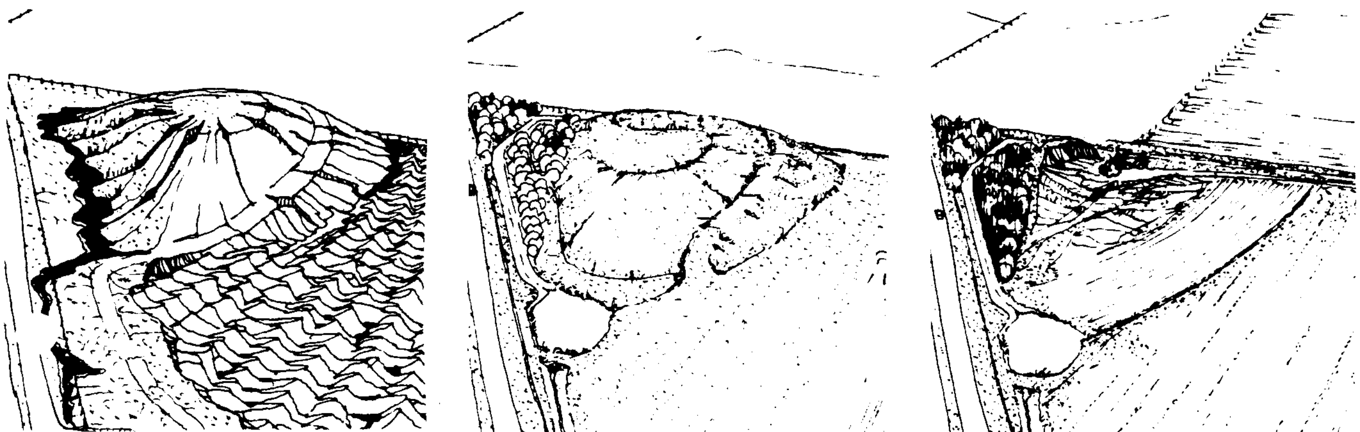


Figure 3. Temporary Spoil Piles
a. Uncontrolled b. Controlled c. Being Removed

REFERENCE

(1) Kimball, L.R., 1975, "Slope Stability, Volume 1, Report and Field Book," Department of Natural Resources and Environmental Protection, KY.

PROBLEM & PURPOSE

1. Disposal of excess spoil in surface mine operations may be necessary for various reasons. This sheet deals with this operation on sites in steep terrain as often found in Appalachia. Here the need for disposal of excess spoil is often created by mountain top removal operations.
2. This sheet does not cover the temporary stockpiling of box-cut spoil (see Sheet 6:7). The techniques described on this sheet are for permanent placement of excess spoil. Spoil may be in excess due to thick overburden and a high bulking factor or because the RA has allowed a variance from the "approximate original contour" requirement of the performance standards for regrading.
3. The methods covered on this sheet do not apply to "durable rock fills" which are covered separately in the performance standards [816.74].

APPLICABILITY

This sheet applies only to sites in mountainous or steeply rolling terrain. The Regulations require that all disturbed areas shall be returned to their "approximate original contour" [816.101]. However there are provisions for obtaining variances from this requirement in cases of mountaintop removal [Section 785.14] and in some other situations involving steep slope mining [Section 785.16]. If these variances are granted, there will be a need to dispose of large quantities of excess spoil.

On sites with thick overburden and a high bulking factor [Section 816.105] it will not be possible to regrade to the approximate original contour. In these cases, Head-of-Hollow or Valley fills may be used. The operator will probably wish to dispose of this box-cut spoil permanently in a Head-of-Hollow or Valley fill and create temporary spoil dumps as the need arises to maintain working space in the pit. In this way the haul distance for transporting spoil to fill the final pit is minimized.

REVELANT SECTIONS OF THE REGULATIONS

Because this sheet concentrates on the design requirements of the Regulations for constructing Head-of-Hollow or Valley fills, the Sections of the Regulations containing design specifications are covered under "Guidelines" below.

It is emphasized that the design of "Valley and Head-of-Hollow fills" must be certified by a professional engineer. It is stated in the Regulations [780.14(c)(2)] that spoil disposal facilities, maps, plans, and cross sections may only be prepared by a registered professional engineer. Section 780.35 specifies the application requirements for the disposal of excess spoil. It should be noted that the Regulations are generally more stringent for spoils larger than 1,000,000 cubic yards but on this sheet we concentrate on fills of less than 1,000,000 cubic yards [816.72(b)(3)].

The Regulations contain general requirements [816.71] covering the disposal of excess spoil. These include the placement of spoil in a manner to prevent degradation of surface and ground water and to insure the stability of the fill.

The Regulations distinguish between "Valley fills and "Head-of-Hollow fills". The Valley fills do not completely fill the valley between the ridge lines which is a requirement of Head-of-Hollow fills. The Regulations covering Valley fills [816.72] also apply to Head-of-Hollow but there are additional performance standards for Head-of-Hollow fill [816.73].

DISCUSSION & DESIGN GUIDELINES

In March 1978, EPA published an assessment by Skelly and Loy comparing the methods of Head-of-Hollow fill in West Virginia and Kentucky. The report included the consultants recommendations. The Regulations are very similar to these recommendations and much of the information and data for the drawings on this sheet are derived from that report (1).

I. SITE SELECTION

Applications must include a geotechnical investigation and a stability analysis [780.35]. Section 816.71(e) requires that disposal areas be located on the most moderate slopes available, and that sites with few seeps or drainage channels will reduce the amount of under-drainage required. When the average slope of the disposal site exceeds 1v:2.8h (36%), keyway cuts or rock-toe buttresses are required [816.71(i)]. It is noted that Skelly and Loy's recommendation is that stabilizing structures should be utilized when "the slope of the hollow at the proposed toe of the fill exceeds 10°," 1v:5.7h (1). Section 816.71(h)(1) does not specify the size of keyway cuts or rock toe buttresses and only requires that the size be based on a stability analysis. In cases where the toe of the spoil rests on a downslope, the details shown in Figures 1 and 2 should be taken only as guidelines, and site specific designs must be carried out by the professional engineer.

II. PREPARATION

Section 816.71(c) requires that vegetative and organic matter be removed from the disposal area and that the topsoil be removed, stored and replaced [816.21-816.25]. The RA may allow organic material to be used as a mulch to control soil erosion but the practice of windrowing cleared vegetation at the toe of the slope is not specifically mentioned and probably would not be allowed by the RA. Skelly and Loy's assessment of Head-of-Hollow fill practices points out that carelessly placed windrows may be buried by fill material and result in instability of the fill mass. (Special performance standards for steep slopes [Part 826] forbid burying woody materials in the back-filled areas.)

Specific regulations for the construction of sediment basins with Valley or Head-of-Hollow fills are included in Sections 816.71-816.73 but it is specified that leachate or the runoff must not exceed the effluent limitations in Section 816.42. That Section requires that "any surface drainage from the disturbed area . . . shall be passed through a sedimentation pond before leaving the permit area" [816.42(a)(1)]. Skelly and Loy recommend that "sediment control ponds must be constructed near the proposed toe of the fill" (1).

III. DESIGN

Section 816.71(d) requires that diversion ditches conform to the requirements of Section 816.43. In addition to the main underdrain, lateral drains must be built to any springs, water courses or seeps. The main underdrain and these laterals must be protected with a filter system. The Regulations do not specify the minimum size of lateral drains. The main underdrain may be made of durable non-acid rock (no more than 10% may be less than 12 inches in size and none larger than 25% of the drain width). The width and height of underdrains for fills of less than 1,000,000 cubic yards are shown in Table 1.

Table 1
Minimum Dimensions of Underdrain

Type of Fill	Minimum Size of Drain (feet) Width	Height
Sand Stone	10	4
Shale	16	8

Note - these dimensions are the same in the case of shale as Skelly and Loy's recommendations (1).

Section 816.71(g) permits no depressions or impoundments on the fill mass. However, an exception is made for Head-of-Hollow fills. A "drainage pocket" [816.73(e)(3)] is allowed at the head of the fill to intercept runoff and discharge it through or over the rock chimney drain. Skelly and Loy's report notes that surge ponds located at the head of the rock core in West Virginia's fills, though not intended to retain the water, did so with resultant instability problems when water saturated the fill.

The design criteria for the fill mass as shown in Figure 1 apply both to Valley and Head-of-Hollow fills. But in the case of Head-of-Hollow fills, which must completely fill the disposal site to the elevation of the ridge line, the surface drainage of the fill may be directed inwards to a rock chimney drain as shown in Figure 2 [816.73(a)].

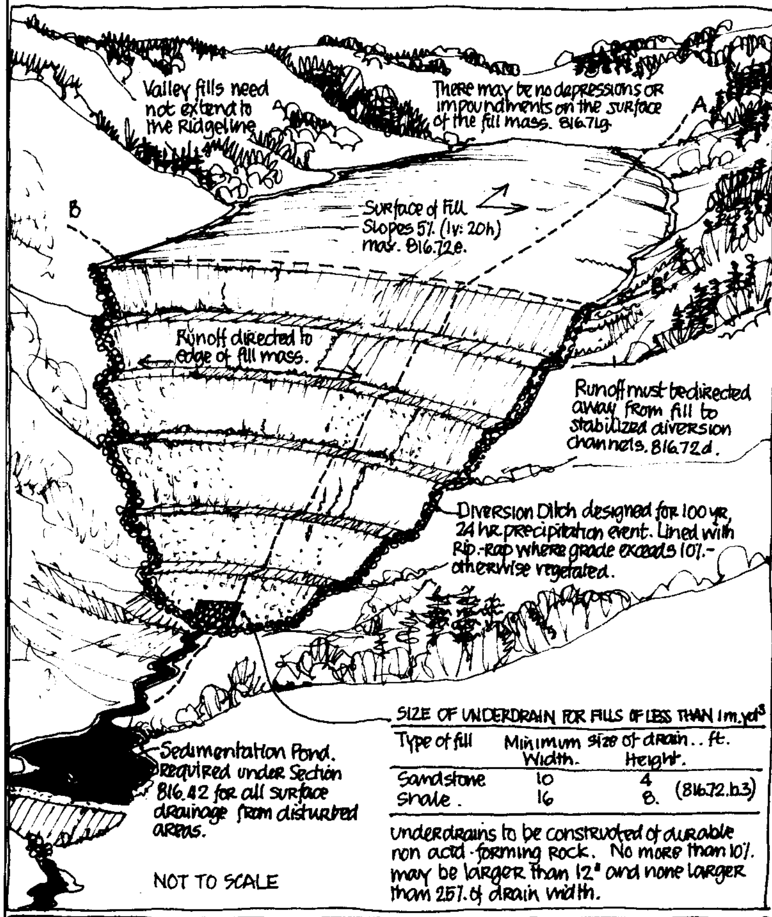
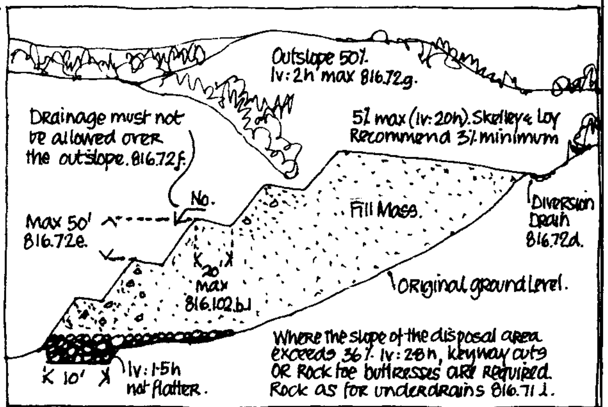
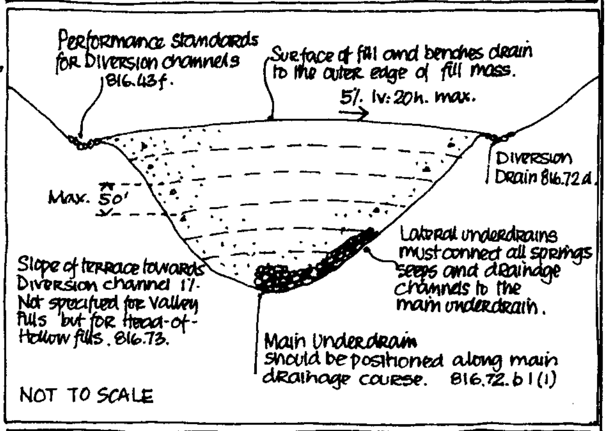


Figure 1 DESIGN REQUIREMENTS FOR VALLEY FILLS. Section 816.72. The surface of the fill must be sloped towards the edges where runoff is collected in protected diversion channels. Terraces must also direct water off the fill to these channels.



DESIGN REQUIREMENTS FOR VALLEY FILLS Section AA' NOT TO SCALE



DESIGN REQUIREMENTS FOR VALLEY FILLS. Section BB' Skelley and Loy Recommend that diversion ditches are located on undisturbed ground & Rip-Rapped.

IV. PLACEMENT

The Regulations require that placement is carried out in such a way as to ensure a long-term static safety factor of 1.5. The requirement that spoil be placed in horizontal lifts of 4 feet or less [816.72(c)] and concurrently compacted makes the placement procedure as used previously in Kentucky unacceptable. Dumping spoil over the outslope of a fill tends to result in the segregation of fill, the large coarse materials at the bottom forming a "natural" French drain system. The requirement that spoil be placed in horizontal lifts of 4 feet or less and concurrently compacted prevents formation of a natural under-drainage system but the increased stability which results from controlled placement and compaction usually outweighs this disadvantage. Placement of spoil in 4-feet lifts was already required by West Virginia law. During the placement process the fill must be inspected at quarterly intervals at least and at certain stages, by a registered engineer or a professional who must submit a certified report. Operators are not permitted to dispose of coal processing waste in Head-of-Hollow or Valley fills.

V. REVEGETATION

Each lift of both Valley and Head-of-Hollow fills should be vegetated immediately upon completion. This was not feasible with the method previously used in Kentucky, and it is an advantage of placing spoil in horizontal lifts that revegetation can be carried out

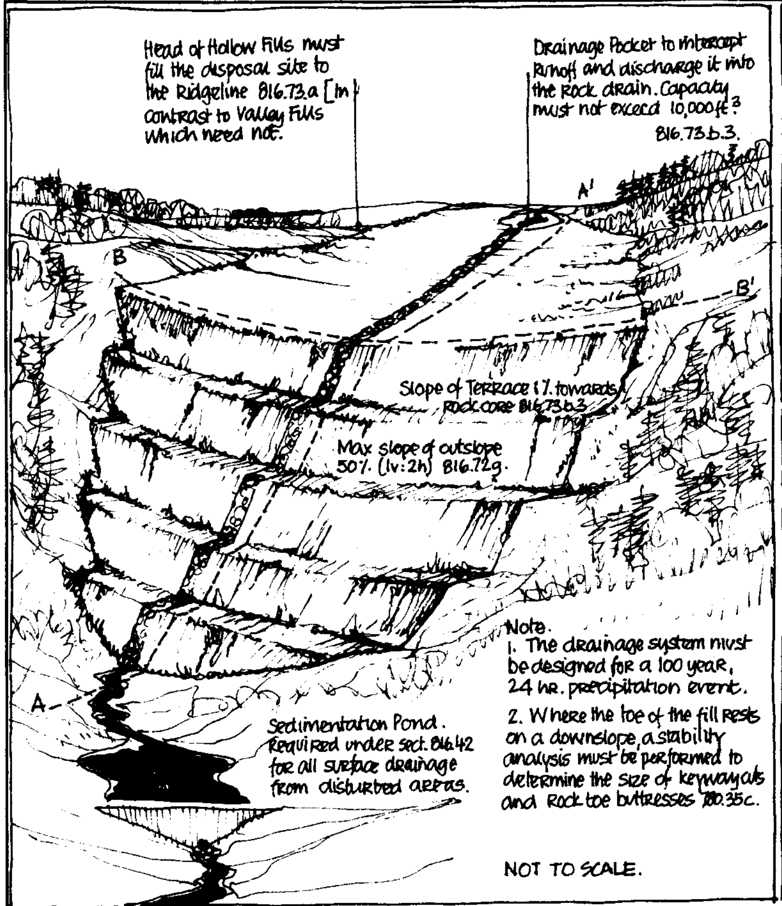
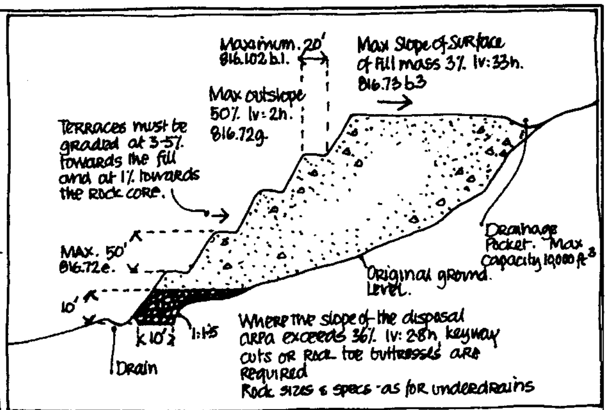
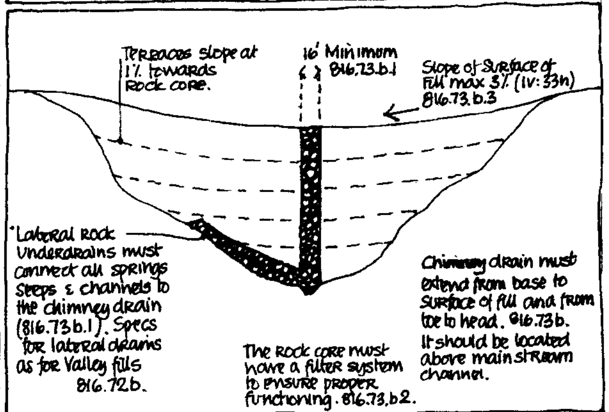


Figure 2 DESIGN REQUIREMENTS FOR HEAD-OF-HOLLOW FILLS Section 816.73 The surface of the fill and terraces should slope inwards to a central chimney drain. The fill must entirely fill the disposal area to the elevation of the low point of the ridge. 816.73.a.



DESIGN REQUIREMENTS FOR HEAD-OF-HOLLOW FILLS. NOT TO SCALE
SECTION AA' Note: This section does not cut the Chimney Drain



DESIGN REQUIREMENTS FOR HEAD-OF-HOLLOW FILLS. NOT TO SCALE
SECTION BB'

concurrently.

Section 816.71(c) requires replacement of topsoil. This will be difficult on outslopes of 1v:2h but can be achieved by dumping soil from the terrace and then spreading using a dozer up and down the slope. The dozer's cleat depressions help to minimize erosion and to trap seed. Hydroseeders are the most effective method of applying seed and mulch (Sheet 7:9 and Sheet 7:14).

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PROBLEM & PURPOSE

From the operator's point of view, keeping the pit free of water is important to minimize delays and to improve working condition. Water which accumulates in the pit is likely to be heavily polluted with sediment or dissolved salts or both. Therefore, pit dewatering is likely to result in heavy pollution loads in the receiving waters. In addition, if the coal lies below the groundwater, pumping to keep the pit dry may lower the water table which may reduce the yield of wells, springs and seeps. There are provisions in the Regulations for diverting surface water around disturbed areas so that it will not contribute to the problem of dewatering the pit. Water may enter the pit from various sources:

1. Groundwater: if coal is below the water table the flow of groundwater into the pit may be more or less continuous and consequently the pit may require continuous dewatering.
2. Abandoned deep mine workings: frequently, abandoned deep mine workings are encourntered during surface mining and may result in sudden flow of large volumes of water into the pit. This water may be seriously polluted.
3. Rainfall and runoff: heavy rainfall and runoff will result in the accumulation of quantities of water in the pit and inevitably this will carry heavy sediment loads.

Whatever the source, the water in the pit bottom will come into contact with coal and other materials which frequently are high in pyrite and other toxic-forming or acid-forming materials. Therefore pit water is usually a serious pollution hazard and, in order to minimize the need for the treatment of drainage water, the operator should make every effort possible to divert water before it flows into the pit as it is likely that water pumped from the pit will need some form of treatment before it is discharged from the permit area.

When water comes into contact with pyrite, which is iron sulfide ($Fe\ S_2$) in the presence of oxygen, ferric sulfate ($FeSO_4$) and sulfuric acid are formed. The reaction and the speed of the reaction depends partly on the presence of certain bacteria. Unfortunately pyrite occurs naturally and in close proximity to coal seams in many coal mining areas particularly in the Northern Appalachians. Mining exposes quantities of pyritic materials to this oxidation process. Preventing oxygen and water coming into contact with pyritic materials therefore is usually the approach taken to controlling acid mine drainage (AMD) and only if this is ineffective, is treatment of acid water considered. The problem in the past has been that, due to the method of removal of overburden, acid-forming materials tended to end up on top of spoil heaps where they were exposed both to oxygen and to the leaching action and runoff of water. Instability of these spoil heaps also tended to expose fresh acid-forming materials continuously to weathering. AMD problems are serious in regions where there is a high content of pyrite in coal seams and in overburden strata. The states of West Virginia and Pennsylvania identified acid mine drainage as their worst water pollution problem. In fact AMD is considerably worse in the northern 1/3 of the Appalachian coal field than in the southern 2/3. This is partly due to the fact that there is more coal mined in the northern Appalachia than in the south but the amount of sulfuritic material exposed for each ton of coal mined in the north may be greater than in the south (21). See Figure 1 in section on Applicability.

It is estimated that in the Appalachian region 6,000 tons of sulfuric acid is being produced daily through the oxidation of pyrite and that the acid drainage from strip mines accounts for about 15% of the total acid production. Note that this was in 1971 (4).

Another study found that acid produced in Appalachian area coal mines (1969) was the greatest from abandoned deep mines (53%). Active underground mines produced 19% and abandoned surface mines only 11% (7). The pattern of acid discharge is erratic. Stream damage may be caused by continuous acid discharges caused usually at low and moderate levels but also by extremely high discharges caused by dewatering of mines during periods of high precipitation which often causes dramatic stream damage (21). The low pH resulting from acid mine drainage may not be a problem in itself. Low pH does make certain heavy metals excessively available to plants and cause toxicity. Manganese and aluminum are two cases. Other heavy metals in toxic amounts may also be found in acid mine water and certain metals are found associated with a high suspended solid concentration often associated with acid mine drainage. Fe, Zn and Ni were generally found to be more abundant in fine sediment in mine runoff (19). There is considerable work in progress to try to assess the mobilization of heavy metals by acid mine water and also their availability to plants (19).

However, extensive neutralization of acid drainage often occurs within the coal regions. In fact Biesecker and George report that acid drainage is most serious in head water streams near active or abandoned mines but that the mixture of alkaline streams with mine drainage waters eventually neutralize all acid streams in Appalachia. Neutralization is usually due to the presence of certain soluble rock minerals, including calcium bicarbonate ($CaCo_3$), which are in sufficient quantities to neutralize drainage water. A problem is that this process increases the total hardness of the water through the addition of calcium and magnesium.

When the acid stream contacts an unpolluted or alkaline stream, it is partly neutralized and the iron begins to precipitate out as ferric hydroxide froming a yellow coating on the streambed, locally known as "yellow boy." As iron, aluminum and manganese are acid soluble, merely neutralizing the water (increasing the pH) will also precipitate these ions but as, is noted by Walmer, this is not as easy as it sounds, as several factors complicate the precipitation. But the approach to solving acid drainage problems is to prevent oxygen and water coming into contact with pyritic materials and treating only as a last resort. Treatment has the advantage of resulting not only in a water with a higher pH, but it also tends to precipitate out some of the heavy metals such as iron, aluminum and manganese.

Even if acid drainage from new surface mining operations can be controlled effectively, the problem of acid drainage from abandoned underground mines and from abandoned surface mines will remain for many years. There is a opportunity for new surface mine operations to reduce some of these problems as part of ongoing surface mining activities: in the case of abandoned underground mines by daylighting and sealing the old working; and in the case of abandoned surface mines by shifting and burying abandoned spoil piles in the working pit.

APPLICABILITY

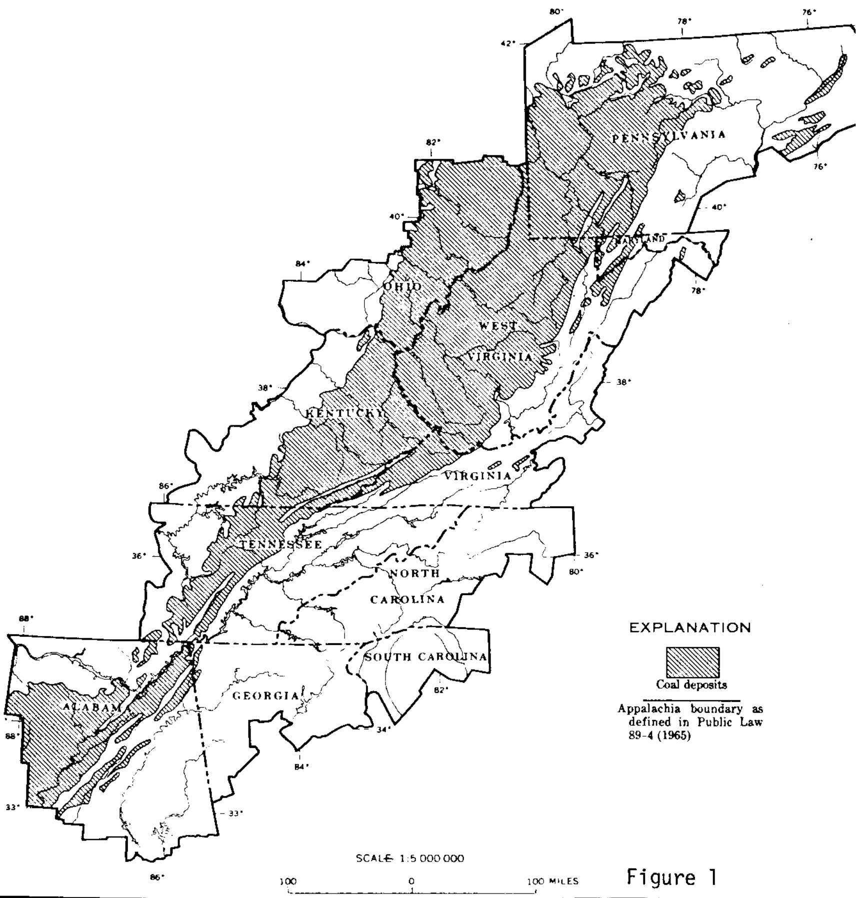

Figure 1

The problem of pit dewatering will apply to all sites. But the impact of dewatering on water pollution and the groundwater hydrology will vary greatly. The groundwater information required as part of the information in the application procedure [Section 779.15] will indicate whether any coal lies below the water table and consequently whether pit dewatering is likely to affect groundwater yield. The "Geology description," also required as part of the application procedure to identify potential acid forming materials in the overburden or pit water in order to control AMD. Therefore, the applicability of these measures depends largely on the hydrologic and geologic characteristics of the area. Measures to control pollution from pit water and AMD apply to all sizes of operation but small mine operators should note that the RA will pay for a laboratory to analyze test borings and to assess the likely impact of operations on the hydrology and water quality of the area.

REVELANT SECTIONS OF THE REGULATIONS

The requirements for a "Geology description" which identifies (amongst other things) potential acid-forming materials in the overburden [Section 779.14] and for groundwater information which identifies the depth of the pit below the surface and the horizontal extent of the water table and aquifers [Section 779.15] have already been mentioned. There are provisions in the Small Operators Assistance Program for results of test borings to be analyzed and assessment of possible hydrologic impact to be made by a certified lab and paid for by the RA.

Section 816.48 specifically addresses the problem of handling acid-forming and toxic-forming materials. This problem is covered in more detail in this Handbook on Sheet 6:10.

Section 816.52 requires surface and groundwater monitoring when surface mining activities may affect groundwater or surface water systems. This would be the case where continuous pumping is required to keep the pit free of groundwater inflow. All discharges from the permit area must meet effluent limitations [816.42] and all drainage from disturbed areas must be passed through a sedimentation pond. If this is not sufficient for drainage water to meet effluent standards "adequate facilities shall be installed, operated and maintained to treat any water discharged from the disturbed area so that it complies with all federal and state regulations." If the pH of the water is below 6.0 an automatic lime feeder is required unless the flow is infrequent in which case the RA may authorize the use of a manual lime feeder [816.42(c)].

DISCUSSION & DESIGN GUIDELINES

The approach to control of acid drainage in the Regulations is based largely upon the selective handling, burying and sealing of acid-forming spoils (see Sheet 6:10), exposed coal seams and old deep mine workings, and generally preventing drainage water from coming into contact with acid-forming spoils. Measures on Sheet 6:5 to divert water around disturbed areas will help considerably, but it will not be feasible to prevent entirely water coming into contact with acid-forming materials. Runoff from all disturbed areas must be passed through a sedimentation pond before leaving the permit area [816.42(a)] which will remove suspended solids. But if the drainage water fails to meet the effluent standards set out in 816.42(a)(7) particularly in respect to pH, which must be within the range of 6.0 to 9.0, some form of treatment will be necessary. An automatic lime feeder or other automatic neutralization process is required by the RA unless the flow of acid water is infrequent and "presents small and infrequent treatment requirements to meet applicable standards." The drainage water from surface mine sites is unlikely to be highly acidic and therefore some of the processes which have been developed for acid mine drainage originating from underground mines are inappropriate to the mildly acidic water from surface mines. These include reverse osmosis and other elaborate treatment techniques. Although it may be necessary to provide some settling pond in which insoluble salts can settle after neutralization, the disposal of acid brines or brine sludge which results from the neutralization process of strongly acid mine waters, will generally be unnecessary.

In the cases where the RA permits manual treatment and the water can be easily impounded, it may be possible to spread lime manually from bags onto the surface of the impounded water. However lime is not readily soluble in water and some form of mixing must be applied to obtain satisfactory utilization of the lime. This is most easily accomplished by installing a pump at one end of the pond but there may be a problem on some mining sites where no electrical outlets are available at the pond site. After treatment the treated water should be transferred to a settling basin to remove the suspended solids and sludge prior to discharge.

Automatic feeders to dose acid drainage with lime slurry have automatic pH controls and generally use hydrated lime. If limestone can be used in treatment plants instead of lime significant savings can occur, but there is a drawback in that limestone has a slow reaction rate and often a coating of iron hydroxide forms on the surface of the limestone. The problem of coating can be solved by some sort of abrasive or tumbling action which also breaks off fines and exposes a reactive limestone surface. Tumbling drums are an effective means of treating acid mine drainage in cases where there is enough hydraulic head to power the drum. Limestone is contained in the drum which is driven by a waterwheel. The outside diameter of the waterwheel should be 1.5 times the diameter of the tumbling drum (Figure 2) (15). Tumbling drums are generally most suitable for complete neutralization of mildly acidic mine water in contrast to limestone barriers which are more suitable for partial neutralization of highly acidic waters.

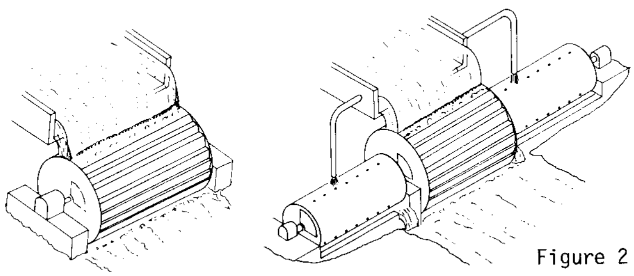

Figure 2

Limestone barriers are probably the most commonly used method of AMD treatment. Experiments carried out by Pearson and McDonald tested the effectiveness of four types of barrier and led to a suggested design procedure for limestone barriers which can be found in reference 11. See also Figure 3.

Some experiments have been done to try to inhibit the activities of bacteria which are responsible for the formation of acid in mine water. Iron oxidizing bacteria (Thiobacillus ferro-oxidans and Thiobacillus thiooxidans) are active in the production of sulfuric acid from iron pyrite, and it has been found that certain detergents and organic acids can inhibit the activity of these bacteria. However, generally the use of these techniques is still in experimental stages and is not sufficiently reliable to justify general use.

Other bacteria are responsible for the breakdown of wastewater constituents and a device called "the rotating biological contactor" utilizes these microorganisms for treatment of acid drainage. This device

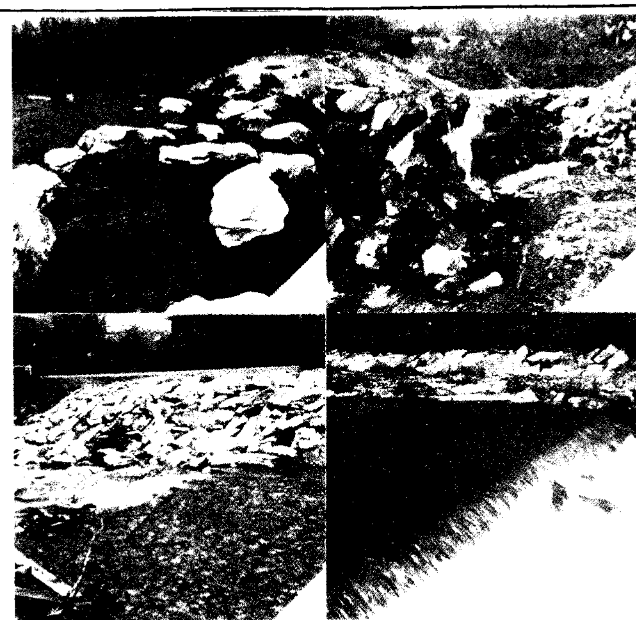

Figure 3. Limestone Barriers Source: (11)

provides a large surface area for the attachment and colonization of the bacteria which oxidize ferrous iron in acid water to an insoluble form which precipitates out. However, this device has a high capital cost and at present is inappropriate for use for small surface mining operations.

It was noted previously that the most effective method of sealing acid-forming spoil from oxidation is to bury it in spoil material and consolidate it. Shumate and Brant (1971) states that "It is unlikely that material buried several feet or more beneath the surface can undergo significant oxidation because of the restriction of oxygen diffusion to these depths" (4). The use of other surface sealants has not been particularly successful. Lime, gypsum, sodium silicate and various rubber latex seals have sometimes been effective. They require repeated application and maintenance and are not recommended for general use. Water barriers can provide an effective seal against oxidation of pyrite, but a safety factor to allow for evaporation is necessary. Also, if things go wrong, sealing acid-forming materials with water may in itself result in serious pollution of surface or groundwater.

Some experiments have been done using irrigation of treated acid mine water to further improve its quality. It was found in one study that acid mine drainage filtering through 40 inches of calcareous soil resulted in a percolate that had a slightly alkaline reaction and was completely devoid of Fe, Al, Mg, Zn & Cu. Even acid soils were effective in improving water although not as effective as calcareous soils (1). The use of acid mine water for irrigation on particularly dry reclamation sites may result in improved quality of vegetation and protection against erosion.

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PROBLEM & PURPOSE

The requirement of 816.100 "that all reclamation, occur as contemporaneously as practicable with mining operations," and the need to minimize double handling, makes it necessary to plan the backfilling operation to occur as part of the task of overburden removal. The way in which backfilling and rough grading are carried out may have a major effect on both groundwater recharge and streamflow. Not only must the spoil be regraded so that it can remain stable but it should be regraded so as to maintain infiltration and percolation of rainfall so as to recharge groundwater sources on which both dry weather streamflow, water supply to springs and seep areas, and the safe yield of springs and wells depend. It may also affect the establishment of an effective vegetation cover, particularly of tree species, as the amount of infiltration will affect the availability of water for plants.

The amount of compaction of the spoil which occurs during regrading will affect the amount of runoff and consequently will affect erosion. Therefore, prior to final grading it may be necessary to pass a ripper over the site to reduce consolidation of rough-graded spoil which may occur during final grading operations, cultivation, etc. (see Sheet 7:3) This process should be carried out along the contour to achieve an optimum level of infiltration and to minimize erosion.

The type of machinery used to shift overburden and to carry out rough grading has an important impact on the infiltration of surface water into the ground. "Where scrapers have dumped spoil and the heavy tires compacted the spoil, the infiltration may be one or two orders of magnitude less than in cases where a dragline dumps the spoils" (13). Therefore, it may be in cases where rough grading is carried out on spoils cast by a dragline using a bulldozer or even a dragline bucket, subsoiling using a ripper may not be necessary to reduce the amount of compaction.

Generally, the Regulations require regrading to "approximate original contour". The degree of approximation which will be permitted by the RA will depend upon a number of factors including the approved post-mining land use, the impact of any change on the natural drainage pattern, hydrology and landscape of the area, etc.

The sequence in which backfilling of spoil materials is carried out and the methods used are of vital importance in minimizing AMD.

Acid-forming materials are frequently found in association with coal, usually within the coal itself and in strata close to the coal. Careful handling is the key to preventing acid drainage in order to prevent oxidation and the forming of acid solution by excluding air and water.

APPLICABILITY

Backfilling and rough grading are of course applicable to all sites, but the requirements of the Regulations vary according to the mining method as to the period or distance allowed before contemporaneous reclamation must begin.

The specific requirements of the Regulations affecting the handling of acid-forming materials will only apply to areas where the analysis of core samples [779.14] shows significant amounts of acid-forming materials. In the case of small mine operations, this analysis will be paid for by the RA under the provisions of the Small Operator Assistance Program.

REVELANT SECTIONS OF THE REGULATIONS

I. BACKFILLING AND ROUGH GRADING.

A detailed timetable for the completion of each major step in reclamation, including a plan for backfilling and grading, is required as part of the reclamation plan [780.18]. The plan for backfilling and grading should consist of contour maps and/or cross sections that show the anticipated final surface configuration of the proposed permit area.

"Reclamation efforts, including...backfilling and grading...shall occur as contemporaneously as practicable with mining operations" [816.100]. Section 816.101 actually specifies time limits for rough backfilling and grading of surface mine sites. In the case of contour mining, backfilling and grading must follow coal removal by not more than 60 days or 1,500 feet. In the case of area strip-mining 180 days is allowed following coal removal, but rough grading may be more than 4 spoil ridges behind the pit which is being worked. In the case of open pit mining the timing of backfilling and grading must be in accordance with the time schedule approved by the RA. Section 816.101(b) contains the requirement that all disturbed areas shall be returned to their "approximate original contour." It also requires that all spoil shall be transported, backfilled, compacted and graded to eliminate all highwalls, spoil piles and depressions, the term "approximate" implies a certain latitude in interpreting this requirement and Section 816.102 states that "post-mining final graded slopes need not be uniform but shall approximate to the general nature of the pre-mining topography." It also requires that final graded slopes shall not exceed the grade of the pre-mining slopes but that backfilling and grading should be carried out to the most moderate slope possible. Cut and fill terraces are only permissible in situations expressively identified in Section 816.102 and require approval from the RA. To obtain this approval, terraces must be compatible with the approved post-mining land use and they must be "appropriate substitutes for construction of lower grades on the reclaimed land." Further discussion on the use of terraces for water conservation and erosion control can be found on Sheet 7:2.

II. BACKFILLING AND GRADING (THIN OVERBURDEN - SECTION 916.104).

The performance standards contain different requirements for backfilling and grading in situations of "thin overburden and thick overburden." Thin overburden applies to situations where the final thickness (Tf) is less than 0.8 of the initial thickness (Ti). Where Ti = the sum of the pre-mining thickness of the overburden (Tb) + the thickness of the in-situ coal (Tc). The final thickness (Ti) = the product of the pre-mining thickness of the overburden (Tb) x the bulking factor (K).

Thus: Ti = Tb + Tc.
Tf = Tb x K.

Section 816.104 applies when Tf is less than 0.8 x Ti. In these situations there is unlikely to be sufficient spoil available to achieve the grades which approximate original contours. If this is the case, the grading must achieve adequate drainage and all acid-forming and toxic-forming material must be covered as required in Section 816.103, i.e., with a minimum of 4' of non-toxic spoil or non-toxic material.

All highwalls must be eliminated by grading or backfilling to stable slopes which may not exceed 1v:2h (50%) unless steeper slopes are approved by the RA [816.104(b)(2)]. In situations where spoil is insufficient to achieve the approximate original contour, a common technique for grading the site is to leave an impoundment in the area of the final cut. An impoundment which is planned must be approved by the RA and this approval is conditional upon the impoundment being suitable for the approved post-mining land use. Approval of an impoundment in the area of the final cut does not

REVELANT SECTIONS OF THE REGULATIONS (CONTINUED)

relieve the operator of the requirement to eliminate the highwall. Where the RA approved a permanent impoundment as part of the restoration plan, it must meet the requirements of Section 816.49.

III. BACKFILLING AND GRADING (THICK OVERBURDEN - SECTION 816.105)

Section 816.105 of the performance standards applies where the final thickness of overburden is greater than 1.2 of the initial thickness using the same method of calculation as in the previous paragraph. That is, it applies when Tf is more than 1.2 x Ti.

This Section [816.105] applies in those situations where the volume of spoil is demonstrated to be "more than sufficient" to achieve the approximate original contour. In these cases, the mine area should be graded to the approximate original contour and any excess spoil should be hauled and disposed of in excess spoil disposal areas in accordance with the relevant sections of the performance standards [816.71-816.74]. As is the case for all other surface mines, highwalls and depressions must be eliminated.

IV. SELECTIVE HANDLING OF ACID-FORMING MATERIALS.

Identification and analysis of potential acid-forming, toxic-forming or alkalinity-producing materials are required as part of the Geology Description [779.14(b)(1)]. These will provide the operator with a good basis for planning the selective handling of these materials, as is required in the performance standards, and of the potential buffering or neutralizing capacity of other strata in the overburden. Section 780.18(b)(7) requires as part of the reclamation plan "a description of measures to be employed to insure that...all acid-forming and toxic-forming materials are disposed of in accordance with Section 816.103." There are two sections in the performance controls which specifically cover the handling of toxic-forming or acid-forming materials. These are Section 816.48 (Hydrologic Balance: Acid-forming and toxic-forming spoils) and 816.103 (Backfilling and Grading: Covering coal and acid-forming and toxic-forming materials).

Section 816.48 specifies that acid-forming or toxic-forming spoils must be buried within 30 days of exposure on the mine site. In some cases temporary storage of acid-forming spoils may be approved by the RA if burial is unfeasible within 30 days, but only if this will not result in water pollution problems.

Section 816.103 requires that acid-forming and toxic-forming materials and all exposed coal seams after mining are covered with a minimum of 4' of "the best available non-toxic...material." If necessary these materials must be treated to neutralize toxicity and in some cases the RA may specify thicker cover and special compaction and isolation measures to prevent contact with groundwater.

The requirements of Section 816.52(a) and (b), that groundwater and surface water be monitored, means that if selective handling of acid-forming or toxic-forming materials is not effective and groundwater or surface water pollution results the RA will be able to trace the source of the problem [816.104(b)(2)].

The performance controls covering the disposal of excess spoil in Sections 816.71 to 816.74 do not specifically prevent the disposal of acid-forming or toxic-forming material in Valley or Head-of-Hollow fills. But there is a general requirement in Section 816.71 that "the leachate and surface runoff from the fill will not degrade the surface groundwaters or exceed the effluent limitations. Also, acid-forming or toxic-forming materials are specifically outlawed for use in under-drainage systems in excess spoil disposal sites.

Coal processing wastes are a major source of water pollution in mining areas. This problem is not specifically covered in this Handbook. For performance standards covering the handling and disposal of coal processing wastes see Sections 816.81 to 816.93.

DISCUSSION & DESIGN GUIDELINES

I. BACKFILLING AND ROUGH GRADING.

Backfilling and rough grading, in order to meet the requirements of the Regulations for contemporaneous reclamation, have to be planned as part of the task of overburden removal. In order to minimize double handling, the techniques of achieving contemporaneous backfilling and regrading will vary with the type of mining operation.

In contour mining, the practice of haulback was being used by many mining companies prior to 1977. The haulback method of surface mining, by backfilling simultaneously with excavation, cuts the area of disturbed lands by two-thirds (3). In doing so, this method also meets the requirement of SMCRA for contemporaneous reclamation, and reduces the disturbed area contributing to erosion. It was found that haulage distance for spoil in single seam haulback operations averaged 500'. (The Regulations allow 1,500'.) This operation involves 3 distinct operations: loading, haulage, and regrading. This, however, makes selective handling and replacement of overburden possible and also can achieve much more compaction of spoil than in cases of overburden cast with a dragline or shovel. Greater compaction of acid-forming materials can significantly reduce acid formation by excluding air.

Generally, smaller operators will not be involved in mountaintop removal operations. The large amounts of overburden to be removed in these cases makes very careful planning, programming and contemporaneous reclamation essential. Usually also there is a need for disposal of excess spoil (see Sheet 6:8); consequently, even prior to the 1977 Act, contemporaneous reclamation was practiced as part of mountaintop removal operations by most operators. An example is Vecellio & Grogan who were cited for excellence in reclamation by West Virginia's Dept. of Natural Resources for their 285-acre mountaintop removal operation near Beckley, WV, where reclamation goes on continuously as coal is mined. It is a loader/haul truck operation with scrapers used to remove and replace 2'-4' of soil on reclaimed areas (4).

In area mining being carried out with a dragline, the operation of backfilling is of course part of the overburden removal process. Rough grading is usually carried out with dozers. Spoil cast by a dragline is unconsolidated and therefore may be liable to settlement for several years after mining. This may cause problems when revegetating due to excessively rapid percolation of water and drying out. Unconsolidated spoil in areas affected by area or open pit mining has the potential for underground water storage, in effect by creating an aquifer.

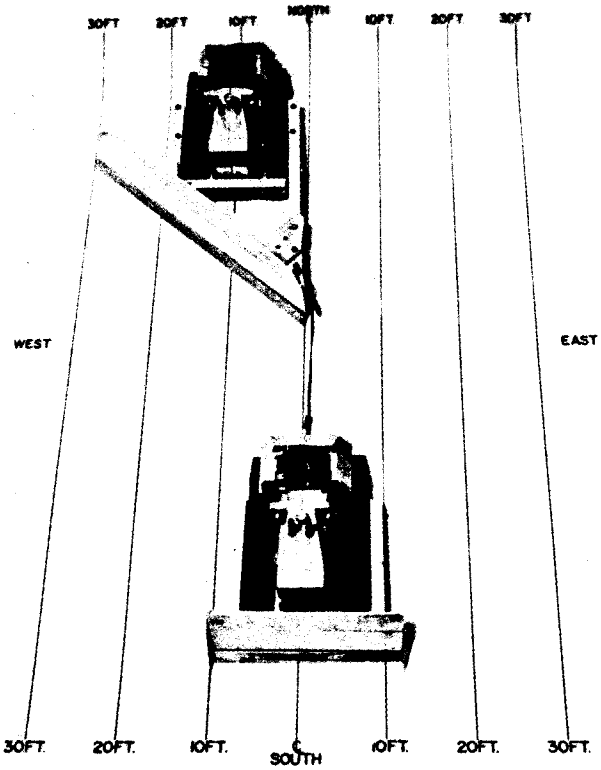
The problem of handling and regrading of box-cut spoils was discussed on Sheet 6:7. In area mining, there may be more flexibility in planning the duration and sequence of working so as to minimize the distance between the temporary spoil dump and the final cut. Some double handling of box-cut spoils to eliminate the highwall and other requirements of Section 816.101 (Backfilling and Grading: General Requirements) is unavoidable.

Selective handling of overburden when it contains acid-forming materials is not easy with a dragline. Placement of the acid-forming material, consolidation and sealing with a relatively impermeable spoil material cannot be carried out with a dragline or a stripping shovel. The presence of a large amount of acid-forming material in the overburden may justify a change in the method of operation and machinery chosen.

Rough grading of unconsolidated dragline spoils can be accomplished using dozers with very wide blades, and some interesting innovations have been tried out to increase the capabilities of bulldozers in this operation. The Push-Tow concept is described by Howland of the Pittsburgh and Midway Mining Co.

Under the Push-Tow concept, application of additional horsepower to the angle blade is made through a single point hitch to the leading edge of the blade. Through directional changes, the lead tractor helps counteract side thrust forces imposed upon the angle blade and "push" tractor. With a 40 degree angle of attack, the 40' blade has a maximum effective width of 30' for spoil relocation west of the centerline, as shown in the above illustration, and 30' east of the centerline on the return pass when tractors are moving north.

Generally, acid-forming spoil which is compacted and covered with relatively impermeable material and a minimum of 4' of non-toxic overburden requires no other sealant to prevent oxidation. In the past, various sealants have been tried to prevent the oxidation of pyrite in acid-forming spoils. It was found that generally compacted clay is the most cost-effective method of achieving this. More expensive materials, including concrete, bitumin and various latex sealers, have been tried but the results have generally been variable and their use is not recommended for covering surface mine spoils, although in some cases their use is recommended for sealing deep mine workings.



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CHAPTER 7

RECLAMATION AND REVEGETATION

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REVELANT SECTIONS OF THE REGULATIONS

The Regulations contain very specific performance standards covering reclamation of surface mine sites. Some of the standards were already in force in coal-producing states prior to 1977. The Regulations, in effect, make it necessary for the surface mine operator to consider reclamation and to carry it out, as an integral part of, and inseparable from, the actual coal extraction operation. The operator must not only carry out the reclamation but he must also preplan his reclamation. The Reclamation Plan is a necessary part of the application process and, significantly, it is in the same part of the Regulations as the Operations Plan (Part 780 Surface Mining Permit Application-Minimum Requirement for Reclamation and Operations Plan).

One of the requirements of the Regulations which makes it necessary for the operator to consider reclamation as part of the mining operation is Section 816.100 which requires that "reclamation efforts....of all land that is disturbed by surface mining activities shall occur as contemporaneously as practicable with mining operation." Section 816.101 goes on to specify just how "contemporaneous" this must be by setting time limits for backfilling and grading. The Reclamation Plan [780.18] requires that each application must contain "a detailed timetable for the completion of each major step in the Reclamation Plan."

It should be noted that the contemporaneous reclamation requirement does not only refer to backfilling and regrading, but also to revegetation [816.113]. "When necessary to effectively control erosion, any disturbed area shall be seeded and planted as contemporaneously as practicable...with a temporary cover of small grain, grasses and legumes until a permanent cover is established."

Section 780.18 includes, as part of the Reclamation Plan, the following requirements:

1. a detailed timetable for the completion of each major step in the reclamation plan;
2. a cost estimate for the proposed reclamation;
3. a plan of backfilling and regrading showing the anticipated final surface configuration;
4. a plan for topsoil handling;
5. a revegetation plan which must include:
   a) schedule of revegetation
   b) species and seeding rates
   c) methods of planting and seeding
   d) mulching
   e) irrigation and pest and disease control where appropriate
   f) measures to be used to determine the success of revegetation
   g) a soil test plan

There are also other requirements in this Section.

The Reclamation Plan must include details of the proposed post-mining land use [780.23]. "Where a land use is proposed," the plan must contain the materials specified in Section 816.33. Land uses different from the pre-mining uses may be approved by the RA if they are compatible with the adjacent land uses, if the necessary public services are available, and certain other conditions in Section 816.133(c) are being met. Throughout the performance standards there are a number of cases where it is stated that the reclamation must be compatible with the approved post-mining use of the land. The performance standards of the Regulations put a lot of emphasis on revegetation [816.111-816.117]. Both the requirements and the methods for judging the standards for success of revegetation vary with the approved post-mining use of the land [816.116]. The emphasis placed on revegetation is in large part due to the need to re-establish vegetation capable of preventing erosion. As has been noted, the reclamation practices which are required by the performance standards are very specific. The following sheets take these practices individually and give some guidelines for each.

Figure 1. Ineffective reclamation. This site shown above was regraded, seeded and planted, but there was no topsoil replaced, and severe erosion has occured on the long slopes.
Source: Chapman, A.G., Aug 1967, "Effects of Spoil Grading on Tree Growth," Mining Congress Journal.

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PROBLEM & PURPOSE

The purpose of terraces is to reduce erosion on regraded land by intercepting runoff on long slopes and conveying it, at non-erosive velocities along its length, to a drained or disposal area. The length of slope is an important factor affecting the amount of erosion (see Soil Loss Equation-Sheet 6:1). This is due to runoff accumulating on long slopes and, as it does so it gains momentum. Its erosive capacity increases and it begins to form gullies. Soil Conservation Service studies on sloping farmland have proved conclusively that terracing reduces the amount of sediment very significantly.

Vogel notes that one of their Forest Service studies at Berea, KY showed that terracing on gently sloping spoils cut sediment yields and the storm peak runoff rate in half (1).

By slowing down the rate of runoff, terraces will also cuase more water to infiltrate the regraded spoil. There are 2 important implications:

1. Infiltration into the spoil mass may reduce its shear strength and result in instability of the mass and slumping. There is a danger of this on excess spoil disposal sites and great care should be taken to ensure that runoff does not pond on the terrace, but flows steadily at a uniform gradient to stable ground. (The Regulations require a 1% longitudinal gradient for terraces on Head-of-Hollow fills.)
2. Increased infiltration will tend to increase the availability of water for plants, resulting in improved survival and growth.

However, terraces result in an increased grade between terraces which can also result in more severe erosion. Secondly, they may interfere with post-mining land uses and, thirdly, on steep fill slopes the increased infiltration which results from slowing down the runoff can cause instability and slides. Therefore, terraces are permitted on reclaimed surface mine sites only with the approval of RA. Terraces, therefore, should be considered in situations where spoiling and revegetation will not be sufficient to prevent erosion.

There is some confusion in the definition of the term "terrace." There is not a definition included in Section 701.5 (Definitions). The confusion is whether a terrace acts simply as a bench, graded to a slope almost flat but in the same direction as the overall slope or whether it has a reverse grade and therefore actually intercepts runoff (Figure 1). The latter is usually the case and this is the terminology used here. But there are two distinct types of this sort of terrace: 1. the level terrace which is, as implied, level and simply intercepts and impounds runoff and 2. a gradient terrace which has a longitudinal gradient and directs water along its length to an outfall on stable ground. The latter is the most usually used.

APPLICABILITY

Terraces are appropriate for use on surface mine sites where revegetation alone is not sufficient to prevent erosion. This may be the case on regraded spoil which has a high erodibility which may be caused by:

1. excessive steepness;
2. long, uninterrupted slopes;
3. highly erodible spoil and/or topsoil.

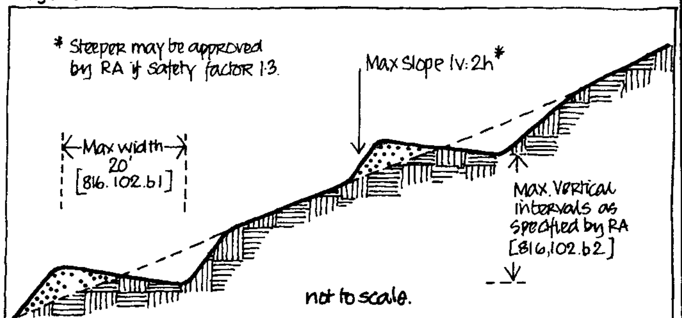
Terraces are commonly used on excess spoil disposal sites, Head-of-Hollow and Valley fills, where the steepness of the outslope usually makes terracing necessary. Terraces require the approval of the RA. Some mining companies use terraces during reclamation of sloping land then remove the terraces when the areas between are revegetated and protected from erosion.

Carefully constructed terraces can solve erosion problems on steep sites and on rolling terrain, and the operator should not be discouraged from seeking approval for their use from the RA if there is doubt that other methods will not prevent erosion on the reclaimed site.

REVELANT SECTIONS OF THE REGULATIONS

Sections 816.72 and 816.73 (Disposal of excess spoil: Valley fills and Head-of-Hollow fills) contain some specific requirements for the design of terraces on excess spoil disposal sites. Section 816.71(h) mentions the use of terraces in these areas but approval of the RA is still required. Further guidelines for the construction of excess spoil disposal facilities will be found on Sheet 6:8.

The Regulations state that cut and fill terraces may only be used in certain situations and then only with the approval of the RA [Section 816.101]. Section 816.102(b) states that "on approval by the regulatory authority in order to conserve soil moisture, insure stability and control erosion on final graded slopes, cut and fill terraces may be allowed, if the terraces are compatible with the approved post-mining land use and are appropriate substitutes for construction of lower grades on the reclaimed lands." Some of the design requirements of the performance controls are summarized on Figure 1.



REGULATIONS AFFECTING SPACING & WIDTH OF CUT & FILL TERRACES.
Figure 1

DISCUSSION & DESIGN GUIDELINES

In the case of gradient terraces, which conduct water along their length, the design of terraces to prevent scouring should be based on the same criteria used to design grass waterways (Sheets 6:5 and 7:4). Additional information on the design of grass waterways may be found in the Soil Conservation Service's "Engineering Field Manual for Conservation Practices." Operators may also find it useful to refer to the Soil Conservation Service's (Kentucky) "Standard and Specification for A Gradient Terrace" modified to conform to the requirements of the performance standards. Some guidelines from that reference are included here. It is emphasized that gradient terraces should be used only where suitable stabilized outlets are available to dispose of drainage water. The performance standards of the Regulations require that the RA approve the vertical spacing between terraces [816.102(b)(2)]. The Soil Conservation Service, to determine the vertical interval (VI) between terraces in farmland, uses the equation: $VI = XS + Y$; where X is a factor which varies regionally as indicated in Figure 2, S is the slope in feet per 100 feet, and Y is an erodibility factor which is 1.0 for highly erodible soils and 4.0 for erosion-resistant soils containing a large amount of organic residue. It is suggested that a value of 1 is used for estimating the vertical interval for most reclaimed mine sites.

Example on a site with a slope of 10 feet per 100 feet (10%) in Eastern Kentucky:

VI = 0.6 x 10 + 1 = 7. The vertical interval between terraces should be 7 feet which on a 10% slope is a horizontal spacing of 70 feet.

Generally, the capacity of gradient terraces should be sufficient to handle the peak runoff from a 10 year frequency storm.

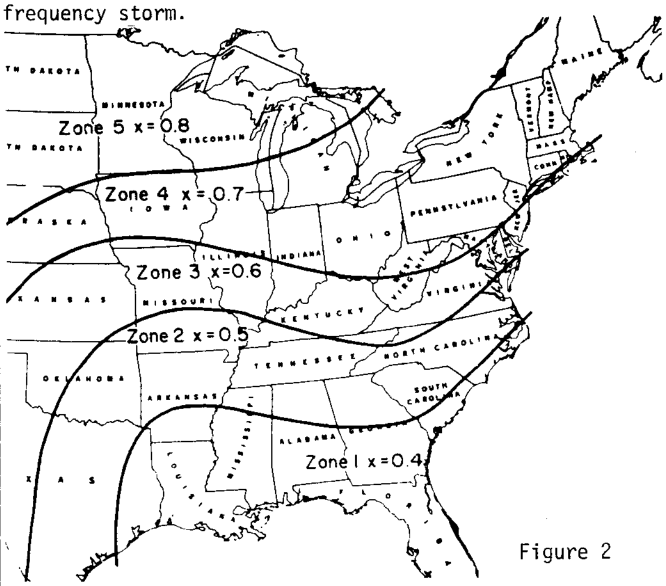
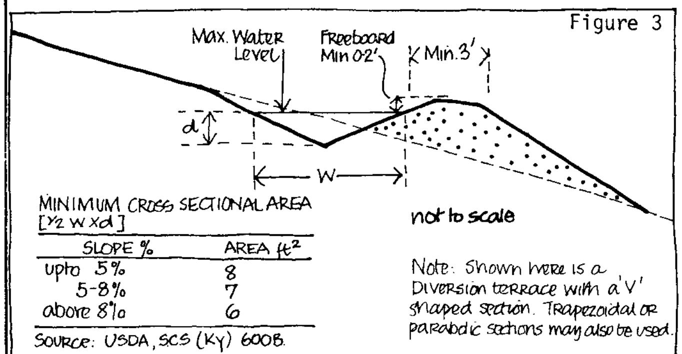


Figure 2

Figure 3 shows a cross-section through a hypothetical gradient terrace: the minimum depth is d = 9 in. The depth has a minimum average of 0.1 ft/100 ft and a maximum average of 0.5 ft/100 ft (the absolute minimum and maximum for short length are 0 and 1 ft/100 ft). However, mine operators should beware of creating areas where runoff ponds as this may cause instability on steep fill slopes. All terraces must have adequate outlets such as a grass waterway, an existing vegetated area or a conduit outlet.

Figure 3



As for diversions, gradient terraces may be constructed with parabolic, V-shaped or trapezoidal sections. Figure 3 shows a V-shaped section, Figures 4 & 5 a trapezoidal and parabolic section respectively. V-shaped are the simplest to construct with standard equipment and minimum number of passes. The parabolic cross section requires special construction equipment.

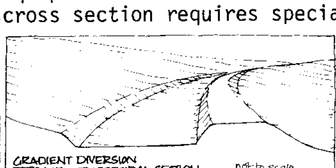


Figure 4

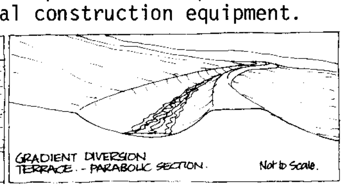


Figure 5

In rolling terrain, where the conservation of soil moisture is particularly important for the establishment of vegetation, and in areas to be reclaimed for agricultural uses, a "Rome Bedding Harrow" may be useful (Figure 6). These generally are suitable for use only on slopes of less than 15%. In pre-1977 experiments on regraded mine spoil, it was found that the use of terraces constructed with the Rome Bedding Harrow resulted in peak flows of 65% less than on a control plot and a sediment yield of 52% less. Total runoff averaged 42% less (the plots had been hydroseeded with a mixture of annual rye grass, sweet clover, Kentucky fescue and black locust). Lime was not used as a pH was generally above 7 (3).

Figure 6

TERRACES ON SITES OF DISPOSAL OF EXCESS SPOIL

Terraces should be stabilized with a suitable grass mixture. Various grass mixes for channels of varying flow velocities are shown on Sheet 6:5 (Diversions). This sheet also includes guidelines for stabilizing outlet points and eroding channels.

One of the most common uses of terraces in reclamation will be on steep slopes associated with Valley fills and Head-of-Hollow fills to dispose of excess spoil during the mining operation. Section 816.71(h) states that "terraces may be utilized to control erosion and enhance stability if approved by the Regulatory Authority."

If terraces are permitted, the vertical distance between terraces (for Valley fills) should not exceed 50 ft [816.72(e)]. This Section also specifies that drainage should not be directed over the outslope of the fill. Further details of the configuration of Valley fills can be found on Sheet 6:8. In the requirement for Head-of-Hollow fills, it is stated that terraces on fill should be graded with a 3-5 percent grade towards the fill and a 1 percent slope towards the rock core (in effect, a "gradient terrace").

It should be noted that Section 816.73 requires the drainage control system for Head-of-Hollow fills to be capable of passing safely the runoff from a 100-year, 24-hour precipitation event. It is not clear whether the terraces form part of the "drainage control system" and operators are advised to clarify this point with the RA if they are constructing Head-of-Hollow fills.

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GROUP	RECLAMATION AND REVEGETATION
MEASURES	FINAL GRADING

PROBLEM & PURPOSE

The procedure during reclamation can be divided into:

1. Backfilling and rough grading to the general landforms shown on the reclamation plan (see Sheet 6:10).
2. Final touch-up grading to ensure that final grades are correct, particularly in respect of drainage channels.
3. Surface treatment of regraded spoil to reduce compaction. If soil is pyritic lime should be applied now.
4. Replacement of topsoil and seeding (Sheet 7:5).

(This Sheet deals with Steps 2 and 3).

The landforms created by rough grading will have a major impact on the amount of erosion. Steepness and length of slope are the two most important factors. Sheet 7:2 described the use of terraces to reduce the length of slope. "Gouging" involves the creation of small depressions in the surface of the spoil before topsoil is replaced. These help to slow the rate of runoff and increase infiltration. Their use requires approval from the RA. Dozer basins have a similar function but are larger and also require the approval of the RA.

The methods used during grading can reduce erosion significantly. The Regulations require that all final grading "be done along the contour to minimize subsequent erosion" [816.102(e)]. Rough grading which is carried out with scrapers will tend to result in compaction and will reduce infiltration of water into the spoil. This will also increase the rate of runoff and erosion. Grandt and Lang in 1958 measured 0.9" (2.3 cm) per hour infiltration on regraded spoil compared with 11.8" (30 cm) per hour on ungraded spoil (1). It was found, however, that when spoil was revegetated the infiltration rate increased. Curtis suggests that "every effort should be made to maintain high infiltration rates on surface mined land" (1).

The survival rate and growth of vegetation on regraded spoils may be severely reduced by the excessive compaction caused during regrading, especially on spoils with a large percentage of clay. Not only is the infiltration of water reduced, but compaction reduces the aeration of the spoil in the tree root zone. Experimental plots were established as far back as 1946 and 1947 in Ohio, Illinois, Missouri and Kansas which have shown better survival and growth of trees planted on ungraded spoil than on graded spoil. This difference is in part attributed to the severe compaction caused by grading (3).

Prior to topsoiling, various measures can be taken to reduce compaction including ripping and scarification. Section 816.24 (Topsoil:Redistribution) does require regraded land to be scarified or "otherwise treated as required by the RA," before replacement of topsoil, specifically to promote root penetration. It is important that scarification or ripping be done along the contour which should be possible even on steep slopes using a tracked dozer [816.102(e)].

Timing of final grading operations is important. Final grading during wet conditions will increase the amount of compaction and should be avoided, and this also applies to the replacement of topsoil. The operator will generally find it pays to try to minimize the period between final grading and seeding so as to avoid the need for any "touch-up" grading of gullies, etc., due to erosion during the intervening period. "Gouging" may be useful to reduce gully erosion in cases where there is an unavoidable delay between final grading and seeding.

In spite of the desirability to reduce compaction of regraded spoils, in some cases (usually where large volumes of fill is placed on sloping terrain), increasing the infiltration will increase the instability of the fill mass, and therefore in these cases is undesirable.

APPLICABILITY

1. Sites. Carefull attention to final grading technique and to the requirement of the Regulations that all such operations should be carried out along the contour is particularly important in sloping and rolling terrain, where steep or long slopes increase the rate of erosion. (There are special performance standards which apply to mining on slopes of 20° or more.) The gouger described below is not suitable for use on slopes steeper than 1v:10 h.
2. Operations. Operations using scrapers for backfilling and rough grading will result in heavy compaction of the overburden. In contrast, overburden cast with a dragline and rough graded with the bucket or with dozers will not be compacted and may even settle considerably after working. Therefore the method of operation will affect the amount of ripping or scarification needed.
3. Size of operation. Some of the machinery used for final grading is very specialized and few small operations would have access to the equipment. However, alternative means of achieving the desired objective can be found using standard equipment.

REVELANT SECTIONS OF THE REGULATIONS

The performance standards affecting rough backfilling and grading were covered on Sheet 6:10. Two requirements of the performance standards are particularly important in determining the overall reclaimed landform. Section 816.101(b)(1) requires that all disturbed areas are "returned to their approximate original contour....and graded to eliminate all highwalls, spoil piles and depressions." Section 816.102(a) requires that the grade of final graded slopes should not exceed either the approximate pre-mining slopes or lesser slopes if required by the RA. This Section also implies that there is considerable latitude in interpreting "approximate original contour" in that "post-mining final graded slopes need not be uniform but shall approximate the original general nature of the pre-mining topography" (see Sheet 6:10).

Final grading is considered in the Regulations as part of the reclamation process. The requirements for the reclamation plan include a detailed timetable for each major step in the reclamation process [780.18(b)(1)]. The requirement of 816.100 in the performance standards is that reclamation efforts including backfilling and grading "shall occur as contemporaneously as practicable with mining operations."

The reclamation plan must contain "a plan for backfilling, soil stabilization, compacting, and grading, with contour maps or cross sections which show the anticipated final surface configuration," [780.18(b)(3)], and grading practices must be consistent with the performance standards in Sections 816.101-106.

Section 816.24 (Topsoil:Redistribution) requires that "after final grading and before replacement of topsoil ...regraded land shall be scarified or otherwise treated."

Section 816.102(e) requires that "all final grading, preparation of overburden before replacement of topsoil,.... shall be done along the contour to minimize subsequent erosion and instability." An exception is made when such operations would be hazardous to the operator, but they must in all cases be conducted in a manner which minimizes erosion.

Section 816.102(c)(1) states that "small depressions"

REVELANT SECTIONS OF THE REGULATIONS (CONTINUED)

may be constructed, if they are approved by the regulatory authority to minimize erosion, conserve soil moisture, or promote vegetation."

DISCUSSION & DESIGN GUIDELINES

The measures suggested on this Sheet should be applied before topsoiling. Section 816.24 requires that after final grading, all regraded land shall be scarified or otherwise treated before topsoiling. In some cases, however, it may also be desirable to scarify after topsoiling.

The measures outlined on this Sheet have the following purpose:

a. To reduce compaction;

b. To improve the availability of soil moisutre both by increasing infiltration and by increasing root penetration, particularly of tree species;

c. Increasing the level of groundwater recharge; and

d. Reducing runoff and therefore erosion.

Generally the maximum gradient for the normal operation of farm equipment is 30%. Tracked vehicles and bulldozers can of course operate at considerably steeper slopes. Bulldozers also have the advantage of up-and-down operations resulting in clean depressions in the spoil which are useful in trapping sediment and seed. (See "5. Tracking" below.)

The following equipment may be required during the final grading process.

1. Ripper. A ripper normally consists of one, two or three ripper shanks mounted on a ripper bar on a crawler tractor (Figure 1). The ripper (single or multiple shank) is used in cases where compaction is too serious to be broken up using scarification, disking and chisel plowing, and where it is necessary to break up the compaction of depths greater than 12". Using a single shank ripper, compacted overburden can be broken up to depths of 3-4 ft. This operation should be carried out along the contour, usually on 10 ft centers (Figure 1). The ripper forms a deep groove in the spoil 3-4" wide and fragments the spoil 2-3 ft either side of the ripper shank. The Montana Agricultural Expermental Station also developed the "triple ripper" to increase ripper channel density. Two additional shank holders were welded onto the ripper bar spaced 4 ft apart. Penetration was less than for the single ripper (2-3 ft) (5).

Figure 1

2. Scarification-Disks, etc. In order to meet the requirements of Section 816.24, spoils should be scarified or otherwise treated. This calls for the use of special pieces of equipment. In a lightly compacted spoil a heavy disk plow may provide the necessary scarification but on heavily compacted sites a ripper may be required. In some cases sufficient scarification may be given by dragging the bucked teeth of a front-end loader over the surface of the spoil.

3. Gouger. The "gouger" was developed at the Montana Agriculture Experimental Station at Bozeman, Montana. Three heavy-duty disk plough blades were mounted on a 12 ft wide chisel plough frame, spaced 48 in on center. The blades were set upright with the concave side of the disk facing the direction of travel (Figure 2). The operator alternately lowers and raises the disks, using the tractor's hydraulic system. This gives elongated surface depressions, 30-36 in long, 14-16 in wide and 4-6 in deep. Generally there is a 12 in space between depressions but this can be varied by the operator. A tractor of at least 50 hp is required and operating speeds 2-3 mph are usual, making it possible for an experienced operator to grade 2½-3 acres/hour. There will be 2,400-2,800 depressions per acre.

The gouger, however, is ineffective on slopes of more than about 1v:10h.

Because the manual operation of the hydraulics is tiring to the operator, a motor-driven gouger using two ranks of alternately spaced disks was developed to produce a dense staggered pattern of gouged depressions. However, this machine was not very satisfactory in practice and did not provide any real advantage in water retention. The original prototype therefore was developed using a high quality, heavy-duty hydraulic cylinder (previously susceptible to failure) and a hydraulic fluid sealer. The pattern and configuration of gouged depressions is shown in Figure 3.

Figure 2

Figure 3

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

4. Dozer Basins. Dozer basins were first constructed using a standard dozer blade to form deep elongated depressions on the contour. These were 15-20 ft long, 6-8 ft wide, and 3-4 ft deep, spaced at 20-25 ft center to center. Studies showed in arid regions these depressions improved the establishment of perennial grasses and shrubs. This operation, however, was slow and tended to result in excessive compaction in the base of the basin. A "V" shaped blade, therefore, was designed to take the place of a ripper shank (mounted on a D-9 caterpiller). Figure 4 shows a dozer basin blade in operation. Notice how the "V" shaped blade scoops out material and also shapes the dam. The configuration of these basins is as follows: width 7-8 ft, depth 2-3 ft, spacing 15-20 ft on center. There are 220 to 280 basins per acre which give a water storage volume of 1½ to 2 acre-inches. An experienced operator can treat 2-2.5 acres per hour in moderately sloping terrain.

5. Tracking. "Tracking" involves passes up and down the slope with a bulldozer which leaves cleat marks from its tracks on the surface of the spoil. This is not a substitute for scarification and does not meet the requirements of Section 816.102(e) requiring that final grading operations be done along the contour. It may be useful, however, for reducing erosion and seed loss on steep topsoiled sites.

6. Grosser Bars. The "grosser bar" or slope disk can be used to roughen the surface of steep spoil before replacement of topsoil. The equipment is best used on terraced slopes with the tractor running along the terrace.

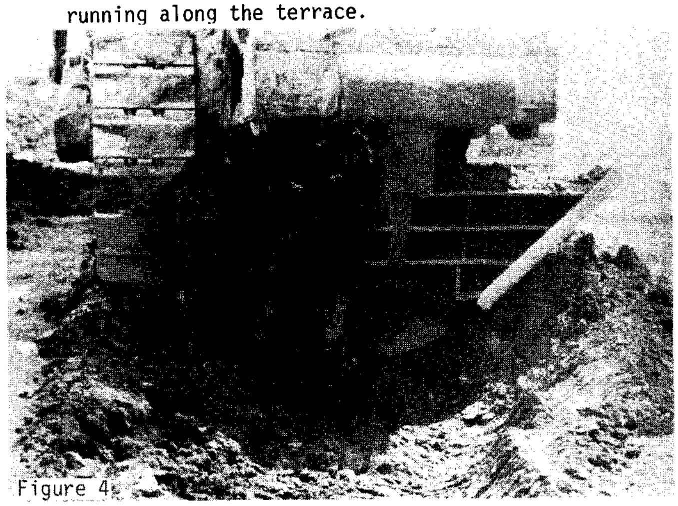


Figure 4

REFERENCE

(1) Grandt, A.F. and Lang, A.L., 1958, "Reclaiming Illinois Coal Strip Land with Grasses and Legumes," University of Illinois, Agricultural Experimental Station, Bulletin 628.
(2) Curtis, W.R., June 9, 1978, "Planning Surface Mining Activities for Water Control (Author copy)," Proc. 5th North American Forest Soils Conference, Berea, KY.
(3) Chapman, A.G., Aug 1967, "Effects of Spoil Grading on Tree Growth," Mining Congress Journal.
(4) Gardner, H.R. and Woolhiser, D.A., 1978, "Hydrologic and Climatic Factors," Proc. of the Reclamation of Drastically Disturbed Lands Symposium, Shaller, F.W. and Sutton, P., (Eds.), ASA, CSSA, SSSA, Madison, WI.
(5) Jensen, I.B. and Hodder, R.L., Oct 1976, "Custom Designed Surface Manipulation and Seeding Equipment for Erosion Control and Vegetation Establishment," Sixth Symp. on Coal Mine Drainage Res., Nat. Coal Assoc., Louisville, KY.

PROBLEM & PURPOSE

This sheet describes the construction of grass waterways and other measures to convey overland flow and occasional groundwater seepage at non-erosive velocities to a safe disposal point. Sheets 6:4 and 6:5 dealt with problems of diverting overland flow and ephemeral, intermittent and permanent streams so as to enable the mining operation to take place in an orderly way, to divert water away from the workings and to prevent the contamination of clean runoff and streamflow from upstream of the permit area. The requirements of the Regulations differ for diversions which are permanent and those which are temporary. This Sheet describes measures which must be taken for permanent diversions of overland flow and for construction of grass waterways during reclamation.
This sheet is also relevant to gradient terraces which are in fact grass waterways. For further information on the construction of terraces see Sheet 7:2.
Runoff spreaders are devices to change flow which is concentrated in a grass waterway into sheet flow over a large area of ground, well-stabilized by existing vegetation.
Chutes and slope drains are means of conveying runoff down a steep slope without damage. They are structural measures which, as will other non-vegetative stabilization devices, require the approval of the RA for permanent installation.
Underdrains may be necessary for areas with very poor natural drainage especially where the post-mining use is cropland. Underdrains may also be necessary to prevent permanent wetness in the base of grass waterways.

APPLICABILITY

These measures are applicable to all sites but especially those where there is land upstream of the permit area which drains across the site. Gradient terraces are applicable only in rolling and steep terrain. This Sheet is also applicable to all types and sizes of operations. Generally, operators of contour mines will probably make use of temporary diversions and restore permanent waterways during the reclamation. Operators of area mines, where the natural drainage pattern is not so deeply cut into the landform, may tend to make stream diversions permanent installations.
Underdrains are used only in special cases where, for instance, the proposed post-mining use is cropland or to dry up wet conditions causing erosion problems in grass waterways.

REVELANT SECTIONS OF THE REGULATIONS

Grass waterways should preferably be constructed in natural drainage swales. They carry runoff during heavy rainfall but are otherwise dry. Their use is covered in Section 816.43 of the performance controls (Diversions and conveyance of overland flow and shallow groundwater flow, and ephemeral streams). If the waterway is to be a permanent diversion it must be designed to carry peak runoff from a precipitation event with a 10-year recurrence interval. (If the diversion is temporary, the recurrence interval need only be 2 years.) This refers to waterways which are designed to carry overland flow, ephemeral streams and occasional shallow groundwater flow. The relevant sections of the Regulations for permanent and intermittent streams can be found on Sheet 6:5.
It is also required in Section 816.43 that diversions should have a minimum freeboard of 0.3' [816.43(f)] and that energy dissipators should be installed at discharge points "where diversions intersect with natural streams and exit velocity of the diversion ditch flow is greater than that of the receiving stream." It is also required that channel protection is provided in critical areas.
A very important requirement of the Regulations is that permanent diversion and waterways are to be stabilized by vegetation. Riprap is permissible in critical areas but "asphalt, concrete and other similar linings shall be used only when approved by the regulatory authority" [816.43(b)].
Section 816.56 requires that, before abandoning the permit area, all diversions shall be renovated to meet the criteria specified in the detailed design plan for permanent structures and improvements. (Section 780.29 requires that each application contain detailed descriptions of each proposed stream diversion in the permit area.)
There is no specific reference made to the use of runoff spreaders in the Regulations, but as a means of handling runoff they are in the spirit of the Regulations. This is not the case for the permanent use of chutes of flumes. As has been noted, the use of asphalt concrete and other similar linings (presumed to mean smooth, hard linings which cause acceleration of flow and require long-term maintenance) is not permitted without approval from the RA for permanent diversions. In cases where it has been necessary to convey runoff down steep slopes temporarily using chutes or slope drains, and where it is not feasible to convey runoff in channels with safe gradients, riprapped chutes will be necessary, giving the required roughness to dissipate the energy of the flow. Section 816.102(b)(4) states that culverts and rock drains should only be used on terraces with the approval of the RA. In practice it is sometimes necessary to conduct runoff accumulated on one terrace down to the next terrace in some form of protected waterway. But it is evident that any form of lined waterway will require the approval of the RA. In the case of roads, both Class I and Class II [816.153(c)(2)(vi) and 816.163(c)(2)(vi)] it is stated that water from culverts should be discharged below the toe of the fill. Generally, therefore, chutes, flumes and pipe slope drains are useful in surface mine operations only for temporary situations for conducting concentrated flow down steep slopes.
The use of underdrains is not specifically referred to in the performance standards nor in the special performance standards for prime farmland [Part 823].

DISCUSSION & DESIGN GUIDELINES

I. GRASS WATERWAYS
The cross section of grass waterways may be V-shaped, trapezoidal, or parabolic. V-shaped and trapezoidal cross sections are easier to construct with standard equipment. Diagrams of these sections may be found on Sheet 6:4, Figure 1. The flow velocity in grass waterways should generally not exceed 5-6 ft/sec.
The Soil Conservation Service's "Engineering Field Manual of Conservation Practices" gives good guidelines on the calculations required for the design of grass waterways. Different grasses have different erosion resistance and flow retardance characteristics. Table 1 on Sheet 6:4 gives the maximum permissible velocity of flow for various grasses based upon their flow retardance characteristics.
Grass protects the waterway from erosion. Its erosion resistance is a maximum if a dense turf is maintained which results only if it is mown regularly. Hence gentle side slopes should allow high speed mowing with mechanical equipment and should not interfere with other mechanical operations. Slopes of 1v:3h or preferably 1v:4h should be maximum.
Grass will deteriorate if there is a permanent moisture in the waterway, in which case riprap or crushed stone center drain, a plastic under-drain, or a crushed stone and filter cloth French drain should be installed (see

"underdrains" below).

Various measures can be taken to stabilize grass channels if erosion is taking place. The measures outlined on Sheet 6:4 are temporary and can be used to stabilize permanent waterways while vegetation becomes established. Their permanent use would not be approved by the RA but various fiber mats and netting (jute, paper or plastic) can be used to reinforce the turf. These will be expensive and therefore their use is recommended only where flow velocity exceeds the maximum or in critical areas (on bends, etc.). Below-surface fiber glass erosion checks also are described on Sheet 6:5 and can be used to stabilize grass waterways. Asphalt or concrete linings for waterways require the approval of the RA, but smooth channel linings should be avoided whenever possible as they tend to increase the velocity of flow. Energy dissipators are required by the RA where waterways enter a natural stream if the vleocity in the waterway exceeds that in the stream. A plan and profile of a dumped riprap energy dissipator is shown in Figure 1.

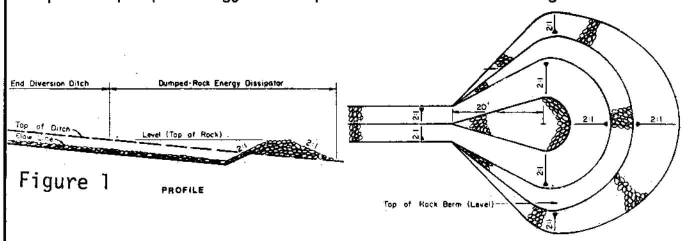
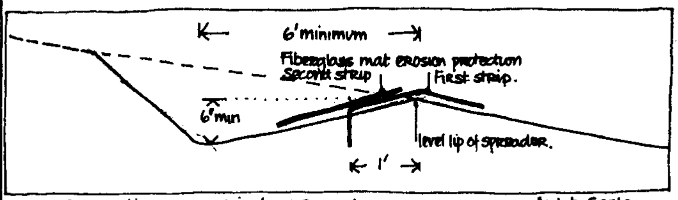


Figure 1

II. RUNOFF SPREADERS

The function of a runoff spreader is to disperse runoff at non-erosive velocities over undisturbed areas stabilized by existing vegetation. Concentrated runoff is changed into sheet flow, much of which will infiltrate in undisturbed areas. A grass channel may either terminate by joining a natural waterway or may discharge via a runoff spreader onto an undisturbed area. The spreader should be constructed on an undisturbed area which is neither poorly drained nor highly erodible. It is necessary to estimate the in-flow value Q in cubic ft per sec to determine the length, L, of the spreader. Periodic inspection and maintenance is vital during the restoration period. Table 1 shows the required length, L, for values of Q. Figure 2 shows a hypothetical design for a level spreader.



Schematic Cross Section Level Spreader. Not to Scale.

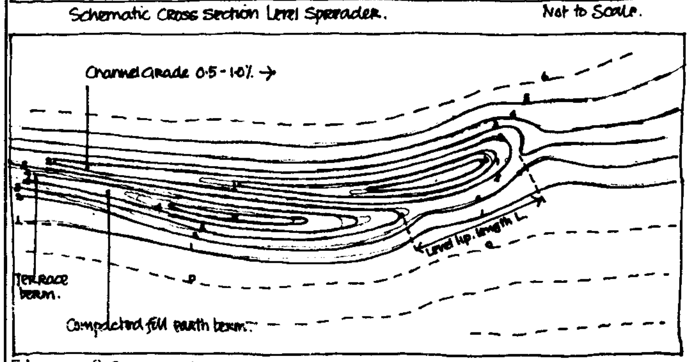


Figure 2 Schematic plan. Level Spreader. Not to Scale.

Table 1 - Design Variables for a Level Spreader

Q (ft^3/sec)	Minimum Length (L - ft)
Less than 10	15
11-20	20
21-30	26
31-40	36
41-50	40

Source: (4)

III. CHUTES AND FLUMES

Chutes and flumes are used where the velocity of flow exceeds the maximum for grass waterways. The Soil Conservation Service's "Engineering Field Manual for Conservation Practices" explains the procedure for the design and sizing of chutes and flumes. The maximum drainage areas for these installations is normally 36 acres. The velocity of flow will increase as runoff passes down a chute or flume, and the protection of the outlet with an energy dissipating device or riprap is necessary. These devices should be used as temporary measures only. Approval from the RA is required.

IV. PIPE SLOPED DRAINS

Pipe sloped drains are also intended to convey runoff down steep slopes without causing erosion. They normally have a preformed inlet but the outlet requires the same type of energy dissipating protection as chutes or flumes. They are usually made of flexible tubing and are widely used for temporary installations. Ridged pipe is more common for permanent installations but approval for surface mine sites from the RA would be unlikely. The Soil Conservation Service's "Engineering Field Manual" gives details for sizing these drains but they are not used for drainage areas exceeding 5 acres (2). Pipe slope drains should be used as a temporary measure only. Approval from RA is required.

V. UNDERDRAINS

In some areas it may be placed to intercept runoff on a slope without any physical interruption as, for instance, caused by a diversion channel. Underdrains are expensive but can be extremely effective if properly installed. When crushed stone is available on site or at low cost, the detail in Figure 3 is appropriate. Measures to prevent clogging of the pore space in these French drains should be taken. Shown here, a plastic filter cloth is used. These cloths are available from several manufacturers. These cloths may also be used to wrap perforated pipe to reduce clogging in underdrains (Figure 4). Underdraining of land relcaimed for agriculture or intensive open space uses may be necessary.

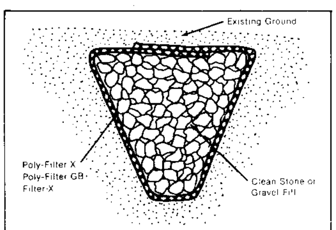


Figure 3 FRENCH DRAIN (No pipe required)

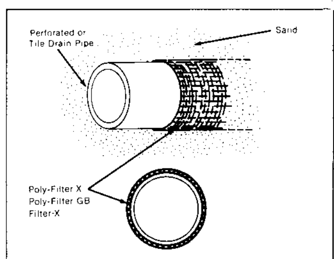


Figure 4 PIPE WRAPPING (cut-away view)

REFERENCE

(1) Soil Conservation Service U.S. Dept. of Agriculture, 1975, "Engineering Field Manual for Conservation Practices."
(2) Glover, F. et al., 1978, "Grading and Shaping for Erosion Control and Rapid Vegetative Establishment in Humid Retions," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W. and Sutton, P., (Eds.), ASA, CSSA, SSSA, Madison, WI.
(3) US EPA, Oct 1976, "Erosion and Sediment Control: Surface Mining in the Eastern U.S. - Design," EPA 625/3-76-006.
(4) USDA, SCS, July 1975, "Standards and Specifications for Soil Erosion and Sediment Control," College Park, MD.

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PROBLEM & PURPOSE

The replacement of topsoil has been found in many cases to improve the survival and growth of vegetation and its effectiveness in controlling erosion. The difficulties experienced in the past in establishing vegetation on unreclaimed mine spoils, where erosion prevented formation of soil and often continually exposed toxic material at the surface, are found to be reduced by the application of topsoil which not only reduces erosion but also the oxidation of acid-forming materials in the spoil where these are present. Topsoil may also be a valuable source of seeds, both herbaceous and woody

In some areas, notably much of the Appalachian coal field, the topsoil is extremely thin. If the topsoil and the unconsolidated material beneath do not make up a total thickness of 6", the operator should find out whether the overburden contains suitable topsoil substitutes. The RA will pay for overburden analysis under the Small Operator Assistance Program (SOAP).
species, which are unavailable commercially and will result in more diversity of plant material on reclaimed land.

APPLICABILITY

The requirement of the Regulations that topsoil be stripped and replaced on reclaimed areas applied to all sites, and, in cases where the thickness of topsoil is not sufficient, the Regulations require subsoil to be removed with the topsoil. The Regulations also contain provisions for the use of topsoil substitutes from the overburden material on sites where topsoil is thin or of poor quality. Often, in steep mountainous terrain, topsoil is thin and poorly developed, and this is likely to be the case in much of Appalachia.

This requirement applies without distinction to all types and sizes of surface coal mining operation. The methodical, orderly method of working Area mines makes programming of removal and immediate redistribution of topsoil much easier. Operators should make sure to request identification of suitable topsoil substitutes as part of the overburden analysis in cases where topsoil is thin.

RELEVANT SECTIONS OF THE REGULATIONS

Section 780.18(b)(4) requires a plan for the removal, storage, and redistribution of topsoil, subsoil, and other materials as part of the reclamation plan. "Topsoil" is defined under Section 701.5 (definitions) as the "A" soil horizon layer of the three major soil horizons. The performance standards do not specify precisely the thickness of topsoil which must be replaced after grading.

Section 816.22(e) permits the use of suitable topsoil substitutes "if the regulatory authority determines that the resulting soil medium is equal to or more suitable for sustaining vegetation than is the available topsoil." The determination is based in part upon the overburden analysis (required as part of the application procedure). The RA will pay for a certified laboratory to carry out this analysis as part of the Small Operators Assistance Program.

Wherever possible, it is required that topsoil should be redistributed in the same operation as stripping from unmined sections of the site [816.21]. Topsoil should only be stored where this is not possible. Section 816.23 requires that topsoil should not be moved from storage until it is actually required for redistribution on a regraded area. Topsoil redistribution is covered by the performance standards specifically in Section 816.24, and the addition of nutrients and other amendments to topsoil is covered in Section 816.25 (see Sheet 7:6).

Section 816.24 (Topsoil: Redistribution) requires that "Regraded land shall be scarified or otherwise treated as required by the regulatory authority to eliminate slippage surfaces and to promote root penetration." The term "otherwise treated" is used so as to enable the RA to specify other techniques where scarification is unnecessary or could result in contamination of the topsoil. Sheet 7:3 described techniques for reducing compaction of regraded spoil. In some cases, the RA may approve scarification after topsoiling has been carried out. The Section requires that topsoil is spread to a uniform, stable thickness which is consistent with the approved post-mining land uses, contours and surface water drainage systems. But it does not specify to what thickness the topsoil must be placed. It requires that there is not excessive compaction of the topsoil and that it should be protected from wind and water erosion before and after it is seeded and planted. Part 823 (Special Performance Standards for Operations on Prime Farmland) contains much more stringent regulations for topsoil handling and replacement. (A minimum of 48 inches of reconstructed soil is required on prime farmland.) Section 816.102(e) requires that all final grading operations and the replacement of topsoil shall be done along the contour to minimize subsequent erosion and instability. Only where this operation may be hazardous to the operator may distribution be done in the other directions.

DISCUSSION & DESIGN GUIDELINES

Topsoil provides an improved rooting medium, improved availability of moisture and nutrients for plants, and leads to more rapid and vigorous vegetation cover and better erosion control. Some spoils are not toxic and have a good texture and water-holding capacity, and, providing nutrients are added, are a good growing medium for plants. Topsoil substitutes are permitted with the approval of the RA if a suitable material is identified in the overburden (see Sheet 6:6). Important factors to be considered in the process of redistributing topsoil include the following:

1. To avoid double handling and to achieve rapid reclamation, topsoil redistribution should be planned and carried out as part of the topsoil removal process.
2. The physical condition of the regraded spoil prior to replacement of topsoil is important. Roots of trees and shrubs will penetrate the spoil beneath the layer of topsoil before the operator is released from his bond. Therefore, the operator should make sure that the surface of the regraded spoil is not severely compacted. The Regulations do require regraded spoil "to be scarified or otherwise treated...to promote root penetration." If possible, avoiding final grading during wet weather will reduce the amount to compaction. A purpose of the scarification required by the Regulations is to eliminate slippage surfaces. This may be important on sloping sites.
3. The chemical reaction of the overburden immediately beneath the topsoil will also affect the growth of vegetation. The requirements of the Regulations for selective handling and placement of acid-forming overburden should eliminate problems of very low pH. However, immediately prior to replacing topsoil, spot checks with a pH meter of the regraded spoil are worthwhile to identify possible trouble spots where lime or other soil amendments <u>prior</u> to topsoiling could avoid future failure of vegetation.
4. Care should be taken while spreading topsoil to:
   (a) achieve a uniform thickness. This will be

made easier if the final grading has left a uniform (but rough) surface. The use of scrapers also makes it easier to place topsoil evenly;

(b) avoid damage to the topsoil and excess compaction by ceasing stripping and spreading operations during wet weather. Compacted topsoil will obstruct root penetration, have poor aeration, and result in poor survival and growth of vegetation;

(c) avoid contaminating the topsoil with spoil material by making sure that the final graded surface is uniform before spreading soil.

5. After topsoiling, a disc harrow is normally used to prepare the surface for seeding. This is normally done after applying lime and other soil amendments (see Sheet 7:6). Disking will break up surface compaction caused during topsoiling operations but will also help to settle the surface, leaving a rough tilth suitable for seeding. A smoothing harrow should never be used to give a fine seedbed as this will be very susceptible to erosion. In some cases a conventional chisel plow may reduce surface compaction more effectively than disking. A chisel plow was found to be highly effective in reducing compaction in experiments by the Montana Agricultural Experimental Station. It also resulted in excellent seedbed preparation. Figure 1 shows the plow in action consisting of a hydraulically-mounted frame with four shanks mounted on each of three cross members. The points penetrate 8-10 in. The seedbed was too rough for a conventional seed drill but that was excellent for broadcast seeding.

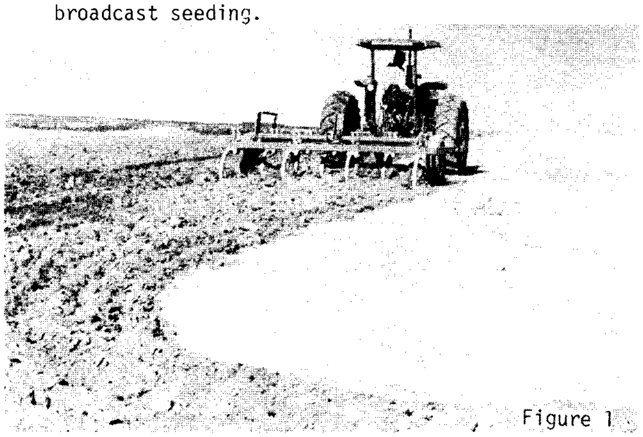
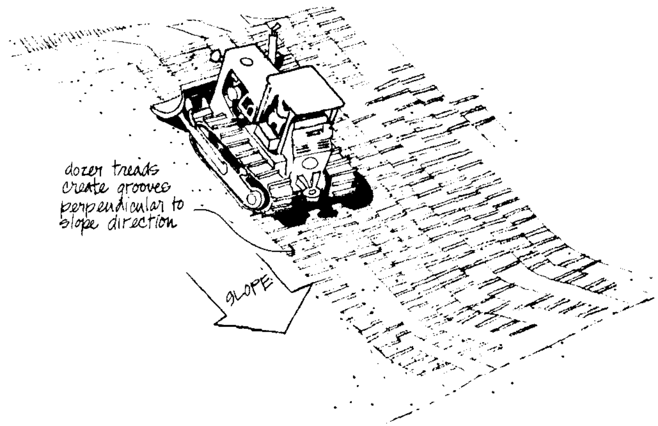


Figure 1

On sites where the spoil is subject to settlement and the lack of compaction is a problem, the Jones and Brague Mining Company have found that a vibratory compactor gives better results than conventional disking and harrowing after spreading 6" of topsoil. The company has been recognized for excellence in reclamation by the Soil Conservation Service (3).

On steep slopes, it may not be feasible to use a disk harrow for seedbed preparation if operations are (as required on the Regulations) carried out along the contour. In these cases a slope disk or a chain-type pick harrow should be used (Figure 2). Where operators do not have a slope disk, it may be desirable to run a dizer up and odown the slope to leave cleat marks to help control erosion while seed germinates (Figure 2).

Figure 2



UNVEGETATED SLOPES SHOULD BE TEMPORARILY SCARIFIED TO MINIMIZE RUNOFF VELOCITIES

Topsoil is a valuable source of seeds, particularly of native species which may be unavailable commercially and which will result in much more diversity of plants on reclaimed land. The operator can also be assured that the seeds found in the topsoil on the site are adapted to the locality. Seeds of many species remain viable in the soil for several years and therefore should survive topsoil storage for short life sites.

REFERENCE

(1) Jensen, I.B. and Hodder, R.L., Oct 1976, "Custom Designed Surface Manipulation and Seeding Equipment for Erosion Control & Vegetation Establishment," 6th Symp. on Coal Mine Drainage Research, NCA/BCR, Louisville, KY.
(2) Beauchamp, H. et al., Apr 1975, "Topsoil as a Seed Source for Reseeding Strip Mine Spoils," Res. Journal 90, Agricultural Experiment Station, Univ. of Wyoming, Laramie, WY.
(3) Davis, H., Dec 1976, "Jones and Braque Recognized for Excellence of its Reclamation," Coal Age, pp. 94-97.

PROBLEM & PURPOSE

1. Lime - Substantial dressings of lime may be required on acid soils to raise pH values, although it is probably rare that acidity is the limiting factor to plant growth on mine spoils (even those which were haphazardously dumped prior to these Regulations). More frequently, toxic levels of manganese and aluminum which are available to plants at low pH values are likely to be the cause of poor growth and survival of vegetation on unreclaimed mine spoils with very low pH.
   Whatever the actual cause of poor vegetation growth, addition of lime to raise pH values to between 5.5-7.5 results in much-improved vegetation growth. The operator will be advised to try to achieve a soil pH within this range if the standards for the success of revegetation are to be met with minimum delay.
   The growth of most grasses and particularly legumes is inhibited on spoils with a low pH, and is much improved by additions of lime. Liming may not only neutralize acid spoils but it may also reduce the rate of formation of sulfates from pyritic sulfur by reducing the activity of the bacteria involved in this reaction.
2. Fertilizers - There are likely to be deficiencies of soil nutrients necessary for plant growth on most reclaimed mine sites, even after replacement of topsoil. Deficiencies may be severe, especially in cases where a topsoil substitute of selected overburden material is being used. Deficiencies can be corrected quite easily by the addition of fertilizer. The balance of nutrients in the fertilizers used should be matched to the soil tests as required in the Regulations and to the nutrient demand of vegetation which is to be established. For instance, a high phosphate fertilizer that is relatively low in nitrogen tends to favor legumes. The variability of mine spoils, even when backfilling has been carried out with great care, makes the prescription of fertilizer requirements valueless without careful sampling and analysis. Topsoiling, as required by the Regulations, makes the fertilizer requirements of reclaimed surface mines more predictable. But as plant roots penetrate beyond the soil horizon, the response may be erratic.

APPLICABILITY

Liming should generally be carried out on all reclaimed surface mine sites. It is particularly important where the overburden has a low pH value and particularly so on highly diverse spoils where there is an increased chance of acid-forming materials mistakenly being placed too near the surface. The rate of application will depend on soil tests as required in Part 780 of the Regulations. When spoil has a very low pH value, it may be advantageous to apply lime before replacing topsoil and scarifying the regraded spoil and again after replacement of topsoil.

Fertilizers are also likely to be required on all reclaimed mine sites. The proportion of nutrients in the necessary fertilizer will vary widely from site to site. Many sites will not only require an initial application of fertilizer but will also require maintenance applications. This is most likely to be true for nitrogen which is easily and rapidly leached from the soil and utilized by the plants.

Application rates and the balance of nutrients in the fertilizer used will vary according to the results of soil tests. It is likely that recommended fertilizer and lime applications can be obtained from the overburden analysis, the cost of which is covered in the provisions of the Small Operator Assistance Program. In cases where a suitable topsoil substitute is identified in the overburden analysis, nutrient deficiencies are likely to be severe.

RELEVANT SECTIONS OF THE REGULATIONS

As part of the reclamation plan, surface mine operators are required to submit a soil testing plan for "evaluation of the results of topsoil handling and reclamation procedures related to revegetation" [780.18(b)(5)]. The performance standards requiring nutrient and soil amendments to topsoil [816.25] also refer to soil tests. "Nutrients and soil amendments in the amounts determined by soil tests shall be applied to the redistributed surface soil layer...all soil tests shall be performed by a qualified laboratory using standard methods approved by the Regulatory Authority." The chemical analysis of overburden strata required as part of the Geology description [779.14] will give the operator an indication of the strata which he should attempt to place near the surface to reduce low pH problems. This analysis is eligible for payment by the RA under the provisions of the Small Operator Assistance Program.

DISCUSSION & DESIGN GUIDELINES

I. LIMING

Most of the lime used will be atricultural lime (ground limestone). It will ususally be spread by the supplier with spinners on the back of the supply truck. The operator should make sure that the supplier provides evidence of the $CaCO_3$ equivalence, the measure of effectiveness of limestone which should be at least 90%. Using cheaper limestone with a lower rating may not justify the high cost of haulage. All particles of ground limestone should pass a 60 mesh screen for rapid effectiveness which is necessary for good response from vegetation. Operators should insure that spreading is carried out evenly, and lime should be tilled into the soil after application to a depth of 3 inches using a disc harrow.

Mays & Bengtson note that marl, blast furnace slag, cement plant flue dust and various other materials may also be used as soil additives to raise the pH value but, due to limited supply, only occasional localized use can be made of these materials (1). Operators who are close to a steel or cement works, however, would do well to investigate if these materials are available. EPA gives the following guidelines for application of lime (7).

1. Application of lime and fertilizers should be based on spoil test results.
2. Applied lime and fertilizers should be evenly spread over the area being treated.
3. Applied lime should be incorporated by disking and it appears that two or more disk treatments are needed where lime rates are greater than 20 tons per acre.
4. Applied lime should not be expected to move downwards below the zone of incorporation.
5. pH of spoils increases over a long period of time following incorporation.
6. Lime rates should be sufficient to react with acid brought to the surface during dry periods.
7. Fertilizer amendments may be applied to the surface after disking to incorporate lime.
8. Lime particles may be inactivated by coating with iron oxide, especially on acid sandy soils, thereby becoming useless for further reaction with acid.

Most plants grow best in soil with a pH range of 5.5 to 7.1 (1). Mays and Bengtson note that in the past, much research was aimed at finding plant species which would tolerate a low pH level and which would give the required vegetative cover primarily for erosion control on unreclaimed spoils. However, since the Act, the growing conditions on reclaimed surface mine sites will be so much improved that most operators will find it advantageous to select species with a reasonable tolerance to surface mine spoil conditions, but also with an economic value.

The requirements of the Regulations to bury acid-forming materials will undoubtedly result in a very marked improvement in the quality of revegetation of surface mine sites, especially in the case where pyritic materials previously tended to end up on top of the spoil where it was exposed to continual weathering. But other requirements of the Regulations, particularly that requiring replacement of topsoil, will not only improve plant growth but may also increase the tolerance of vegetation of acid conditions. Mays and Bengtson cite the careless placement of sulphur-bearing overburden as the most common cause of surface soil acidity on unreclaimed sites. But in these cases, additions of lime to correct the situation is only a temporary measure as further oxidation of the residual pyrite will again lower pH values. The mine operator may find it useful to acquire a small pH meter for carrying out spot checks on replaced spoil on the site to insure that the pH is within the desired range. Unfortunately, the simple colorimetric meters are not very reliable, but with experience in interpreting the results, they can be quite useful.

II. FERTILIZERS

Severe deficiencies in some plant nutrients, particularly nitrogen and phosphorous, are common on mine spoils and are more likely to be a limiting factor to plant growth than high acidity on many sites. Because nitrogen is more readily available to plants in soils with a high organic content and because little nitrogen is present in overburden, mine spoils are especially susceptible to nitrogen deficiencies. The Regulations require the replacement of topsoil which will, to some extent, improve the organic content of the soil and will contain some nutrients and, probably most importantly, soil microorganisms, but fertilizer will also be necessary. The Regulations require soil amendments [816.25] as indicated by the soil requirements.

Phosphorous (P) is commonly deficient on reclaimed sites and is important during the establishment of plants, particularly for legumes. P is not easily lost from the soil and one application is normally sufficient without subsequent maintenance applications. Application rates are normally 35 lbs.-71 lbs./acre (40 to 80 kgs/ha).

Nitrogen (N) is also commonly deficient on reclaimed sites; however, unlike P, it is highly mobile in the soil and is easily leached. Maintenance applications of N are almost certain to be required to keep plants growing vigorously unless there are plenty of legumes present in the vegetation capable of fixing atmospheric nitrogen. Fortunately, N deficiency is easy to identify in plants which are usually pale and yellowish and can be corrected rapidly with an application of fertilizer. Initial application rates of N are normally 45 lbs. - 90 lbs./acre (50-100 kg/ha) (1).

Potassium (K) is sufficient on most reclamation sites for plant growth. It is usually contained in the soil and produced during weathering. Generally, it is only in cases where plant materials are harvested that K is lost from the system in quantities that require replacement.

Mays and Bengtson note that deficiencies of micronutrients is rarely a problem (1)

Nitrogen is usually applied as ammonium nitrate Urea is also used but may inhibit germination of seeds. Phosphorous is usually applied as triple superphosphate and potash (as has been noted) is not often needed. Ideally, the ratio of N:P:K in a fertilizer mix should be determined by analysis and then blended to order. Otherwise, diammonium phosphate (18:46:0) or ammonium polyphosphate (12:54:0) may provide the correct balance of nutrients. Usually fertilizers are spread in granular form but soluble fertilizers are applied also along with seed by hydroseeders; however, unless fertilizer requirements are small, application in a separate operation from hydroseeding before seedbed cultivation is more satisfactory.

Trees are generally more tolerant of nutrient deficiencies, particularly when established, than herbaceous plants. Ironically, young tree seedlings and direct seeded trees are often better able to survive on nutrient deficient spoils because the competition from vigorous grasses, etc. on fertile soils is more intense. Elsewhere in this Handbook, it is noted that efforts to establish trees and herbaceous cover together by direct seeding have not been very successful (see Sheets 7:13 and 7:14). It is difficult to justify maintenance fertilizer programs on the basis of future timber yields on sites restored for forestry. And so, if the post-mining land use is planned to be commercial forestry, considerable care should be taken in the choice of both tree species and herbaceous species. In some cases, choice of a leguminous tree with some timber value (e.g. European Alder for pulp) may be appropriate. In other cases, it has been found that the legume Sericea lespedeza provided sufficient nitrogen for newly transplanted loblolly pines on a site where 90 lbs./acre (100 kg/ma) of nitrogenous fertilizer would have otherwise been necessary. (1) Soil sampling to determine fertilizer needs is a very imprecise science. Although the cost of fertilizer is low compared with other requirements of reclamation, the fertilizer prices are rising rapidly. Recommendations should be obtained based on samples and analysis, but observant and responsive corrective action are needed, especially on sites with highly variable physical conditions and overburden types.

Mays and Bengtson note that fertilizer costs for reclamation sites are usually $16 - $32/acre ($40-$80/ha) and are small compared to the costs of backfilling and regrading (1978 costs).

Figure 1 Source: Soil Service, Inc., Denton, MD.

REFERENCE

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(7) Powell, J.L. et al., Oct 1977, "The State of the Art of Reclaiming Land Surface-Mined for Coal in the Western Kentucky Coal Field," Proc. Fifth Symposium on Surface Mining & Reclamation, NCA/BCR, Louisville, KY.

(8) Vogel, W.G., 1975, "Requirements and Use of Fertilizers, Lime and Mulch for Vegetating Acid-Mine Spoils," Vol. 2 Proc. Symp. on Surface Mining and Reclamation, 3rd, Louisville, KY.

PROBLEM & PURPOSE

The growth of vegetation on reclaimed mine sites can be improved by increasing the organic matter in the soil (which increases the water holding and the cation exchange capacity of the soil). This is particularly true when using selected overburden materials as topsoil substitutes which will be completely devoid of organic matter and most soil micro-organisms. Additions of sewage sludge can increase the amount of organic matter in the soil, provide some of the necessary micro-organisms, and a source of nutrients for plant growth (a ton of sludge solids might contain 30-40 lbs of ammonium nitrogen, 50 lbs of organic nitrogen, 40-100 lbs of phosphorus). Sewage sludge will also contain some organic acids which have been found to inhibit the activity of two of the bacteria involved in the production of sulfuric acid from iron pyrite. These are Thiobaccillus ferrooxidans and T. thiooxidans. Sewage effluent which is slightly alkaline (pH 6.8 to 7.2) can be applied with, or separately from, sewage sludge. (6) The use of sewage sludge appears to have tremendous potential in the reclamation of orphan mine land. This is also the case for surface mine operations which are conducted in conjunction with reclamation of orphan land where it may be necessary to supplement the available topsoil with a topsoil substitute. Sewage sludge can be useful in reconstructing topsoil substitutes.

APPLICABILITY

Providing the various pre-mining studies show that the disposal of sewage sludge on reclaimed sites is feasible and the approval of the RA can be obtained, the disposal of sewage sludge on reclaimed mine sites is applicable to most areas; however, it is important that operators meet Federal and State effluent regulations. Because of high haulage costs, a disposal site will have to be reasonably close to the treatment works. Repeated applications of sludge from industrial areas are not recommended because of the possibility of heavy metal buildup in the soil. The composition of sludges is highly variable and so careful analysis and monitoring is necessary.

Sites planned for long-term application of sewage sludge must be well drained, but application must not result in pollution of groundwater.

REVELANT SECTIONS OF THE REGULATIONS

There are no sections in the performance standards of the Regulations dealing specifically with the disposal of sewage sludge. However, it should be noted that Section 816.42 requires that all discharges of water from areas disturbed by surface mining activities shall be in compliance with all Federal and State laws and regulations. And at a minimum, the water quality effluent limitations set out in this Section must be met. Therefore, if any runoff of sewage effluent occurs or runoff of storm water which is polluted by sewage sludge, it must meet the quality standards of Section 816.42. Thus, application methods should be devised to minimize runoff. Section 816.25 of the performance standards which cover nutrients and soil amendments require that nutrients and soil amendments are applied in the amounts determined by the soil tests. Insofar as sewage sludge will contain some of the required nutrients, it may be that the RA will permit application of say N and P as sewage sludge and other nutrients identified as being necessary in the form of artificial fertilizer.

DISCUSSION & DESIGN GUIDELINES

I. SLUDGE CONTENT

The content of sewage sludge is highly variable, and it will be necessary to base applications upon analysis of the sludge and of the soil to be treated. The proportion of N:P:K and the concentration of various heavy metals are the most important variables which must be determined. A potentially toxic level of heavy metal is sometimes found in industrial sludge, though this problem is not likely to be serious unless repeated applications of sewage sludge are made. A typical N:P:K analysis for municipal sludges quoted by Halderson and Zenz is 5:2.5:0.4 (1). A corn crop utilizes 168:28-34:39 (by weight). Therefore, if sludge is used to supply the nitrogen demand, the phosphorous requirement will be exceeded considerabley, but potassium will still be deficient and the potassium (K) would have to be made up with artificial fertilizer. It should be noted, however, that much of the nutrient is in organic form and the rate at which it becomes available to the plant is difficult to estimate, so it is not possible to be precise about supplemental fertilizer requirements.

II. FEASIBILITY

Because of the difficulty of spreading liquid sludge and the need to cease spreading of sludge during wet weather, it may be necessary for the operator to have storage facilities on site which may not be feasible on smaller sites. Dried sludge (solids content 30% or greater) is more feasible for the smaller operator to use as it can be readily stockpiled, providing any runoff from the pile is not allowed to discharge into a waterway. Usually it can be handled using a front-end loader and an agricultural manure spreader. The ease of handling dried sludge will depend partly on the type of treatment and dewatering. Difficulties in handling sludge may make utilization uneconomical.

The feasibility of long-term utilization of sewage effluent is also limited by the cost of transportation and the desirability to cease application during wet weather conditions. In the majority of cases, therefore, long-term disposal of sewage effluent on reclaimed mine sites will only be feasible where the site is close to the treatment works where storage facilities can be provided, where applications will not result in pollution of surface or groundwater and where post-mining land uses will prevent the buildup of excessive nutrients in the soil.

III. HAULAGE

Only on sites close to a treatment works will the cost of sewage sludge be sufficiently low to justify utilization. Usually it will be transported by tanker and only where disposal sites are very large will rail haulage be feasible. Sewage sludge can be shipped liquid (less than 12% solids) or dry (more than 30% solids). The use of dry sludge is generally more feasible for smaller operation.

IV. STORAGE & SPREADING

Liquid sludge has up to 12% solids. The weather and soil conditions for spreading sludge are not always right, and unless an operator can get deliveries only when weather and soil conditions are correct (which is unlikely, as treatment plant managers are faced with continuous output) storage facilities will be needed on site. These are usually earth structures but are nevertheless expensive. In addition, solids will tend to settle when sludge is stored which makes handling more difficult. Handling of the liquid sludge is difficult and requires either special machinery or irrigation equipment. Or it requires a very precise ground shaping to give an even distribution by overland flow. Probably the smaller operator would consider using liquid sludge only when 1) the treatment plant will deliver when specified and in tankers equipped with a spreading system (probably a tank-type injector), or 2) when the site is planned for long-term sludge disposal as an approved post-mining land-use, when it may be economically feasible to install the necessary storage and distribution systems.

There are three major ways of spreading liquid sludge:

1. Overland flow. In this technique, liquid sludge is released from a gated pipe at the top of the slope and is allowed to flow above ground over carefully graded and cultivated land. Generally, slopes of less than 15% can be treated in this way if the objective is only to establish vegetation. Agricultural machinery is used but precise cultivation patterns are required along the contour to insure good distribution of sludge.

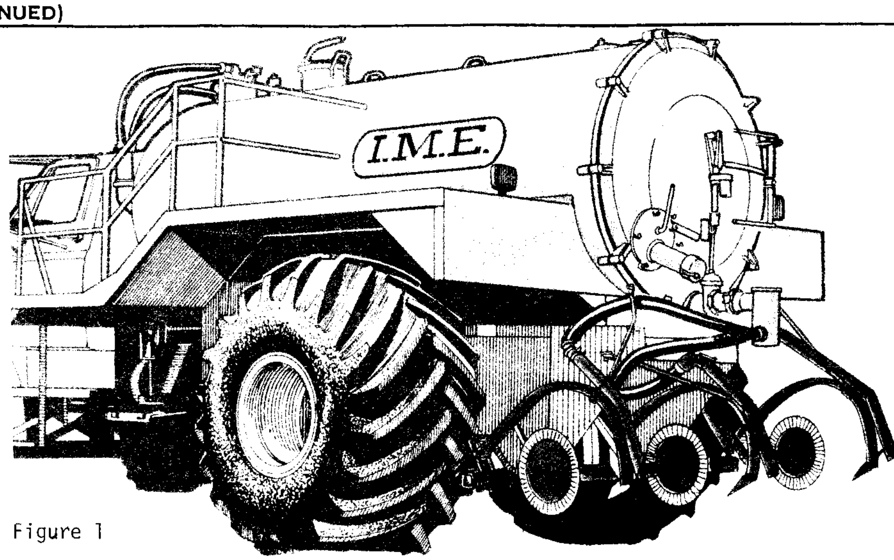

Figure 1

2. Injectors or Incorporators. Various injectors (using equipment rather similar to a chisel plow) and incorporation discs (using an adaptation of agricultural discs) are used to incorporate sludge directly into the soil. This reduces runoff. Injectors can be used where grass cover has already been established. The equipment is expensive and would be used on small sites only if attached to the delivery tanker. Figures 1, 2 and 3 show examples of injection equipment. In Figure 1, the IME tanker and sludge applicator, in Figure 2, the "Big Wheels" applicator, and in Figure 3, Biscroe Maphis applicator. The Big Wheels Injector is capable of injecting 600 gals-800 gals/min at depths of 6 in-8 in of speeds up to 6 mph. This injector has a 3-knife colter design and a new diesel unit has a 5-knife design.

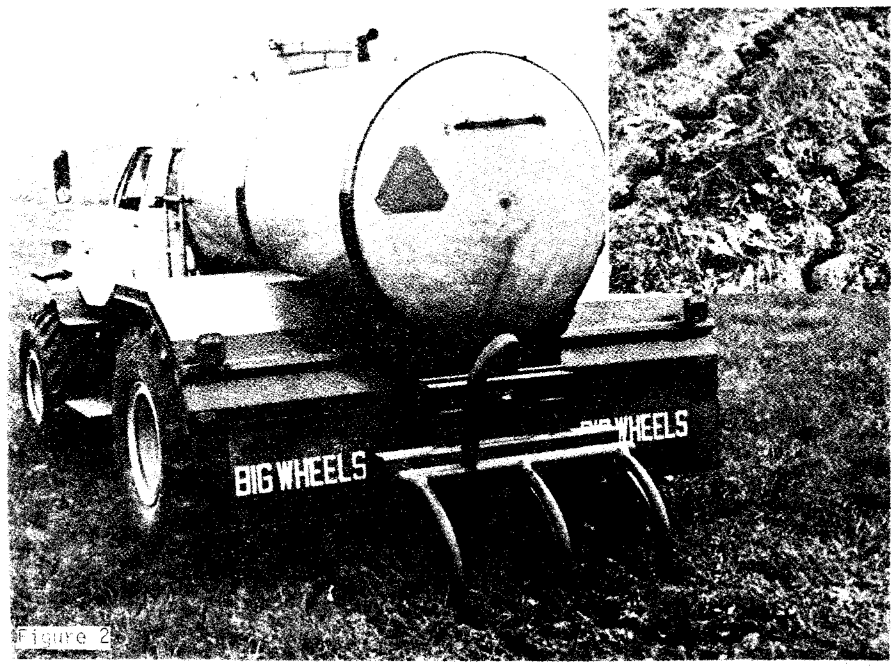

Figure 2

3. Irrigation Systems. Various irrigation systems have been used to apply sewage sludge. Nozzles must be a sufficient size to prevent clogging. It may be feasible for small operators to set up permanent irrigation and storage systems on sites where the approved post-mining use of the land is for long-term disposal of sludge. For short-term disposal, sludge will be pumped direct from the tanker.

Utilization of solid sludge (more than 30% solids) is much more practical for the small operation. Spreading is simpler and can usually be carried out with conventional agricultural equipment and storage presents no problems. However, dried sludge may not be readily available. If it is, the RA may approve application of sludge prior to the spreading of topsoil on regraded sites though it is more usual to apply sludge after topsoiling.

V. PROBLEMS

1. Runoff - The operator must be careful to minimize the amount of runoff contaminated with sludge which leaves the site. All runoff leaving surface

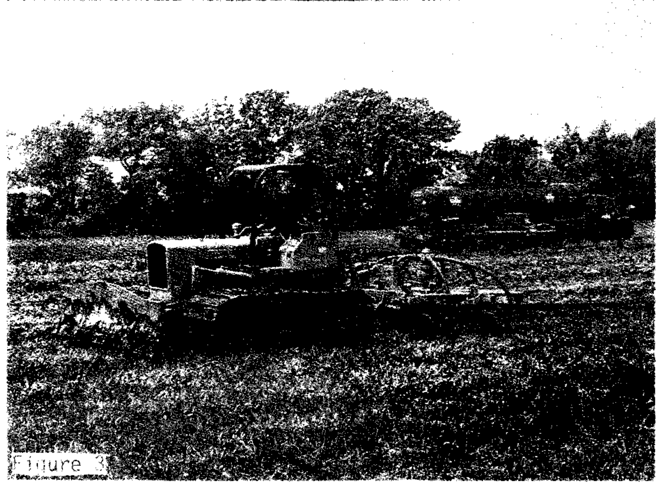

Figure 3

mine sites is subject to Federal and State effluent requirements and specifically to the requirements of Section 816.42. This may be difficult for operators in steep and mountainous terrain. Sludge which is applied with an injector is less likely to cause runoff problems.

2. Heavy Metals - Sewage sludge from industrialized areas may contain high levels of heavy metals and there has been concern that this can cause toxicity in plants and also may be taken up by animals. This problem may have been over-emphasized in the past, but the high risk warrants caution, and many States have guidelines for land application of sludge. Sewage sludge with high heavy metal concentrations should not be applied to spoil at pH lower than 6.5 as acid spoil conditions increase heavy metal availability to plants.

3. Odor - is unlikely to be a problem when sludge has been well stabilized; however, even in the absence of odor, complaints may be received if sludge is used near residential property.

4. Groundwater - Nitrogen is the most mobile nutrient in the soil and may percolate to some depth. This is unlikely to pose problems on most surface mine sites.

5. Seed Germination - was found to be inhibited by heavy applications of sewage sludge on some test sites.

6. Composition - the composition of sludge is highly variable and the nutrients in sludge are not in the balance as utilized by plants; therefore, deficiencies must be remedied by artificial fertilizers.

VI. LEGAL

The US EPA has published guidelines for the use of sewage sludge for land application. Most states have either legislation or guidelines for land application of sludge, and both EPA offices and the State divisions of natural resources or environmental protection should be contacted prior to using sludge treatment. In addition, the RA must be approached to determine their ruling on this operation.

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(2) Earl, T.A., June 1976, "Strip Mining Restoration Through Solid Waste Disposal," Society of Mining Engineers, AIME, 260.
(3) Sopper, W.E. et al., 1976, "Reclamation of Anthracite Coal Refuse Using Treated Municipal Wastewater and Sludge," Penn State University, Institute for Research on Land and Water Resources.
(4) Lejcher, T.R., Mar 1973, "Utilizing Treated Municipal Wastes for Strip Mine Reclamation," Mining Engineering.
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(6) DNR, Wisconsin, 1975, "Guidelines for Application of Wastewater Sludge to Agricultural Land in Wisconsin," Department of Natural Resources, Technical Bulletin 88, Madison, WI.
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PROBLEM & PURPOSE

Fly ash, a waste product from coal-burning power plants, has been used to improve the texture and the water-holding capacity of spoil or coal refuse, to raise the pH of acid spoil, and to reduce the surface temperature of coal refuse by lightening its color. It may be especially useful in situations where there is little or no topsoil available for reclamation, i.e., in reclaiming orphan land and in providing treatment for topsoil substitutes. In these situations, due to the variations in the characteristics of both fly ash and spoil, each application must be individually planned and will require specific approval from the RA. This makes the practice unattractive to most operators.

APPLICABILITY

This practice is applicable for use in reclaiming most surface mining sites but only as a "one-off" operation. It appears to have special potential for use in reclaiming orphan land where there is little or no topsoil available for reclamation.

REVELANT SECTIONS OF THE REGULATIONS

Section 816.25 (Topsoil: Nutrients and soil amendments) makes no reference to the possible use of fly ash. "Soil amendments in the amounts determined by soil tests shall be applied to the redistributed surface soil layer." Fly ash may also be used together with fertilizer, providing that its chemical constituents are known. This requires approval of the RA.

DISCUSSION & DESIGN GUIDELINES

Due to the variability of both spoil and fly ash, precise guidelines for the use of fly ash in reclaiming surface mine spoils cannot be given. Each case requires soil tests and analysis before application rates can be fixed and before plant species and fertilizers can be recommended. Hence, the practice will not be attractive to the smaller operator unless it has been successfully used on sites immediately adjacent which have similar overburden characteristics.

Fly ash disposal is a problem at coal-fired power stations and very little at present is utilized (only about 10% of the production). It was estimated (3) that in the early 1980's coal-fired generating stations will be producing 40 million tons of fly ash annually, the bulk of which is transported to waste disposal areas. The material is available free or for a minimal charge at the power station, but transportation costs rule out fly ash use unless the power station is close to the site. It is estimated that, as a substitute for limestone, approximately 10 times as much fly ash may be required; hence, the transportation costs are very high. Of course if the mine is supplying the coal to the power plant, transportation costs can be minimized theoretically as coal trucks can return loaded with fly ash to the mine site. Capp notes that the fly ash production of Ohio, Pennsylvania, West Virginia, and Kentucky amounts to over 7 million tons/year (1).

Fly ash is generated from burning coal. It is mostly fine material (1-50μ in diameter). In contains compounds of silicon, aluminum, iron and calcium, but also a wide range of other compounds and many trace elements, including those essential for plant growth (except nitrogen) (1). The benefits of using fly ash include:

1. Improving the water-holding capacity of the spoil and hence increasing the availability of water to plants;
2. Raising the pH of acid spoil though not all fly ash is sufficiently alkaline to give a significant improvement. pH values of ash used in Bureau of Mines experiments however were mostly over 11 (1).
3. Reducing the surface temperatures of dark colored spoils and coal refuse which may seriously inhibit plant growth. Fly ash will lighten the color of the spoil and cause more reflection of heat from the surface.

The inconsistency of results involving the use of fly ash is the most serious problem in recommending its future use, particularly on highly variable spoils. Fly ash also contains much higher concentrations of trace element than are found in soil, yet with the exception of some signs of boron and aluminum toxicity, neither plants nor animals were severely affected in tests (1). Cases of high uptake of aluminum by plants causing toxicity is usually associated with low pH values.

I. PROCEDURE

1. Before carrying out any feasibility studies on the use of fly ash during reclamation process, the RA should be approached to determine their policy. It is anticipated that where small mine operators are planning the reclamation of orphan land in conjunction with their surface mining operations, the RA will be receptive to suggestions for the use of various soil additives such as fly ash and sewage sludge to improve the quality and availability of suitable topsoil substitutes.
2. Find out if any field tests have been carried out in the area on sites which have similar overburden characteristics.
3. A soil analysis must be carried out to determine at least the water-holding capacity, pH, fertilizer requirements, and the texture of both spoil and soil (most of these are required by the Regulations).
4. Ash must be analyzed to determine its possible effect on the spoil including its pH, texture, chemical content and identification of any likely toxins.
5. Haulage from the power station must be arranged, preferably as a back-haul arrangement in coal trucks.
6. Spreading will ususally be carried out with a dozer or front-end loader or a grader if available. The thickness will vary considerably according to the results of spoil and ash tests.
7. Good mixing of the fly ash with the spoil or refuse is essential and is normally carried out with farm machinery, plowing or disking usually several times or roto-tilling.
8. The amount of fertilizer and the type of fertilizer will vary from site to site and will depend upon laboratory analysis. Capp (1978) (1) recommends that generally, a minimum of 1,000 lbs/acre of 10:10:10 analysis fertilizer be used.
9. Seeding of herbaceous species or grass is usually carried out with agricultural machinery or with a hydroseeder. This should be done in early spring or fall for best results. The seed mix shown in Table 1 has been found by Capp to be successful (1). Note that it contains 1 legume (Lotus corniculatus). This mix was usually applied at the rate of 46 lbs/acre (52 kg/ha) and mulching is recommended (1).
In other field experiments in revegetating unreclaimed surface mine spoils, 8 grasses and 7 legumes were tried out on a spoil with a pH of 2.5-3.0. Fly ash was applied at the rate of 600 tons/acre producing a spoil with a pH of 3.5-4.5 and a 10:10:10 fertilizer at 800 lbs/acre was applied. Survival of Kentucky 31 fescue, rye, redtop, orchard grass and birdsfoot trefoil occurred in scattered patches. Two hundred tons/acre more fly ash applied resulted in

spoil with pH values of 6.7-7.0 (the pH of the fly ash in this case was 9.9). It was noted that nodule formation on the roots of the birdsfoot trefoil associated with its nitrogen fixing capacity, had significantly improved with addition of fly ash.

(TABLE 1)
RECOMMENDED SEED MIX FOR UNRECLAIMED SPOILS TREATED WITH FLY ASH

Species		% by Weight
Kentucky 31 Fescue...	(Festuca arundinaceae)	35
Redtop Grass	(Agrostis alba)	14
Orchard Grass	(Dactylis glomerata)	18
Rye Grass	(Lolium perenne)	28
Birdsfoot Trefoil....	(Lotus corniculatus)	5

Source: (1)

10. Trees planted on sites that were treated with fly ash had a high failure rate in experiments carried out by the Bureau of Mines and the U.S. Forest Service (1). The cause of the high failure rate is not conclusive but probably was not due to the high acidity of the spoil. It is more likely to have been due to a chemical interaction between the ash and the spoil possibly affecting the availability of trace elements. However, after a period of 5 years, survival was good and it is likely that weathering and leaching of the treated spoil was largely responsible for the improved survival. Species with survival rates higher than 50% after three growing seasons are shown in Table 2.

II. COSTS

The costs of using fly ash in reclaiming a difficult 62-acre (25-ha site) by the Dept. of Natural Resources in West Virginia are shown in Table 3 (1). Capp notes that fly ash for this project was obtained free of charge. Because of the cost of transportation, the cost of utilizing fly ash will vary considerably from site to site. Operators must therefore adjust the costs when using Table 3.

(TABLE 2)
SURVIVAL OF TREE SPECIES ON MINE SPOIL TREATED WITH FLY ASH

Species		Survival Rate (3 growing seasons)
Crab Apple	(Malus sp.)	100%
Red Oak	(Quercus borealis)	67%
European Alder ...	(Alnus glutinosa)	58%
Scotch Pine	(Pinus sylvestris)	58%
Norway Spruce ...	(Picea abies)	50%
Black Walnut	(Juglans nigra)	50%

Source: (1)

TABLE 3
COST OF UTILIZATION OF FLY ASH IN RECLAIMING SURFACE MINE SPOILS (a)

Item	Cost/Acre	Cost/ha.
Fly ash (b)	$187.65	$463.68
Spreading and ripping (c)	178.07	440.00
Fertilizer (d)	75.00	185.33
Seed (e)	26.53	65.56
Fertilizer and Seeding	16.50	40.77
Soil Testing	15.00	37.07
TOTAL	$498.75	$1,232.41

Source: (1)

(a) Land acquisition, Grading and Supervision not included.
(b) 133 tons/acre (336 tons/ha) at delivered cost 10 miles (16 km) from power station at $1.08/ton (fly ash provided at no cost); $0.27/ton loading fee.
(c) 8.1 machine hours/acre (20 hrs/ha) at $22/hour.
(d) 1,000 lbs/acre (1,120 kg/ha) of 10:10:10 fertilizer.
(e) 46 lbs/acre (52 kg/ha) seed mix.

REFERENCE

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(3) Capp, J.P. and Adams, L.M., 1971, "Reclamation of Coal Mine Wastes and Strip Spoil with Fly Ash," Morgantown Energy Research Center, Bureau of Mines, Morgantown, WV.

PROBLEM & PURPOSE

It is important to protect seeded areas during the period of seed germination and growth. When the soil surface is highly susceptible to erosion and drying out, mulches reduce erosion. They reduce evaporation and increase soil moisture availability to young plants; also, they modify temperature extremes at the soil surface. Mulches provide a small amout of plant nutrients upon decomposition. Cover crops (Sheet 7:11) or mulch will protect the soil from rain impact and reduce soil crust formation (2). Mulches intercept and disperse much of the radiant energy of sunshine and the kinetic energy of rainfall. They also reduce evaporation from the soil surface so increasing the availability of water particularly for small seedlings. Mulches reduce the velocity of runoff and hence its erosive capacity.

APPLICABILITY

The use of mulches is applicable (and is required by the Regulations) to all surface mine sites. There are many mulch materials which can be used depending on the availability in the area and the price. In agricultural areas in the central coal province, straw and hay will probably be the most readily available. But in Appalachia, where many timber operations exist, wood bark and chips may be more readily available and cheaper.
On highly erodible sites (steep or long slopes), mulches are especially important in achieving effective vegetation cover without erosion. The use of mulches is particularly useful in the reclamation of orphaned land when the growing conditions in the spoil may be extremely unfavorable to plant growth.

REVELANT SECTIONS OF THE REGULATIONS

The Regulations specifically require mulching during the revegetation process on all sites as part of Section 816.114. (Revegetation: Mulching and other Soil Stabilizing Practices) "Suitable mulch and other soil stabilizing practices shall be used on all regraded and topsoiled areas to control erosion, promote germination of seeds, or increase the moisture-retention capacity of the soil." It should be noted that the RA may suspend the requirements for mulch if it can be demonstrated that mulching is not required. The RA may also require the mulch to be mechanically or chemically anchored to the soil surface [816.114(b)]. Cover crops can also be used, alone or in conjunction with another mulch, if approved by the RA (see Sheet 7:11) and chemical soil stabilizers can also be used in conjunction with vegetative covers approved for the post-mining land use [816.114(d)].
Section 816.114 does not specify a minimum amount of mulch that must be used. This is because it was felt that this should be left to the discretion of the RA to specify on a site-to-site basis because of the widely differing needs for mulch on different sites.

DISCUSSION & DESIGN GUIDELINES

Mulches are usually organic waste materials (straw, bark, etc.) but may also occasionally be inorganic materials. Spread over the surface of bare soils, they promote rapid and effective growth of vegetation by reducing erosion and by reducing the loss of moisture from the surface of the soil (where young plants are rooted). They also modify extremes in the surface temperature of the soil which is very important during the germination of seed. Mulches should be applied with additional fertilizers as the bacteria which break down the mulch material will utilize much of the nutrient in the soil and plants may suffer as a result. Partially rotted mulch will not cause this problem. Agricultural and forest product residues are the most commonly used mulches.

I. AGRICULTURAL RESIDUES

Straw and hay are probably the most widely used mulches in the United States. Other agricultural residues include peanut hulls, mushroom compost, and corn cobs. The use will depend principally on availability in each area. Agricultural residue mulches are likely to be considerably more expensive than forest product residues in hill terrain. Hay and straw will probably be delivered in bales, either standard bales or big bales. The latter can be handled with a front-end loader but spreading may be more expensive without specialized equipment. Straw and hay are chopped before application if a hydroseeder is used. They should be applied after the area has been seeded and fertilized and should be 'crimped' into the ground with a disk (mechanical anchoring may be required by the RA). Sometimes asphalt or a chemical stabilizer is sprayed over the mulch to hold it in place during windy conditions. The effectiveness of straw mulch was demonstrated in experiments on steep slopes using six different application rates. Rates of only 0.2 tons/ac (0.56 m tons/ha) and 0.45 tons/ac (1.12 m tons/ha) reduced soil loss to less than 1/3 of that from unmulched areas during a series of intense simulated rainfalls. 0.90 tons/ac (2.24 m tons/ha) decreased soil loss to 17% of the loss with no mulch and 1.8 tons/ac (4.48 m tons/ha) and 3.6 tons/ac (8.96 m tons/ha) reduced it to less than 5%. Runoff velocity was slowed by 0.22 tons/ac (0.56 m tons/ha) to half of that with no mulch. The photographs (Figure 1) show mulch rates as they appeared following 5" (12.7 cm) of intense simulated rainfall (6). The effect of the straw mulch rate on erosion and runoff velocity is indicated in the following table. The soil is unplowed Fox loam with a slope of 15% and length of slope 35.1 ft (10.7 m).

TABLE 1
EROSION RATES & RUNOFF VELOCITIES FOR VARIOUS RATES OF STRAW MULCH

Mulch rate		Erosion		Velocity	
tons/ac	m.tons/ha	tons/ac	m.tons/ha	ft/sec	cm/sec*
0	0	24.9	62.3	0.46	13.9
0.2	0.56	8.0	20.1	0.23	7.1
0.45	1.12	7.8	19.4	0.23	6.9
0.9	2.24	4.6	11.5	0.18	5.6
1.8	4.48	1.0	2.5	0	0
3.6	8.98	0.6	1.5	0	0

Source: (6)

*Average for plot section from 12.5' (3.8m) to 32.5' (9.9m) downslope.

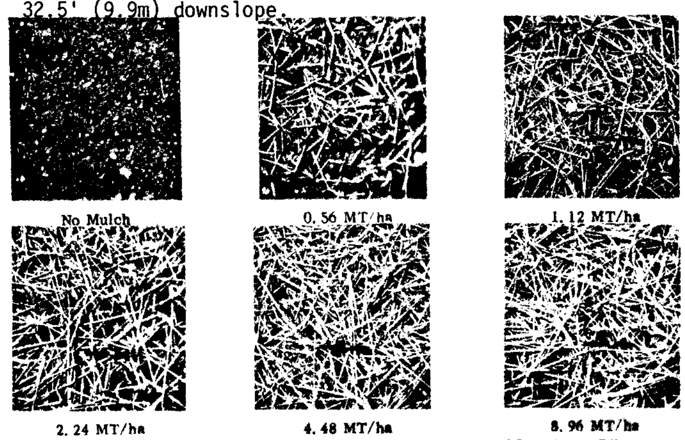


Figure 1. Mulch rates as they appeared following 5" (12.7 cm) of intense simulated rainfall. Photographs taken near top of plots. (Source: 6).

II. WOOD RESIDUE

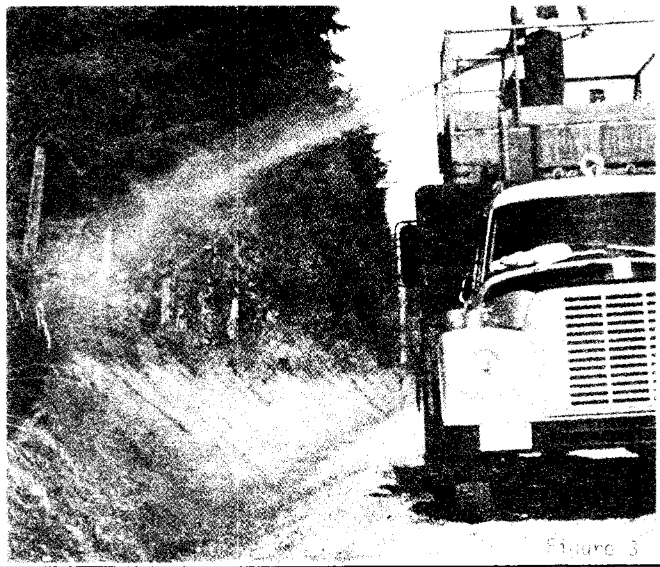
Bark, sawdust and wood chips of both hardwood and softwood are commonly used mulching materials. The use of shredded-chipped vegetation is highly suitable for operations in steep forested terrain where clearance of vegetation is made necessary by the Regulations which require topsoil to be removed. Even when the site is logged for saw timber or pulp, there will be considerable amounts of slash and debris which can be chipped and either applied immediately to contemporaneous reclamation areas or stockpiled for future use. Plass notes that the concern shown in the past over toxins in hardwood barks has been over-emphasized and that it is an excellent mulch. Woodchips and sawdust may cause temporary nitrogen deficiencies particularly when they are fresh. Partially rotted woodchips and sawdust are preferred as they tend to be waterlogged and less susceptible to be being blown away. If susceptible to wind, chips or bark mulches may be sprayed with asphalt or a chemical stabilizer. Bark mulch was found to give better protection than straw against soil erosion on steep slopes (Figure 2). There was significantly better revegetation on both plots with straw or bark mulch than on the unmulched control plots.

To spread bark or chips quickly, specialized equipment is necessary which may reduce the attractiveness of these materials. But faced with continuous availability and assured supply of these materials, it may be worthwhile to purchase equipment or to adapt an old farm manure spreader for the purpose. Plass suggests that application rates of 29-50 cu yds/ac (56-94 cu in/ha) gives adequate protection on most sites (1). The results of some experiments using medium and heavy rates of bark mulch which may be particularly appropriate for reclamation of orphan land in conjunction with surface mining activities may be found in (5).

Wood fiber mulches are widely used for application in hydroseeder mixes with a chemical soil stabilizer. Processed wastepaper (usually known as "wood cellulose")

Figure 2. Comparison of erosion on bark mulched plot (2a) and a straw mulched plot (2b) after 4 months of winter weather. Source: (5)

is similarly applied. Application rates are from 0.45 tons/ac (1,120 kg/ha) and 0.67 tons/ac (1,680 kg/ha). Both materials are applied with a color dye which helps the operator judge the evenness of the application. Weyerheuser recommends a minimum rate of cellulose fiber mulch of 1,200 lbs/acre on slopes flatter than 1v:4h or 1,500 - 2,000 lbs/acre on steeper slopes (7). Hydroseeder contractors will have experience with these materials. Truck-mounted hydroseeders cover 20 ac/load, the spreader reaching up to 200 ft (3) (Figure 3).



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(7) Weyerhaeuser Company, Box B, Tacoma, WA (Silva-Fiber mulch).

(8) Vogel, W.G., 1975, "Requirements and Use of Fertilizer, Lime and Mulch for Vegetating Acid-Mine Spoils," National Coal Association Surface Mining and Reclamation Symposium III, Vol. 2.

PROBLEM & PURPOSE

The purpose of soil stabilizers is similar to that of mulches, i.e., to prevent erosion and sometimes improve conditions for seed germination and growth. They cause soil particles to adhere to one another forming a crust which can be penetrated by water and germinating seedlings. The use of soil stabilizers is a comparatively new technique and not well proven, although the use of chemical binders or stabilizers in hydroseed mixes is normal practice by most contractors. Generally operators would not be advised to use chemical stabilizers alone unless successful results have been obtained in similar near-by situations or unless a manufacturer is prepared to carry out trial tests on the site.

APPLICABILITY

Applicable to all surface mining operations where the use of mulch is appropriate but generally should be used in combination with an organic mulch, as a binding agent. This is valuable for windy sites and for anchoring light mulches on steep sites where anchoring with a disk harrow is not feasible.

REVELANT SECTIONS OF THE REGULATIONS

Chemical soil stabilizers are permissible for use in revegetating reclaimed surface mined sites under Section 816.114 of the performance standards. "Chemical soil stabilizers alone, or in combination with appropriate mulches, may be used in conjunction with vegetative covers approved for post-mining land use" [816.114(d)]. Although the Regulations permit the use of chemical stabilizers alone, research results do not appear to indicate conclusively their effectiveness, and use as a binder or "tack" in combination with a chopped straw, bark, woodchip or other vegetative mulch may be more reliable.

DISCUSSION & DESIGN GUIDELINES

Chemical soil stabilizers should not restrict infiltration of rain water into the soil nor should they restrict the emergence of seedlings after germination. Formation of too dense a crust may be highly effective in erosion control yet prevent emergence of seedlings. Too thin a crust may not be effective in controlling erosion.

Soil stabilizers either penetrate the soil, forming a surface crust, or they form a thin film over the soil surface. They have variable durability, generally decomposing after several months. They tend to be rather costly and their performance under the highly variable conditions of surface mine sites (especially on orphaned mine land) is difficult to predict. In the absence of reliable local field trials of the product, operators should request manufacturers to carry out field tests on the product in order to evaluate the effectiveness and determine application rates, etc. Research offices of larger mining companies may also be a source of good local data on the use of soil stabilizers.

Unlike mulches, soil stabilizers, fertilizers and seed can be applied in one operation usually using a hydroseeder. Plass also notes that stabilizers help to reduce seed loss due to surface runoff as they are held in place until germination occurs (1). Chemical soil stabilizers are sometimes used to spray on mulches to hold them in place. Asphalt emulsion is also classified as a chemical soil stabilizer. Its use is fairly well proven both as a tack for organic mulches, and as a soil stabilizer. Wood fiber or celulose mulch may be very effectively combined with a chemical soil stabilizer and applied simultaneously with a hydroseeder. This is a standard practice by most hydroseeding contractors.

Application rates vary considerably for different products and for different soil conditions. In all cases the manufacturers recommendations, supplemented with data from any local field trials, should be used. In most cases it is suggested that small operators should use more traditional and more proven practices unless reclamation is being carried out by contractors.

A helicopter system named the hydrospyder was developed by Amcem Products, Inc., with Pennline Service Inc., Scottdale, PA. It uses a chemical mulch (Hyvetrol by Amcem) with fertilizer and seed included in the mix. Coverage was good in difficult terrain and the operation was carried out extremely quickly (2). The high cost per gallon for helicopter application makes the use of chemical stabilizers more economic than using organic mulches.

Reinco Industries of Plainfield, NJ, used a binder-tack called terra-tach which is mixed with wood fiber mulch and seed and sprayed together with hydroseeding equipment.

EFFECTIVENESS OF SOIL STABILIZERS IN FIELD TRIALS

In field trials, it was found that stabilizers were not necessary for vegetation establishment and that in a number of cases germination was inhibited. Sediment loss however was reduced in some cases but soil stabilizers were not more effective than conventional mulches. These experiments were recorded by Plass and compared vegetation establishment and erosion loss following thirty treatments with various mulches and twelve soil stabilizers (3).

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(1) Plass, W.T., 1978, "Use of Mulches and Soil Stabilizers for Land Reclamation in the Eastern United States," Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W. and Sutton, P., (Eds.), ASA, CSSA, SSSA.

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(3) Plass, W.T., 1972, "Chemical Soil Stabilizers for Surface Mine Reclamation," Northeastern Forest Experimental Station, Princeton, WV.

(4) Weid, W.W., Feb 1978, "An Analysis of Procedures, Soil Mediums and Plant Types of North Idaho Tailings Embankments and Tailings Pond's," HECLA Mining Company, Wallace, ID.

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PROBLEM & PURPOSE

Cover crops are used to give temporary vegetation protection to areas which are prone to erosion but are not yet ready for permanent revegetation, such as temporary spoil piles or stockpiles of topsoil. Many farm crops make good temporary cover and local agricultural practices and expertise can be used. Standard farm machinery can also be used to plant cover crops and, if appropriate, harvest them. However, in cases where cover crops are being used to give rapid vegetation establishment on permanently regraded sites, the cover crop is best killed with a herbicide application and the permanent vegetation seeded directly into the dead crop, which then acts as a mulch. Cover crops on storage piles of topsoil may also help to prevent nutrients being leached out of the soil during the storage period.

APPLICABILITY

The use of cover crops is applicable to all surface mine sites, for protecting topsoil storage piles and temporary spoil heaps. They are also useful for protecting areas which have been regraded and topsoiled but the season is not right for seeding permanent vegetation. In this way cover crops enable the operator to meet the requirements of the Regulations for contemporaneous reclamation even during these periods.

These measures are important in the following situations:

1. Where the mining operation results in large quantities of spoil being stored temporarily outside the pit. An open-pit where the coal is deep is an example.
2. On steep or highly erodible sites where it is feared that the speed of growth of a permanent crop may not give the necessary erosion protection. In these cases the annual cover crop may be underplanted with the permanent seed mix.
3. On sites where topsoil substitutes are being used, a two-step reclamation may give more reliable results. A cover crop is seeded onto the regraded area after applying the topsoil substitute and necessary soil amendments. In late summer the cover crop is then disked into the soil substitute and the permanent vegetation seeded immediately. This technique increases the organic matter in the soil substitute material and will also indicate any trouble spots.
4. On sites with highly variable physical conditions and on orphan land where little or no topsoil is available, cover crops are extremely useful as indicator crops. They will show up areas where soil conditions are not favorable for plant growth enabling selective measures to be taken. On orphan land cover crops disked into the soil before seeding permanent vegetation should improve growing conditions for the permanent cover.
5. In some cases, where a site has been regraded but immediate topsoil redistribution is not possible, it may be desirable to seed a cover crop onto the regraded spoil if it is capable of supporting plant growth.

REVELANT SECTIONS OF THE REGULATIONS

1. Protection of topsoil during storage. Section 816.23 requires that topsoil which is stockpiled temporarily is protected by an "effective cover of nonnoxious quick-growing annual and perennial plants, seeded or planted during the first normal period after removal," or other methods approved by the RA [816.23(b)(1)(i)]. Clearly, if the stockpile is to remain in place for more than one season, perennial vegetation must be used in the seed mix. Apparently the RA may require a cover crop to be seeded after only a portion of the stockpiled material is in place "if it is required for stability and to keep important nutrients from breaking down and leaching out."
2. Section 816.113 (Revegetation:Timing) states that "when necessary to effectively control erosion, any disturbed area shall be seeded or planted, as contemporaneously as practicable. . . with a temporary cover of small grains, grasses of legumes until a permanent cover is established."
3. The use of cover crops as a mulch substitute is referred to in Section 816.114 (Revegetation: Mulching and other soil stabilizing practices). "Annual grasses and grains may be used alone as an in-situ mulch or in conjunction with another mulch, when the regulatory authority determines that they will provide adequate soil erosion control and will later be replaced by perennial species approved for the post-mining land use" [816.114(c)]. Note that the use of a cover crop in this case must have the approval of the RA.

DISCUSSION & DESIGN GUIDELINES

Generally, quick-growing annual grasses or cereals are used for cover crops including Rye (Secale cereale), Wheat (Triticum aestivum), Japanese Millet (Echinochola crusgalli var. frumentacea) and Foxtail Millet (Setaria italica) (1). Often they are seeded in combination with perennial species in which case care should be taken to insure that the cover crop's vigour or shade does not seriously inhibit the perennial species. Rye has been found to be tolerant to high levels of aluminum and manganese in the soil, a common occurrence on surface mine spoils. The Soil Conservation Service (Maryland) recommend the following seeding rates and planting seasons for cover crop (Table 1).

The seed should be applied uniformly with a cyclone seeder, a seed drill, cultipacker or hydroseeder (6). The use of winter wheat as a cover crop and indicator crop is illustrated in the case study described below.

Adequate fertilizer and, where necessary, lime should be applied prior to seedings to give rapid growth, unless soil tests indicate to the contrary. Temporary seedings should be accompanied by 400 lbs/acre or 10 lbs/1,000 sq. ft. of 10:20:20 fertilizer or equivalent. Soils which are known to be highly acidic should be limed (6). In some cases, where permanent cover is required, instead of sowing perennial species with the cover crop, the cover crop should be seeded first, then killed with herbicide and permanent vegetation seeded into the decaying crop using a chisel plow.

Table 1 Recommended Cover Crops (Western Maryland)

Grass	Seeding Rate	Above 1800 ft elev.	Below 1800 ft elev.
Italian Rye Grass	40 lbs/acre	Mar 15-Sept 1	Mar 15-Aug 1, Aug 1-Aug 15
Oats	3 bu/acre	Mar 15-Sept 1	Mar 15-June 1
Rye	2½ bu/acre	Mar 15-Oct 1	Mar 15-June 1, Aug 1-Oct 31
Weeping Love Grass	3 lbs/acre		May 1-July 15

Source: (6)

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

Studies at the Northeastern Forestry Experimental Station showed that, even during the summer months, herbaceous cover can be established using summer annuals which enables seeding to take place immediately after regrading and topsoiling (2). In Britain, Germany and some other coal-producing countries, rapidly growing legumes and grasses and other "green manure crops" are grown to be plowed into the soil to increase the organic content and improve texture, moisture-holding capacity and nutrient availability of the soil prior to the land being utilized for more intensive tillage crop production.

A two-step procedure for the reclamation of orphaned land was found to be successful in an experiment in West Virginia to reclaim an acid spoil (pH 3.8-4.0). The experiment involved seeding Rye with fertilizer in September and in May the following year the Rye was killed with herbicide and 1.5 tons/acre (3.8 m.tonnes/ha) of dolomite limestone and 45:94:111 lbs/acre (56:118:140 kg/ha) of N:P:K respectively was spread before reseeding with various mixes of grass and legumes. Germination of clover and grasses was excellent and subsequent yields were also good. Results showed that forage legumes on acid spoil can produce good ground cover and yield using this procedure. It is also promising for operations involving the reclamation of orphaned land in conjunction with surface mine operations.

As an example of the use of cover crops to establish vegetation on mine spoils prior to the 1977 Act the following case is described. In reclamation operations affecting 6,000 acres of old spoil land at the #19 mine in Cherokee County, KS, the Pittsburg and Midway Mining Company seeded the spoil after regrading and adding lime and fertilizer, with winter wheat at 2 bu/acre expecting a yield of 20 bu/acre. Wheat was grown not only for the 2,000-4,000 lbs/acre of organic matter which the crop returns to the soil. It was also an indicator crop to show up any trouble spots which needed special treatment on the site. After this the company finalized the drainage, touched up any rough spots and finally planted the site with permanent grass species (3).

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PROBLEM & PURPOSE

Much of the adverse impact which surface coal mining has had upon water resources in the past and which orphan land continues to have upon water resources is due to failure to revegetate worked-out areas.
Section 816.111 of the performance standards requires that each person who conducts surface mining activities "shall establish on all affected land a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of disturbed land or species that supports the approved post-mining land use." For areas designated as prime farmland, the conditions in Part 823 apply. Note the use of the word "effective." This is taken to mean that the vegetation must be effective in stabilizing the regraded site, preventing erosion and restoring the hydrologic balance. The use of native plant species is also noted and the obvious intention of the performance standards in reestablishing a plant community consistent with the ecology of the locality.

APPLICABILITY

The requirement to revegetate surface mine sites to applicable to all operations. There are some variations in the Regulations according to the planned post-mining land use.
It should be noted that most of the research in the past has been on the revegetation of unreclaimed mining spoils, sometimes spoil which has had minimal regrading but almost never with any topsoil application. The results of this research therefore have some applicability to the reclamation of orphan lands and to sites being worked in conjunction with the reclamation of orphan land. However, the conditions on sites reclaimed to the performance standards of the new Regulations will be far superior to the growing conditions on unreclaimed mine spoil. The selection of species which have some tolerance to the severe conditions of unreclaimed spoils will tend to give good results on reclaimed sites particularly in conditions of thin soils, common to Appalachia. It should be remembered however that many of the species which are most successful on mine spoils are not natives of the U.S.

RELEVANT SECTIONS OF THE REGULATIONS

The performance standards of the Regulations are very specific in respect of revegetation. Revegetation must be carried out promptly and, generally, species of the same "seasonal variety" native to the area must be used. The same "seasonal variety" means that it must consist of a mixture of species comparable to those naturally occurring during each season of the year. The vegetative cover must be capable of stabilizing the soil from erosion [816.11(b)(2)]. Only if approved by RA may introduced species be substituted for native species [816.112] and then only after appropriate field trials have demonstrated the desirability of the substitution.
The requirements that revegetation be carried out promptly means that is should be done during the first "normal period for favorable planting condition." The Section of the performance standards dealing specifically with timing of revegetation [816.113] notes that it may be necessary to use a temporary cover crop to achieve a rapid cover of vegetation (see Sheet 7:11).
As part of the application procedure, a plan for revegetation must be submitted to the RA [780.18]. The revegetation plan must include a schedule of revegetation with species and amounts per acre of seeds and seedlings to be used and the methods to be used in planting and seeding. Any mulching, irrigation, pest or disease control that is planned must be specified; and also measures proposed to be used to determine the success of revegetation should be noted as part of the information requirements that accompany the application. The RA may also require the operator to submit a description of existing plant communities within the proposed permit area and within any proposed "reference area." These are used as a basis for judging the success of revegetation. The methods for judging the success of revegetation are very specific [816.116]. For permit areas of less than 40 acres however, the methods are somewhat simpler (this only applies to sites with an average annual precipitation of more than 26 inches, i.e., all areas covered by this Handbook) [816.116(d)].
Areas which are replanted only to herbaceous species must sustain a ground cover of 70% for 5 full consecutive years. Areas planted with a mixture of herbaceous and trees and shrubs must sustain a ground cover of 70% for 5 consecutive years and 400 woody plants per acre after 5 years (except on steep slopes wehre 600 woody plants per acre are required). On sites larger than 40 acres, the methods for determining success are considerably more complex and vary with the proposed post-mining land use. The use of "reference areas" is required although the RA may approve the use of other procedures (Technical guidance procedures published by USDA on the revegetated area must be equal to the ground cover and productivity of plants on an approved "reference area" close to the site. When this level is achieved a "period of extended responsibility" begins which lasts on all sites with more than 26 inches of rainfall (those covered by this Handbook) for not less than 5 years. At the end of this "period of responsibility" the operator will be released from his bond providing the quality of the vegetation remain satisfactory.
Section 816.116 does note however that, where previously mined lands are reaffected by surface mining operations, the operator may use different standards for success. "As a minimum, the ground cover of living plants shall not be less than can be supported by the best available topsoil or other suitable materials in the reaffected area, shall not be less than the ground cover existing before redisturbance, and shall be adequate to control erosion" [816.116(b)(3)(i)]. This Section also makes specific allowance for sites for which the proposed post-mining land use is industrial or residential and for sites to be used for crop land. Section 816.117 deals with the revegetation of land for commercial forestry. The essential requirement of this section is that the area shall have a minimum stocking of 450 trees or shrubs per acre of which a minimum of 75% shall be commercial timber species.

DISCUSSION & DESIGN GUIDELINES

I. RESEARCH RESULTS

Formal research into revegetation of mine spoils has been going on in the United States for at least 40 years but the emphasis of early research was to identify tree species with a high rate of survival and growth on surface mine spoils with little or no regrading or topsoiling and minimal additions of fertilizer or lime. Vogel notes in his summary of reclamation research that very little attention was paid to the establishment of herbaceous cover until recently when the emphasis of research has tended to shift in this direction. This shift was in response to State sediment and erosion control requirements of surface mine spoils. The present Regulations also require herbaceous cover to control erosion; therefore, we can expect a continued emphasis on the effectiveness of herbaceous cover in research in the near future.
In addition to controlling erosion and sedimentation,

effective revegetation also will help to restore the hydrologic balance. Mining will tend to cause an increase in the peak flow rate in streams draining the mine site. Two-five times the volume of pre-mining peak flows may be expected in moderately steep terrain. Vogel notes that one Forest Service study showed that peak runoff rates were cut in half by terracing and revegetation (1).

Because approval is required from the RA if introduced species are to be substituted for native species, some of the research carried out in the past on the relative growth and survival of introduced species on mine spoils will not be relevant. However, on sites that have been previously affected by mining and in cases where combined surface mining operations and reclamation of orphan land is taking place, this research will be of value.

II. FACTORS AFFECTING SURVIVAL AND GROWTH OF VEGETATION ON SURFACE MINE SITES

The factors which affect the survival and growth of vegetation on reclaimed mine sites will change dramatically when regrading and topsoiling occur. The major factors limiting plant growth and survival on unreclaimed mine spoils are the stability of the spoils, the pH and nutrient availability, and also the water availability in the surface of the spoil. After regrading and topsoiling, the main factors limiting growth will probably include soil compaction and drainage. Clearly, the factors which are important on unreclaimed spoils are not nearly as serious on regraded and topsoiled sites. The slope characteristics will profoundly affect the chances of survival of vegetation. This includes both the steepness of the slope and the aspect of the slope. Steep, south-facing slopes will be very much warmer and drier than north-facing slopes. This can be easily observed by the relative survival of volunteer plant growth on north- and south-facing slopes on orphan land. Even on sites where the operator meets all the regrading and topsoiling requirements of the new Regulations, there are likely to be difficult spots where vegetation fails. These are unlikely to be the result of one factor but of a complex of interacting factors, causing the failure. On particularly difficult sites, it may be appropriate to grow a quick-growing indicator crop (which can also be a cover crop) to show up any problem spots.

Although low pH conditions received a lot of attention in past revegetation research, acidity is in itself very rarely a limiting factor to plant growth on orphan land. Good growth has been found on spoil with pH values as low as 3.4. Indirect effects of the acidity, such as the liberation and mobilization of toxic elements, is probably more serious. An example is aluminum which is released from clay and, in acid conditions, forms aluminum phosphate, making phosphorus unavailable to plants (9). The deficiency of phosphorus is frequently a limiting factor to plant growth on orphan land. Herbaceous species and black locust have been found particularly susceptible. It was found that the performance of legumes is a good indicator of phosphorus availability on mine spoils (7).

The adverse impact of compaction and consolidation on the survival and growth of tree species was demonstrated in experiments in Kansas, Illinois, and Missouri. Besides having a much better survival and growth, there was a greater and more rapid accumulation of plant litter and improvement of soil conditions on ungraded plots. A good herbaceous and shrub understory was observed on ungraded plots but not on graded plots (8).

III. COVER CROPS

The use of cover crops may be necessary where prompt seeding of perennial vegetation is not possible (see Sheet 7:11). However, the use of cover crops is not limited to situations where a quick vegetation cover is required. Cover crops, killed with herbicide before seeding, and permanent vegetation or cover crops plowed into the surface soil can significantly improve growing conditions for permanent vegetation. These management methods are practiced widely on reclamation sites in Britain and Western Germany which are to be used for agriculture as a post-mining land use. On sites to be reclaimed for agriculture the creation of soil conditions by such management practices is important.

IV. COMPETITION BETWEEN HERBACEOUS AND TREE SPECIES

Work is being carried out at the Northeast Forest Experimental Station at Berea, KY, to investigate the effect of competition of herbaceous species on the survival of trees. It has been found that the effect of competition was to reduce growth of trees considerably but not the survival rate. Experiments with alternate strips of grasses and legumes 5.25' wide (1.6 m) and hybrid poplar cuttings 3' wide (0.9 m) are also in progress, and the survival and growth of the poplars have been found to be good (1).

V. NATIVE SPECIES

It has been mentioned that the performance standards require that native species be used unless introduced species are specifically approved by the RA. In the case of herbaceous species, the operator may have some difficulty in obtaining seed which gives a reasonable diversity of plant materials. The topsoil stripped and redistributed will contain seeds of species previously on the site and will result in considerably more diversity than would be obtained from the seed mix alone. Mulch hay for reseeded areas will also often contain considerable quantities of seeds of various herbaceous species. Mulch will improve the diversity of the vegetation.

VI. SEED INOCULATION, SOIL MICROORGANISMS

Some experiments recently have tested the use of inoculation of seed and injection of the soil with bacteria of fungi to speed the buildup of microbial organisms in the soil and to increase formation of nodules of the roots of legumes. It will be some years before this practice can be recommended for general use. The absence of soil microorganisms in topsoil substitutes from overburden materials may result in poor vegetation growth for several years.

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PROBLEM & PURPOSE

In the past much of the emphasis of revegatating mine spoils was on trees and shrubs. However, they are not as important as herbaceous cover in controlling erosion and stabilizing the hydrologic balance in mined areas. The Regulations therefore generally require tree and shrub planting which:

1. is appropriate for the approved postmining uses of the site and
2. is consistent with the variety and diversity of the surrounding plant communities. The amount and type of tree planting on reclaimed sites should reflect the landscape characteristics of the area.

When the approved post-mining land use is for non-commercial forest uses (which include wildlife management, recreation, shelterbelts, etc.) or commercial forest use, the requirements of the Regulations are quite specific relating to the stocking rate and cover of tree and shrub species.

APPLICABILITY

The extent, type and species of trees planted on reclaimed sites will vary with proposed post-mining use of the land and the characteristics and distribution of forest land in the locality. Tree planting is applicable for almost all surface mine sites even in cases where the approved post-mining land use includes no forestry or woodland.

On many of the remote, small, steep sites in Appalachia the approved post-mining land use is likely to include either commercial or non-commercial forestry. Fortunately there has been considerable work in the past on the survival and growth of trees and shrubs on mine spoils.

REVELANT SECTIONS OF THE REGULATIONS

The emphasis of the Regulations is on achieving an effective herbaceous ground cover for erosion control on all sites. The requirements of the Regulations for tree and shrub planting, stocking and success are quite specific on land where the approved post-mining use is commercial or non-commercial forest [816.117].

As part of the application procedure, the RA may require a vegetation map [779.19] delineating and describing existing vegetation types within the permit area and any proposed "reference area." This enables the RA to judge the appropriateness of the proposed planting on the reclamation plan, and also provides a basis for judging the success of revegetation. The reclamation plan [780.18] must include a list of species and seedlings to be used. Section 816.112 specifies that introduced species may be substituted for native species only with the approval of the RA. Consequently the introduced species which have good survival and growth on orphan land may not be appropriate for use on reclaimed sites under the present performance standards without special approval.

The requirements of the Regulations with respect to stocking rate and species of trees and shrubs vary for sites planned for commercial forestry use [816.117(b)] and for sites planned for forestry uses other than commercial forestry such as wildlife management, recreation, and shelter belts [816.117(c)].

Small mine operators should note that, if approved by the RA, a simpler method for judging the success of revegetation than the "reference area" is permissible. This applies only to permit areas of less than 40 acres. [816.116(d)]. "Areas planted with a mixture of herbaceous and woody species shall sustain . . . 400 woody plants per acre after five years. On steep slopes, the minimum number of woody plants shall be 600 per acre."

DISCUSSION & DESIGN GUIDELINES

I. FACTORS AFFECTING SURVIVAL AND GROWTH AND THE CHOICE OF TREE SPECIES

Much of the early research into surface mine reclamation dealt with the survival and growth of tree species on reclaimed mine spoils. Although some research was begun more than 40 years ago, few experiments on tree planting are much more than 10 years old. At present the Northeast Forest Experimental Station at Berea, KY, is evaluating the survival and success of tree species on mine spoils in Indiana, Ohio, Illinois, Missouri, Kansas and Oklahoma (3). Early research produced lists of recommended species for various conditions which were often related to the pH. It seems from the published results that much of the emphasis of the early research was on the tolerance of species to low pH levels while other spoil conditions particularly physical conditions, water-holding capacity, etc., received little attention. There has been speculation amongst researchers that individual plants which survive in very adverse conditions are genetically different from those which fail. However this hypothesis is not substantiated. It is difficult to give a reliable pH range at which trees of various species will survive. With herbaceous species, it is possible to be more precise but depending on other growth conditions, particularly moisture-holding capacity and nutrient availability, some trees will tolerate widely varying pH values. In fact it is unlikely to be the pH which actually determines the survival of the plant species but some side effect which pH has, for instance, on nutrient availability or toxicity. Therefore, the pH ranges given in Table 1 should be used with caution.

The availability of water is one of the most important factors effecting the survival of young tree seedlings in competition of herbaceous cover, for lack of both water and nutrients may seriously inhibit growth of young seedlings. Larger trees may also have difficulty obtaining the necessary soil moisture. On Sheet 7:12 mention was made of methods of avoiding herbaceous competition with trees by seeding alternate strips of grass and trees (Figures 1 and 2). It should be noted that pines are more generally tolerant of dry conditions than hardwoods because, though they take up about the same amount of water in optimum growing conditions, the rate of uptake falls more rapidly in pines under dry conditions.

Figure 1. Experimental Plantings of Alternate Strips of Hybrid Poplar and Herbaceous Cover. Trees are 4 Months Old. Source: (9)

Figure 2. Experimental Plantins of Alternate Strips of Hybrid Poplar and Herbaceous Cover. Trees are 3½ Years Old. Source: (9)

Trees differ widely in their ability to tolerate excess water and poor drainage. The most tolerant species are generally hardwoods, with the exception of spruce (Picea), and include willows (Salix), Cotton Wood (Populus), Sycamore (Platanus) Sweetgum (Liquidamber) (2). It should also be noted that where air pollution is a problem broadleaf species tend to be more tolerant than coniferous species. Bennett notes that red maple (Acer rubrum) and sugar maple (A. saccharum) were tolerant of most air pollutants (2). A major difficulty that is likely to be encountered in establishing tree species is competition from herbaceous vegetation. There are various approaches to trying to insure that herbaceous vegetation does not severely inhibit the survival and growth of trees and shrub species. The first is that already mentioned of sowing alternate strips of herbaceous plants and planting the intermediate strips with tree seedlings. The second is to sow the whole site to a fast growing cover crop followed by a herbicide application to kill the crop after it is well established. When this has been done, permanent herbaceous vegetation can be seeded into the dead vegetation in strips, the intermediate strips planted with tree seedlings. The survival of these should be good and benefit from the mulching effect of the dead vegetation. Operators may also have some difficulty in obtaining some of the recommended species.

Direct seeding of trees and shrubs has generally not been very successful on reclaimed surface mined sites and therefore it is recommended that surface operators wishing to establish tree and shrub species should plant these as seedlings. This can be done by hand or using planting machinery. Tree species recommended for use on reclaimed mine sites are listed in Table 1. Shrub species are listed on Table 2.

II. PLANTING METHODS AND MACHINERY

On sites planned for non-forest uses where the amount of tree planting is small, seedlings may be planted by hand. This is probably best carried out in the spring following seeding of herbaceous vegetation, but if the herbaceous vegetation is vigorous, the tree seedlings may not be able to compete for nutrients and soil moisture, resulting in poor growth. This however may not seriously reduce the survival rate. In cases where herbaceous vegetation is smothering tree and shrub seedlings, application of herbicide around each seedling may be desirable. The seedling itself must be protected by a spray guard while applying the herbicide.

Where terrain is suitable for the use of planting machinery, when the number of seedlings to be planted is large or where planting is being carried out by contractors, planting machines will probably be used. There are various types of tree planters available. The Whitfield tree planter (Kentucky Reclamation Association) has a small oscillating device like a snow-plow directly in front of the ripper which clears a path, removing surface rocks which would hinder the proper setting of the seedling. Behind are two packing wheels which are independently mounted so soil can be uniformly compacted around the seedling. The Northeast Forest Experimental Station has developed a furrow seeder pulled by a small crawler tractor, designed to operate on rough land. There is also a Canadian development called a planting gun which inserts the tree in a plastic bullet, containing the seedling in a soil medium. The sides of the bullet are slit to allow the roots of the seedling to penetrate the soil. The Canadian Forest Service calculates a planting rate of 9½ trees per minute. Generally tree planting will be carried out by contractors and therefore the choice and purchase of machinery will not be a concern of the mine operator.

TABLE 1 - TREE SPECIES RECOMMENDED FOR USE ON RECLAIMED MINE SITES

Common Name	Latin Name	Native	Eastern (E) or Interior (I) Province	Comments
Red Maple	Acer rubrum	Yes	E/I	More common where the soil-moisture conditions are extreme - either very wet or quite dry. It is a poor soil-builder. Wood sometimes used for furniture.
Silver Maple	Acer saccharihum	Yes	E/I	Most common where there is a good moisture supply throughout the growing season. A bottom-land species.
Sugar Maple	Acer saccharinum	Yes	E/I	Thrives only on fertile, moist, and well-drained soils. Most commonly grows on soils with a pH range of 4.5-7.0. One of the most valuable hardwood trees: products are maple syrup and lumber.
European Alder	Alnus glutinosa	No	E/I	A very rapid growing nitrogen fixing tree with wide adaptation tolerant of very low pH (as low as 3.5). May have some economic value for pulp wood and can survive in very dry and in very wet conditions adapted to slopes of all aspects.
River Birch	Betula nigra	Yes	E/I	Bottom land species.

TABLE 1 (CONTINUED) - TREE SPECIES RECOMMENDED FOR USE ON RECLAIMED MINE SITES

Common Name	Latin Name	Native	Eastern (E) or Interior (I) Province	Comments
European White Birch	Betula pendula	No	E/(North) I/(North)	A species tolerant of a wide range of soil drainage conditions. May also spread by self seeding and grows in pH values 4.5 and 6.5. It has poor leaf litter and poor surface coverage.
Chinese Chestnut	Castanea molissima	No	E	-
White Ash	Fraxinus americana	Yes	E/I	Develops best on moderately well-drained soils. It is comparatively tolerant of temporary flooding. Provides hard, strong, durable timber.
Green Ash	Fraxinus pennsylvanica	Yes	E/I	A very promising species for use on all slopes prefers loams and clays.
Black Walnut	Juglans nigra	Yes	E/I	Grows best on deep, well-drained, nearly neutral (pH) soils. Reaches greatest size and value along streams and at the base of north- or east-facing slopes. Heavy, strong, durable heartwood easily worked.
European Larch	Larix decidua	No	E	Both Japanese and European Larch have been used successfully on reclaimed mined land. If the soil conditions are right, growth is rapid. But larches are often damaged by severe exposure and sometimes by late frosts. They are also sensitive to compacted soils. Both species provide good leaf litter.
Japanese Larch	Larix leptolepis	No	E	
Sweet Gum	Liquidambar styraciflua	Yes	E/I	Thrives on the rich, moist, alluvial clay and loam soils of river bottoms. Best growth is made on imperfectly and poorly drained soils having a high clay content. Timber products used widely.
Yellow Poplar	Liriodendron tulipifera	Yes	E/(Central and South) I/(South)	Grows well only in moderately moist, well-drained, loose-textured soils. Usually found in valleys and stream bottoms. Wood easily worked; used for shingles, boats, pulp.
Norway Spruce	Picea abies	No	E	Uplands species.
Jack Pine	Pinus banksiana	Yes	E/I	Makes reasonably good growth on soils with a pH of 4.5-6.6. Can maintain itself on very dry sandy or gravelly soils. Produces poor timber but widespread in some northern areas that otherwise would support no tree growth.
Short Leaf Pine	Pinus echinata	Yes	E/(South) I/(South)	The optimum pH range is 4.5-6.0. Will not tolerate a high pH. It is intolerant of shade but otherwise is adaptable and will grow on a wide variety of acid spoils. It has some insect problems but will sprout freely if cut or fire killed when young. Good marketable timber.
Austrian Pine	Pinus nigra	No	E	Can be planted on slopes of any aspect. Plant in banks or blocks. When planted near black locust, deer cause browse damage.
Longleaf Pine	Pinus palustris	Yes	E	Grows on soils low in organic matter, light-colored, sandy in the surface portion, and medium to strongly acid. Drainage is often good to excessive. May be worked for turpentine and rosin in combination with timber production.
Red Pine	Pinus resinosa	Yes	E	Susceptible to saw fly damage in some areas. Tolerant of slopes of all aspects.
Pitch Pine	Pinus rigida	Yes	E	Deep rooted and acid tolerant. Can survive fire injury. Small seedlings are susceptible to deer browsing. Plant in bands or blocks.
Eastern White Pine	Pinus strobus	Yes	E/(North) I	Adapted to northern Appalachians. Prefers humid conditions with a pH of between 4.5 and 6.0. Can survive a wide range of soil conditions and a little shade during initial growth.

TABLE 1 (CONTINUED) - TREE SPECIES RECOMMENDED FOR USE ON RECLAIMED MINE SITES

Common Name	Latin Name	Native	Eastern (E) or Interior (I) Province	Comments
Scotch Pine	Pinus sylvestris	No	E	Very tolerant of acid conditions (4.0-7.5) and slopes of any aspect and steepness.
Loblolly Pine	Pinus taeda	Yes	E/I	A very promising species with rapid early growth and a marketable timber. Survives pH 4.4-7.5 but is susceptible to ice and snow damage.
Virginia Pine	Pinus virginiana	Yes	E/I	Adapted to the southeast States. Optimum pH 5.0-6.0 but will grow on soils with pH as low as 4.6. Fairly tolerant of dry conditions below 1,000 ft. Intolerant of shade but responds well to fertilizer. It has a tall narrow growth and is good in combination with black locust.
American Sycamore	Platanus occidentalis	Yes	E/I	Bottom land species.
Eastern Cottonwood	Populus deltoides	Yes	E/I	Bottom land species. A desirable tree with good cover and rapid growth.
Hybrid Poplar	Populus spp.	N/A	E/I	Rapid growth and good survival at low pH. Marketable timber after 20 years. Cannot withstand grass competition.
White Oak	Quercus alba	Yes	E	Survives and grows well on most soil types except wet bottom and optimum pH range 5.5-8.0. Fairly tolerant of nutrient deficiencies and some shade.
Northern Red Oak	Quercus rubra	Yes	E/I	Survives on a wide range of soil types but is sensitive to deficiencies in soil moisture when young. pH range 5.0-7.0. Slow initial growth.
Black Locust	Robinia pseudo-acacia	Yes	E/I	Optimum pH range 6.0-7.6. Will often grow on pH of lower values. Prefers limestone soil. Not tolerant of poor drainage or competition. Plant below 3,500 ft in the Appalachians. It is spread by suckers and was used extensively on spoil banks. Susceptible to damage by the locusts borer which also limits marketability of the timber. Good leaf litter.

TABLE 2 - SHRUB SPECIES RECOMMENDED FOR USE ON RECLAIMED MINE SITES

Common Name	Latin Name	Native	Height Category	Comments
Dull-leaf Indigobush	Amorpha fruticosa	Yes	10'-20'	Legume which survive well in acid conditions. Forms dense thickets - spreads slowly.
Common Buttonbush	Cephalanthus occidentalis	Yes	10'-20'	Shallow ponds and wet shores.
Thorny Olive	Elaeagnus pungens	-	10'-20'	-
Pekin Cotoneaster	Cotoneaster acufifolia	-	10'-20'	-
Autumn-Olive	Elaeagnus umbellata	No	10'-20'	Non-legume but fixes atmospheric nitrogen. Good for wildlife and highly adaptable.
Amur Privet	Ligustrum amurense	No	10'-20'	Fruit provides food for wildlife.
Japanese Polygonum Flower	Polygonum cuspidatum	-	3'-10'	Quite adaptable - prefers moist sites but survives acid conditions.
Coralberry	Symphoricarpos orbiculatus	Yes	3'-10'	Old fields and open woods.
Cherry Olive	Elaeagnus multiflora	-	3'-10'	-
European Barberry	Berberis vulgaris	No	3'-10'	Birds eat fruits.
Blueberry	Vaccinium spp.	Yes	3'-10'	Acid-soil plants; tasty, edible fruit.

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PROBLEM & PURPOSE

A good cover of herbaceous vegetation protects regraded and topsoiled areas from erosion. The performance standards of the Regulations place strong emphasis on the need to establish an effective cover of herbaceous vegetation as soon as is practicable to provide erosion control. Recently there has been considerable research into the establishment of herbaceous vegetation on abandoned mine spoils. This is largely in response to State requirements to control erosion on surface mine sites and this is also a requirement of the present Regulations. The highest sediment yields from mined areas occur during the first six months of mining, and it has been shown that a good vegetative cover can halve the yield of sediment within six months (4).

APPLICABILITY

The requirements of the Regulations to establish an effective herbaceous cover as soon as practicable after regrading and topsoiling applies to all surface mine sites. In cases where it is not feasible to sow permanent species, a quick-growing annual cover crop should be used (see Sheet 7:11). The need to protect regraded and topsoiled areas is most urgent on sites which are highly susceptible to erosion, and a delay could be costly in terms of failure to meet the standards for success for revegetated areas.

REVELANT SECTIONS OF THE REGULATIONS

The relevant sections of the Regulations have been mentioned for revegetation generally on Sheet 7:13. Sections 816.111-816.117 of the performance controls contain the requirements for revegetating mine sites. In Section 816.111 it is stated that "the vegetative cover shall be capable of stabilizing the soil surface from erosion." Section 816.113 requires that "seeding and planting of disturbed areas shall be conducted during the first normal period for favorable planting conditions." That section also requires a temporary cover to be used "when necessary to effectively control erosion." Section 816.115 (revegetation - grazing) states that when the approved post-mining land use is range or pasture land, the reclaimed land must be used for livestock grazing at a grazing capacity approximately equal to that of similar non-mined lands for at least the last two full years of liability required under Section 816.116(b). The standards for success of revegetation are covered in Section 816.116. This requires that "ground cover and productivity of living plants.... shall be equal to the ground cover and productivity of living plants on the approved reference area." On mine sites with a permit area of less than 40 acres, the RA may approve a herbaceous cover of 70% sustained for 5 consecutive years rather than using a reference area for judging success. Mine operators should make sure that Section 816.116 is fully understood as it applies to their site and approved post-mining land use.

DISCUSSION & DESIGN GUIDELINES

I. NUTRIENTS

Herbaceous vegetation shows rapid response to nutrient deficiency or toxicity. At low pH, sufficient molybdenum may not be available for rhizobia in the root nodules of legumes. This partially accounts for the low tolerance which legumes have for spoils with a low pH. "Finding legumes that will grow and nodulate on extremely acid spoils is more difficult than finding grasses." The more tolerant legumes are Birdsfood Trefoil (Lotus corniculatus), Sericea lespedeza (Lespedeza coneata), and annual Lespedeza (L. stipulacea) (10). Aluminum and manganese come into solution in increasing amounts as acidity increases. These appear to be the main cause of toxicity to plants, and Vogel suggests that grasses and legumes tolerant of acid spoils are probably those which are most tolerant of aluminum and manganese toxicity (10). Most orphan mine spoils are deficient in phosphate which is another reason for the low tolerance of legumes to strip mine spoil conditions. The problem probably arises with ferric hydroxide, a product of the weathering of pyrite which can specifically absorb large quantities of phosphate making it unavailable for plants (8). On many sites a fairly heavy dressing of phosphate fertilizer will be necessary. Various researchers have shown that mine spoils in the eastern USA are frequently deficient in phosphorus and nitrogen but that potash is normally adequate. Phosphorus is particularly important in establishing legumes which are usually recommended to reduce the long-term requirement for nitrogen fertilizer because of their ability to fix atmospheric nitrogen. Refertilization is frequently necessary and observant, and responsive management is essential to correct nutrient deficiencies to obtain vigorous herbaceous vegetation.

II. TIMING

The importance of correct timing in sowing cover must be emphasized. Even during summer months quick temporary cover crops (see Sheet 7:11) can be provided by summer annuals giving effective erosion control at an early date.

III. RECOMMENDED SPECIES

In field trials on acid spoils in Kentucky, three grasses performed especially well: Weeping lovegrass (Eragrostis curvula), Blackwell stitch grass (Panicum virgatum), and Kentucky 31 tall fescue (Festuca arundinaceae). Lovegrass, when fertilized, was superior on acid spoils and even 70-90% cover was obtained in one season on spoils with a pH 4.0-4.5 when other species made hardly any growth (10). The Soil Conservation Service (MD) recommends the following seed mixes for use reclaimed mine spoils (Table 1).

TABLE 1
SEEDING MIXES & PLANTING SEASONS FOR USE ON RECLAIMED MINE SITES

Species	Rate Lbs/Ac	Seeding dates Below 1800' Elev.
1. Birdsfoot trefoil, "Viking" (triple inoculated)	10	Mar. 5 - Jan. 1 &
"Kentucky 31" tall fescue	50	Aug. 1 - Oct. 1
Canada bluegrass	10	
2. Crownvetch (triple inoculated)	10	Mar. 5 - June 1 &
"Kentucky 31" tall fescue	50	Aug. 1 - Oct. 1
3. Birdsfoot trefoil (triple inoculated)	10	Jun. 1 - Aug. 1
Weeping lovegrass (on site, with lower pH than Crownvetch)	3	
4. Crownvetch (triple inoculated)	15	Jun. 1 - Aug. 1
Weeping lovegrass	3	
5. Weeping lovegrass*	3	Jun. 1 - Aug. 1
6. Redtop	5	Mar. 5 - Jun. 1 & Aug. 1 - Oct. 1

Source: (1)
*Add briskly locust, black locust, autumn olive or Russian olive to mix at 1 to 2 lbs/ac.

Grandt recommends the following legumes for revegetating mined lands in the Interior coal province: alfalfa (Medicago sativa), Yellow sweet clover (Melilotus officianalis), Birdsfoot trefoil (Lotus corniculatus), Annual lespedeza (Lespedeza stipulaceae), Perennial lespedeza (Lespedeza cuneata).

The following Tables list and describe species of grasses, small grain and legumes which are frequently used in soil conservation. Various mixes of these species will be suitable for various conditons on different mine sites, and local expertise and experience should be used in choosing a suitable mix, fertilizer ratio and lime requirement for each site.

TABLE 2 - GRASSES COMMONLY USED IN SOIL CONSERVATION

Common Name	Latin Name	Comments
Weeping Lovegrass	Eragrostis curvula	A perennial bunch grass 5' (1.5 m) tall, with an extensive but shallow fibrous root system providing good, quick, and effective erosion control. Will tolerate pH as low as 4.0. It has low nutrient requirements but is responsive to fertile soil. It is hardy in all regions and is propogated by seed. Some values as a forage crop.
Bermuda Grass Vars.	Cynodon dactylis	A fast, spreading perennial grass with deep, spreading rhizomes and stolons. Very effective in erosion control. Will tolerate pH levels as low as 3.5. Responsive to nitrogen in the soil. Prefers lighter soils. Not hardy north of Indiana and Pennsylvania. It is propogated by seeding or by planting rhizomes and stolons. A good forage crop.
Tall Fescue	Festuca arundinaceae	A perennial bunch grass, deep-rooted and valuable for erosion control, especially in combination with legumes. Tolerates pH of 4.5. N, P, K, C, Mg must be available for good survival. Tall fescue is drought-resistant but prefers moist, medium to heavy soil. It is hardy in all zones and is propagated by seed. Used extensively on mine spoils.
Chewings Fescue	Festuca rubra	A fine-stemmed grass with a deep fibrous root system, very effective for erosion control. Tolerates pH above 4.5. N, P, K, Ca, Mg must be available for survival. Drought-resistant and hardy in all zones. Propagation by seed and used widely in soil conservation.
Red Top	Agrostis alba	Perennial grass with upright and creeping stems and a fibrous root system. Good for erosion control. Tolerant of low pH levels and survives with low nutrients but responds well to fertile soil. Tolerates poor drainage. Should not be grown in the southern Appalachians. Propagated by seed and fairly tolerant of shade and wear.
Switchgrass	Panicum virgatum	A perennial, broadleaf grass reaching 5' (1.5 m) tall. Produces dense sod, making it highly effective for erosion control. Tolerates pH above 4.5 and low fertility, though it responds well to fertilizer. Drought-tolerant but prefers moist soil. Used in central and eastern states only. Propagated by seed. Spreads slowly by short rhizomes. As a forage, it has low nutritional value but is used for hay on some mined areas.
Colonial bentgrass	Agrostis tenuius	Generally similar characteristics to Agrostis alba.
Creeping bentgrass	Agrostis palustris	Generally similar characteristics to Agrostis alba.
Velvet bentgrass	Agrostis canina	Generally similar characteristics to Agrostis alba.
Big bluestem	Andropogon gerardi	A grass reaching 5' (1.5 m) in height, with a strong and deep root system producing a dense sod, highly erosion-resistant. Tolerates pH above 6.0 and survives infertile soil, though responds well to fertilizer. Best on moist, well-drained soils and is hardy in all zones.
Little bluestem	Andropogon scoparius	Reaches 3' (0.9 m) in height, producing a dense underground root system resistant to erosion. Tolerates pH of 4.5, survives infertile soils but is more drought resistant than Big bluestem. Hardy in all zones. Difficult to establish and the seed may be difficult to obtain.
Broomsedge bluestem	Andropogon virginicum	A grass with a shallow root system, not good for erosion control but may be useful on soils with a very low pH (3.5). It is also tolerant of very poor soils and is hardy in all zones. Forage is of low quality.

TABLE 3 - SMALL GRAINS COMMONLY USED IN SOIL CONSERVATION

Common Name	Latin Name	Comments
Rye	Secale cereale	An upright annual, not spreading, with a fairly shallow root system, giving a rapid cover. Valuable as a temporary cover crop. It is the most productive small grain on acid soils and also can tolerate low fertility and poor drainage. Hardy in all zones and propagated by seed.
Barley	Hordeum spp.	Annual, upright, with shallow root system giving a rapid cover. Different varieties of varying pH tolerance but generally sensitive of soil fertility or drainage problems. Hardy in all zones, propagated by seed.
Oats	Avena sativa	Annual, upright, with shallow root system giving a quick cover. It has a wide range of pH tolerance but requires fairly fertile soils. It is more tolerant of poorly drained soils than barley but prefers cooler zones. Propagated by seed.
Wheat	Triticum aestivum	Annual, upright, with shallow root system giving a rapid cover. Has narrow pH tolerance range and requires fertile and well-drained soils. Hardy in all zones and propagated by seed.

TABLE 4 - FORAGE LEGUMES

Common Name	Latin Name	Comments
Alfalfa	Medicago sativa	A deep-rooting legume, good for erosion control, particularly in a grass mixture. Tolerant pH between 6-7. Good fertilization and drainage are essential. Hardy in most zones and propagated by seed. Excellent forage.
White Clover	Trifolium repens	A deeply-rooted legume, always used in combination with grass, giving good erosion control. The pH range is 6-7. Prefers fertile and well-drained soils. Hardy in all zones and propagated by seed. Extensively used in reclamation of disturbed areas.
Crimson Clover	Trifolium incarnatum	A legume with both tap roots and fibrous roots. It has a rapid fall growth and is valuable for erosion control. The pH range is 5.5-8. Good fertilization is essential for effective cover. Generally only used in southeastern states. Propagated by seed and used extensively for disturbed areas. Provides good winter grazing.
Birdsfoot trefoil	Lotus corniculatus	A perennial legume with taproot which penetrates to 3' (0.9 m) in depth with a lateral root system providing good erosion control. Tolerant of low pH and also tolerant of soils with low fertility and poor drainage. Used in northeastern and north-central states. Propagated by seed. A useful forage crop used extensively with a grass mixture on acid spoils.
Sericea lespedeza	Lespedeza cuneata	Perennial 5'-13' (1.5-2 m) tall with deep taproot system. Good for erosion control, with a pH range of 4.5-6.5. Tolerant of fairly low soil fertility and drought. Used mainly in southeastern states, propagated by seed. Used for hay and pasture.
Annual lespedeza	Lespedeza stipulacea	An annual lespedeza, deep-rooted and good for erosion control. The pH range is 4.5-6.5. Tolerant of low fertility but responds well to fertilizer. Also used mostly in southeastern states.
Red Clover	Trifolium pratense	Perennial, deep, taprooted legume with dense fibrous root system, effective in erosion control. Tolerant of pH as low as 4.5. Performs best on fertile soils which are well-drained. Mostly used in northeastern states and propagated by seed, often with a nurse crop of small grain.
Crownvetch	Coronilla varia	Perennial legume, with a root system which is spreading but also with a deep taproot. Very good for erosion control and tolerates a low pH, but best when pH is above 6.0. Prefers fertile soils though is tolerant of low fertility and drought conditions. Hardy in all zones and propagated by seed though it is slow to establish. It is used widely for stabilizing highway embankments.
Hairy vetch	Vicia villosa	A perennial legume with a mat growth. Very fast to spread. Effective in erosion control. A pH range of 4.8-8.2. Lime is needed on acid spoil. It is hardy in all zones and propagated by seed. Good for livestock forage.
Lathco flatpea	Lathyrus sylvestris	Tall climbing perennial, good for erosion control. A pH range of 4.8-5.0, Responsive to fertilizer. Drought-tolerant, used mostly in the northeastern states. Propagated by seed and good for wildlife cover.

TABLE 5 - AGRICULTURAL AND LAWN GRASSES FOR POSSIBLE USE IN RECLAMATION

Common Name	Latin Name	Comments
Bromegrass	Bromus inermis	A cool season grass. Spread by rhizomes and producing a deep root system and a heavy sod. Excellent in erosion control especially in combination with a legume. The pH range is 5-6, best on fertile soils. Fairly drought-resistant. Should only be planted in the eastern states. Propagation by seeds. Forage is highly palatable.
Timothy	Phleum pratense	Cool season grass, forming a dense sod, excellent for erosion control, tolerant of pH above 5 if nutrients are available. Not tolerant of poor soils. Do not plant in southern states. Propagated by seeds and may produce a valuable hay crop.
Orchard grass	Dactylis glomerata	Good for erosion control especially in combination with legumes. Has a pH tolerance range of 4.5 to 7. Tolerant of infertile soils but responds well to fertilizer. Hardy in all zones, propagated by seed. Produces valuable forage and grazing pasture of better quality mine spoils.
Perennaial ryegrass	Lolium perenne	A bunch grass valuable for erosion control because of the rapid cover it provides. Has a pH tolerance range of 5.5 to 7 but is not tolerant of low fertility nor drought. Not hardy in the northern and northeastern states. Propagated by seed and useful for pasture hay or silage, alone or in combination with other grasses or legumes.
Italian ryegrass	Lolium multiflorum	A bunch grass, not creeping, but used for erosion control in combination with other species. Similar characteristics to ryegrass and used to give rapid cover during cold months.
Kentucky bluegrass	Poa pratensis	Gives rapid cover. Perennial with dense rhizome sod. Rapidity of cover and density of sod make it excellent for erosion control. Tolerant of pH as low as 5.5. Best on highly fertile soils but tolerant of poorer soils. Prefers cool moist conditions and northern exposure.
Canadian bluegrass	Poa compressa	Perennial grass not as rapid as Kentucky bluegrass but giving good erosion control. The lower limit of pH range is 5.0. Grows well on soils deficient in nitrogen and phosphorus and drought-resistant. Prefers cool conditions and northerly exposures. Propagated by seed.
Reed canarygrass	Phalaris arundinanceae	Tall, coarse, cool season grass forming a sod with a dense root system giving good erosion control. The pH range is 4.9-8.2. Responds well to fertilizer and is tolerant of wet conditions. Useful in most of the northern Appalachians and the north-central states. Propagated by seed or by divots spread with a manure spreader and disk harrowed. Good for waterway stabilization.
Bahiagrass	Paspalum notatum	A warm-season perennial with a deep-rooted rhizomatous sod. Excellent in the southeastern states for erosion control. Prefers pH between 5.5 and 6.5. Tolerant of low fertility soils and tolerant of drought. Propagated by seed. Only for use in southern states.
Japanese lawn grass	Zoysia japonica	A low-growing rhizomatous grass, good for erosion control. Once established responds well to fertilizer but also tolerant of low fertility. Mostly confined to the southeastern states. Spread by rhizomes.

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CHAPTER 8

POST-MINING LAND USES

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MEASURES			0

PROBLEM & PURPOSE

The performance controls of the Regulations vary in a number of places according to the approved post-mining land-use. This sheet is intended to give the operator an overview of the alternative post-mining uses, and some of the implications of each. The post-mining land use will be a major factor affecting the future hydrology and water quality of the area.

Generally any change in land-use, particularly in cases where it involves obtaining variances from the approximate original contour restoration requirement, is likely to lengthen the application process. However, carefully selected and planned post-mining uses can save operating costs and significantly raise the post-mining value of the land.

APPLICABILITY

All mine operators should carefully consider all the alternative post-mining uses of the site. The choice will depend on a number of factors which will affect the feasibility of each use. For instance, some counties in West Virginia are reported to have only 6% of their land area which is not too steep for urban or agricultural uses (5). In these areas the demand for development land is likely to be high. If the local planning agency approves such a change of use, the RA is likely to grant a variance [785.15]. Generally any change in use must result in a post-mining use which is an equal or better economic or public use.

In some cases, the potential for creating new land-forms which surface mining offers can be realized. For instance Peabody constructed a 400 m gallon water supply reservoir for the town of Lynnville on one of their surface mining sites (6). In such a case, careful operational planning to make sure that the final cut is located correctly to minimize earthmoving to create the reservoir is essential.

In areas of poor groundwater resources it may also be feasible to create aquifers. Due to fracturing and shifting of the overburden, voids increase and the potential water storage capacity also increases. If the volume is confined by impermeable geologic strata, this can form an underground reservoir (7).

REVELANT SECTIONS OF THE REGULATIONS

Section 779.22 (Land-use information) requires as part of the requirements for information on environmental resources, a map of the uses of the land at the time of filing the application, and a narrative of the capability and productivity of the land.

Section 779.27 requires the applicant to determine whether any land within the proposed mine area may be prime farmland. If so the special performance standards for prime farmland (Part 823) apply.

Part 780 (Minimum Requirement for Reclamation and Operators Plan) requires:

1. A Fish and Wildlife Plan [780.16]. This is mostly to show how adverse impacts of mining on fish and wildlife can be minimized. For areas where the approved post-mining use of the land is for fish and wildlife, the applicant will need to show how the site is enhanced for this use.
2. Reclamation Plan: Protection of the hydrologic balance [780.21]. This Section is also mostly concerned with minimizing the adverse impacts of mining water resources. But clearly, where enhancement of the water storage capacity of the area is planned, it must be shown in this Section.
3. Reclamation Plan - Post-Mining Land Uses [780.23]. This Section requires a detailed description of the proposed land uses for the site. The operator must show that alternative land uses have been considered and also show that the chosen use is consistent with the land use policies and plans of the area. In this section it is stated that, "where a land use different from the pre-mining land use is proposed, all materials needed for approval of the alternative use" [816.133] must be provided.
4. Plans of any proposed impoundments which are proposed to be part of the post-mining land use plan must be included as a requirement of Section 780.25.

Part 785 (Requirements for Permits for Special Categories of Mining) included a section [785.14] on Mountaintop Removal mining and a section [785.16] on variances from the "approximate original contour" restoration requirements. These sections may be important for operators wishing to create relatively flat development land in areas of steep terrain.

An important section of the performance controls [Part 816] is Section 816.101 (Backfilling and Grading: General Requirements) which contains the "approximate original contour" requirement. There are also differences in the requirements of Section 816.111 (Revegetation: General Requirements) and Section 816.116 (Revegetation: Standards and Success) according to the approved post-mining land use. Throughout Part 816 there are a number of cases where it is stated that the RA may approve alternative land uses if the proposed use is compatible with adjacent land uses, and if it can be shown that the proposed use is feasible. There are several other conditions.

DISCUSSION & DESIGN GUIDELINES

These "guidelines" are intended as no more than a checklist of post-mining land uses, to provide the operator with a quick reminder of alternative uses and their implications.

LAND USE		DEMAND	PROBLEMS	COMMENTS
Urban Uses	Industrial, Residential, Commercial, etc.	In some areas of steep terrain the lack of level land is a serious constraint to development. Urban uses demand available water and developable land in close proximity. One may be available without the other. Accessibility is necessary.	Variances from the approximate original contour requirement must be obtained. Settlement of spoil mass may cause problems for several years after mining. Creation of developable land must be consistent with land use policy of local planning agency.	The post-mining land value for development land in areas where suitable land is scarce may be more than ten times its pre-mining value. The haphazard creation of areas of flat or gently sloping land in areas of steep terrain may result in an undesirable change in landscape character. In some remote areas accessibility can be improved. There are cases of airstrips on reclaimed mine sites, and improved sections of roads. The clearance of old deep mine dereliction (waste dumps, etc.) in conjunction with on-going surface mine operations has great potential for creation of industrial land and land for other uses.

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

LAND USE		DEMAND	PROBLEMS	COMMENTS
Water Storage	Surface Storage	Poor groundwater resources and unreliable or insufficient stream flow makes surface water storage necessary, particulary in parts of Appalachia. Water impoundments may have potential for multi-use for recreation, wildlife, etc.	Supply should be protected. The presence of acid-forming materials may make impoundment unfeasible. Old deep mine workings in the area may cause problems.	Mining operations may have the potential for creating impoundments either by damming or by excavation. In either case careful planning and coordination is essential to minimize the earthmoving required. Creation of an assured water supply and development land may help small communities in mountainous areas achieve some of their long term objectives. There are a number of cases of impoundments in final cuts which are not affected by acid drainage, being used to supplement local water supply. A reliable water supply may attract some processing industries and offset unemployment problems.
	Ground Water Storage	In some areas, groundwater yield is very low, usually due to the absence of water-bearing strata (aquifers). The creation of aquifers and reclamation to original contour may be feasible.	Fracturing and shifting of overburden will increase storage capacity but the aquifer must also be confined. Pollution of groundwater by acid drainage may make water unusable.	Surface mining increases void space in cast ground by 15-25%. This increases not only the water storage capacity but also the permeability and hence the recharge rate. Provided that the water in the spoil can be confined by relatively impermeable strata it can be recovered by pumping. The problem of oxygenated water coming into contact with pyrite must of course be recognized.
Agriculture	Cropland	Most land suitable for reclamation as cropland will be prime farmland and subject to the special performance standards of Part 823. The creation of prime farmland is likely to cost in the region of $5000 per acre or more. It may not be possible to justify this in some areas.	In steep areas, slope will be limiting as most probably will the availability of topsoil. Poor drainage is a common problem associated with cropland on reclaimed mine land. Where topsoil substitutes were used to supplement existing topsoil, lack of organic matter and soil microorganism may lead to disappointing results.	There is considerable experience in reclaiming mineland for crops in West Germany and Britain. In the US a growing number of companies prior to the 1977 act were experimenting with reclamation for cropland but with the special requirements of the Regulations covering the reclamation of prime farmland, expertise in the US will grow rapidly. Very careful management for a period following surface mine reclamation is necessary to reestablish the drainage characteristics, the moisture and nutrient availability in the soil, etc. Underdrainage is frequently required on reclaimed sites.
	Other Agricultural Uses	Good grazing land can be created on reclaimed sites without incuring heavy costs. Section 816.116 contains specific performance standards for grazing lands. Recently experiments in growing various fruit crops have been carried out.	Good quality pasture will give excellent erosion control on restored sites. When heavy stocking rates are used damage to sod is likely on restored land.	There are many cases of land restored for grazing and forage crops. One of the pioneers in this field has been the Ayrshire Coal Company and their Meadowlark Farms, Inc., operating in Illinois, Indiana and Kentucky. Highly efficient livestock units could be created on reclaimed mine sites, though the site would probably have to exceed 25 acres (3). Experiments in raising fruit on reclaimed mine sites have been conducted in West Virginia with some success (2).

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

LAND USE	DEMAND	PROBLEMS	COMMENTS
Fish and Wildlife	The demand for wildlife habitat may be from sportsmen, nature conservationists etc.	The impact of surface mining on fish and wildlife may be serious in terms of destruction of habitat, pollution of surface water, etc. However even some orphan land now provides extremely rich habitat and in some areas non-acid impoundments provide extremely rich habitat and in some areas non-acid impoundments provide excellent fishing.	The value of habitat for wildlife depends on several factors, some of which can be varied. The Regulations require the use of native species of the same seasonal variety as pre-mining conditions. Wildlife can make better use of native plants than of introduced species, and natural diversity is an important factor in creating wildlife habitat. Food source, cover, "edge" conditions (hedges, woodland edges, etc.) and the presence of water in various forms are important.
Forestry Commercial	Commercial forest also has multi-use potential (hunting/water catchment).	The requirements for mechanized commercial forestry make accessibility and terrain important factors in developing commercial forest land.	Surface mining can improve accessibility but in some cases where haul roads are to be left permanently, the performance standards contain specific requirements. There are also specific standards for stocking of forest land [816.117].
Recreation	Various recreational uses can be considered for post-mining land use on surface mine sites. Accessibility and the presence of water are often two important factors in choice of recreation areas.	Small mine sites may not have the potential for creation of facilities for some recreational activities.	Mine sites close to existing communities may have great potential for the creation of recreational land alone or in combination with development land.

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