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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GROUP	RECLAMATION AND REVEGETATION
MEASURES	TERRACES

HANDBOOK FOR SMALL MINE OPERATORS

7

2

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.

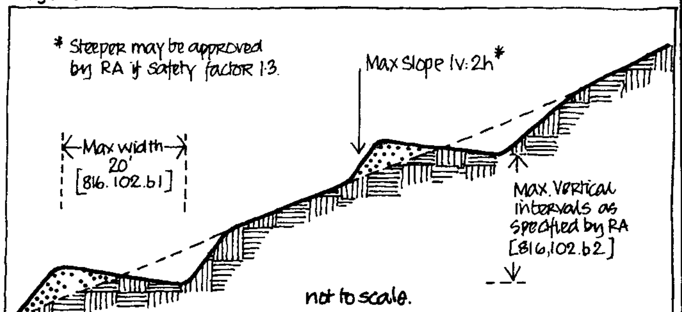
Terraces are commonly used on excess spoil disposal sites, Head-of-Hollow and Valley fills, where the steepness of the outslope usually makes terracing necessary. Terraces require the approval of the RA. Some mining companies use terraces during reclamation of sloping land then remove the terraces when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

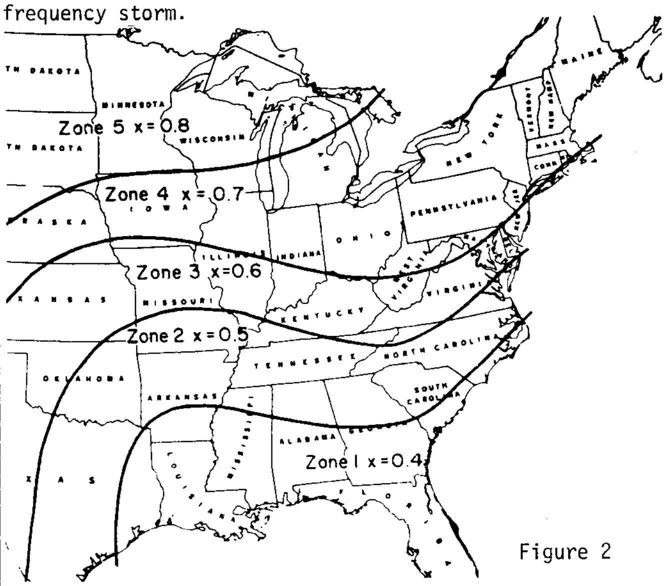
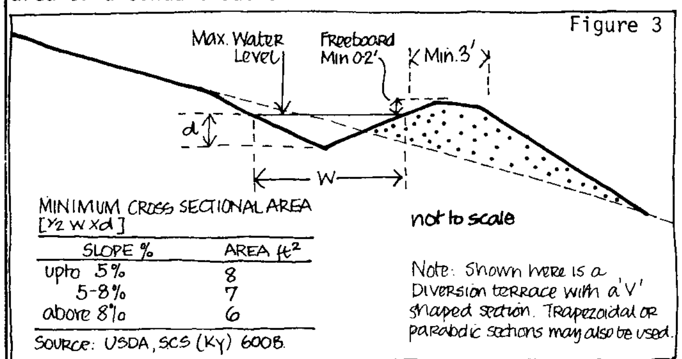


Figure 2

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.

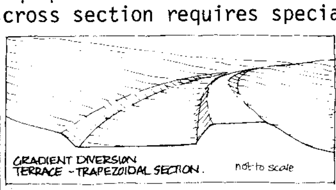


Figure 4

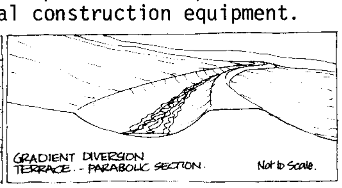


Figure 5

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.

REFERENCE

(1) Vogel, W.G. and Curtis, W.R., 1978, "Reclamation Research on Coal Surface-Mined Lands in the Humid East," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller F.W., Sutton, P., (Eds.) ASA, CSSA, SSSA, Madison, WI.

(2) USDA Soil Conservation Service (KY), 1973, "Standards and Specifications for Gradient Terrace," 600-B, Lexington, KY.

(3) Curtis, W.R., 1971, "Terraces Reduce Runoff and Erosion on Surface-Mine Benches," Journal of Soil and Water Conservation, 26/5.

(4) Curtis, W.R. and Superfesky, M.J., Aug 1977, "Erosion of Surface-Mine Spoils," Proceedings of the Soil Conservation Society of America, Richmond, VA.

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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.

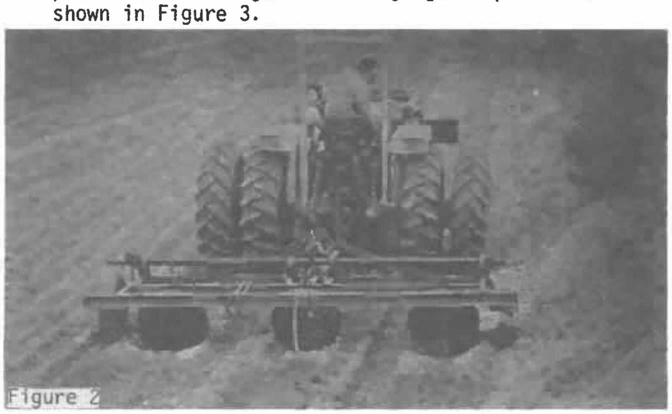
Figure 2


Figure 3

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.

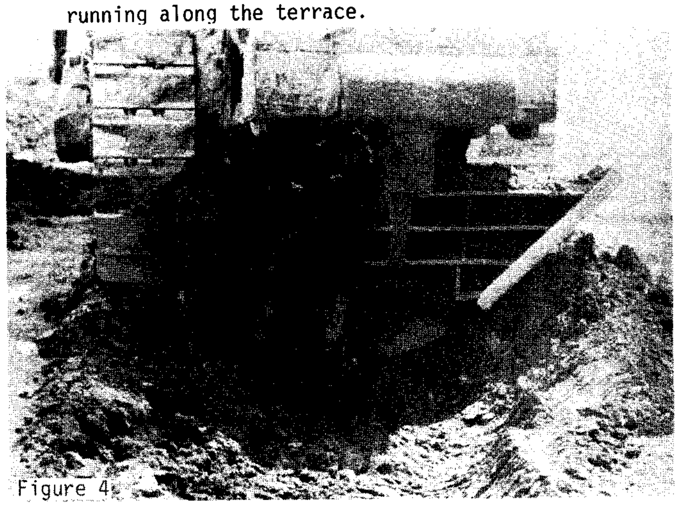

Figure 4

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.

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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.

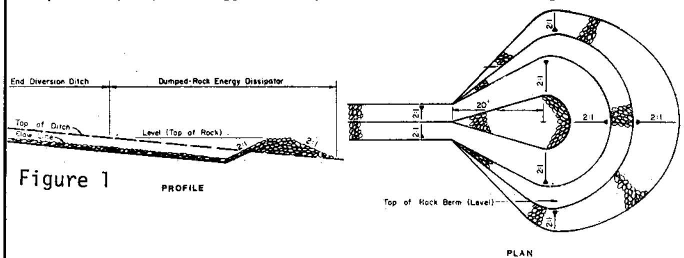
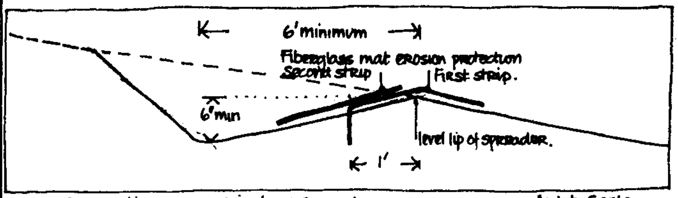


Figure 1

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.

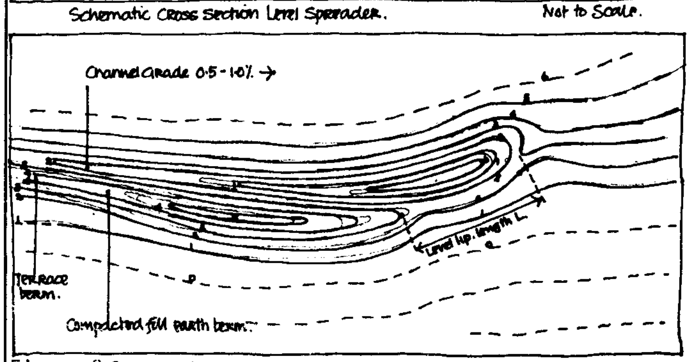


Figure 2 Schematic plan. Level Spreader. Not to Scale.

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.

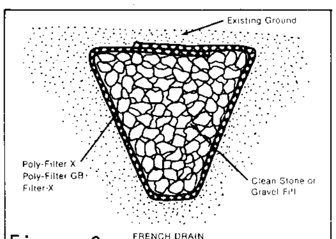


Figure 3 FRENCH DRAIN (No pipe required)

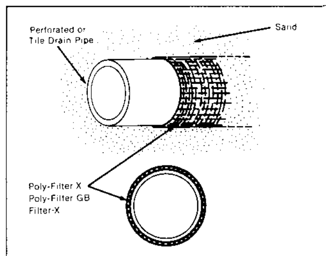


Figure 4 PIPE WRAPPING (cut-away view)

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 prior 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.

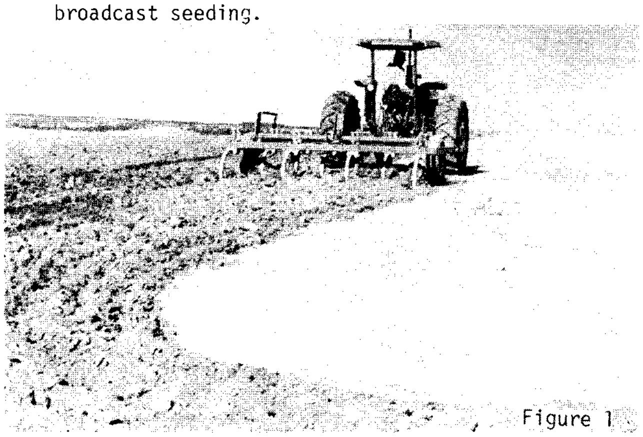
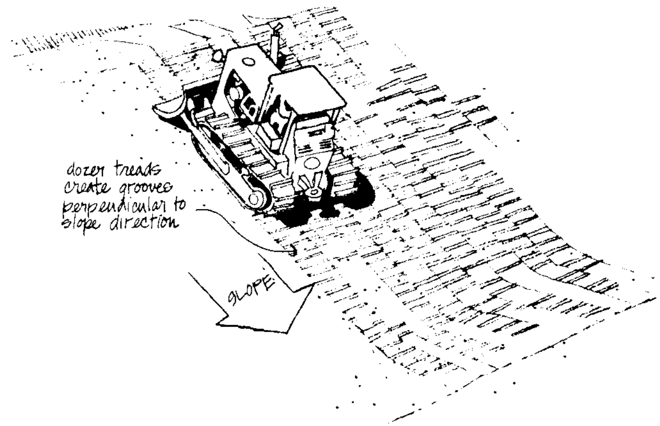


Figure 1

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.

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(1) Mays, D.A. and Bengtson, G.W., 1978, "Lime and Fertilizer Use in Land Reclamation in Humid Regions," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W. and Sutton, P., (Eds.), ASA, CSSA, Madison, WI.
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(5) Palasso, A.J. and Duell, R.W., Sep-Oct 1974, "Responses of Grasses and Legumes to Soil pH," Agronomy Journal 66.
(6) Skelly and Loy, October 1973, "EPA Processes, Procedures and Methods to Control Pollution from Mining Activities, EPA 430/9-73-011.
(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.

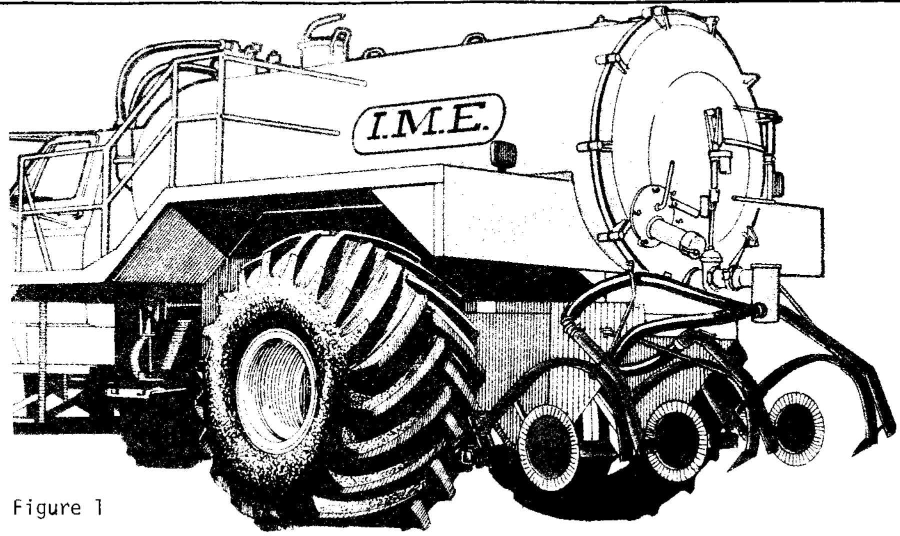

Figure 1

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.

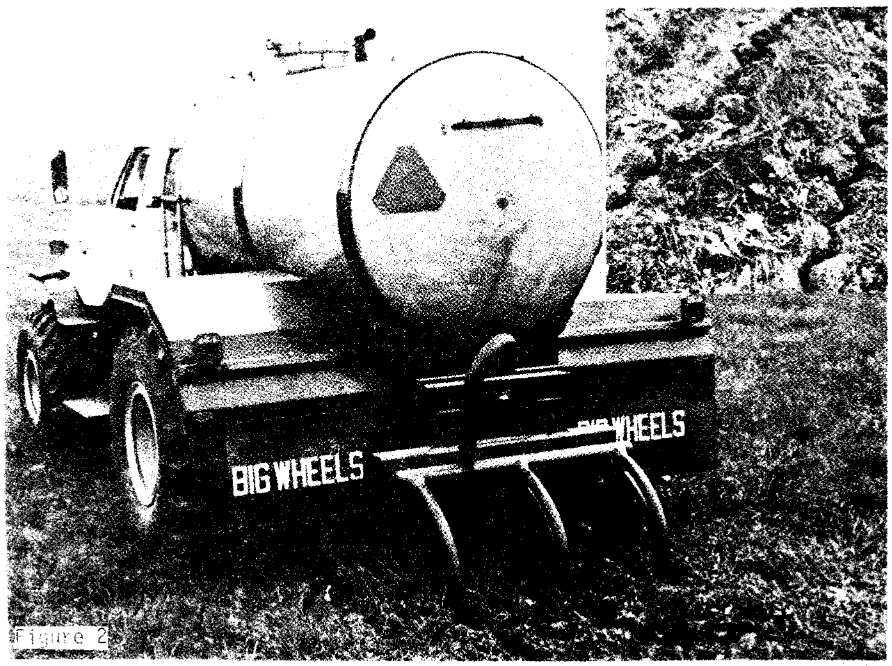

Figure 2

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

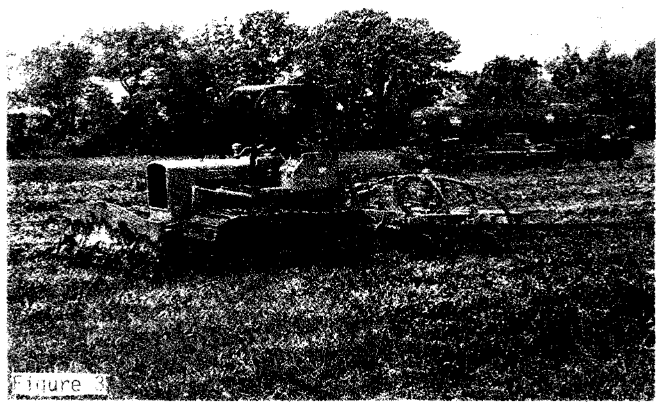

Figure 3

DISCUSSION & DESIGN GUIDELINES (CONTINUED)

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.

REFERENCE

(1) Halderson, J.L. and Zenz, D.R., 1978, "The Use of Municipal Sewage Sludge in Reclamation of Soils," Proc. Reclamation of Drastically Disturbed Lands, Schaller, F.W. and Sutton, P., (Eds.), ASA, CSSA, SSSA, Madison, WI.
(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.
(5) Sopper, W.E. and Kardos, L.T., Oct 1972, "Municipal Wastewater Aids Revegetation of Strip Mined Spoil Banks," Journal of Forestry.
(6) DNR, Wisconsin, 1975, "Guidelines for Application of Wastewater Sludge to Agricultural Land in Wisconsin," Department of Natural Resources, Technical Bulletin 88, Madison, WI.
(7) Hines, T.D. et al., 1974, "Agricultural Benefits & Environmental Changes Resulting from the Use of Digested Sludge on Field Crops," Metropolitan Sanitary District of Greater Chicago, EPA PB-236-402.

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GROUP	RECLAMATION AND REVEGETATION
MEASURES	SOIL AMENDMENTS - FLY ASH

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

(1) Capp, J.P., 1978, "Power Plant Fly Ash Utilization for Land Reclamation in the Eastern United States," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W. and Sutton, P., (Eds.), ASA, CSSA, Madison, WI.
(2) Adams, L.M. et al., Apr 1971, "Reclamation of Acidic Coal Mine Spoil with Fly Ash," Report on an Investigation 7504, U.S. Dept. of the Interior, Bureau of Mines.
(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.

GROUP	RECLAMATION AND REVEGETATION
MEASURES	MULCHES

HANDBOOK FOR SMALL MINE OPERATORS

7

9

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 tons/ac	Mulch rate m.tons/ha	Erosion tons/ac	Erosion m.tons/ha	Velocity ft/sec	Velocity 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.

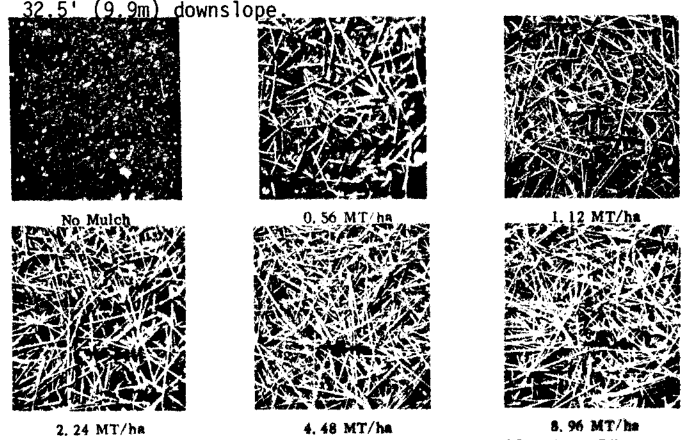

Figure 1. Mulch rates as they appeared following 5" (12.7 cm) of intense simulated rainfall. Photographs taken near top of plots. (Source: 6).

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 2a


Figure 2b

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).


Figure 3

REFERENCE

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

<u>EFFECTIVENESS OF SOIL STABILIZERS IN FIELD TRIALS</u>

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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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)

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).

REFERENCE

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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.

REFERENCE

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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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