HANDBOOK

OF

WESTERN RECLAMATION
TECHNIQUES

Second Edition
2006

FOREWARD

Date of Last Revision: 11/31/2006

NOTE: The first edition of this handbook can be obtained in its entirety from the website on which this edition is published.

ACKNOWLEDGEMENTS

The revisions provided in this second edition were supported by the Abandoned Coal Mine Lands (ACML) Research Program at the University of Wyoming. This support arose from funds returned to Wyoming from the Office of Surface Mining of the U.S. Department of Interior.

University of Wyoming sponsors and coordinators:

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Acknowledgement of funding is gratefully made to the University of Wyoming.

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INTRODUCTION TO THE SECOND EDITION

Reclamation is the practice of returning lands that have been disturbed to a use equal to or better than that which existed prior to disturbance. Reclamation is required for surface mines in the United States and is practiced world-wide by the mining industry. Since its inception in 1978, comprehensive reclamation has evolved rapidly. The primary impetus for this evolution was the Federal Surface Mine Control and Reclamation Act (SMCRA) of 1977 and State statutes such as the Wyoming Environmental Quality Act (WEQA) of 1973. Successful reclamation is integral with successful mining, not only for release of the large bonds required by State and Federal law alike, but also as a necessary adjunct to continued mining. The principles employed for the reclamation of surface mines are applicable to other types of disturbance that may occur in the landscape.

The roots of reclamation science lie in the conservation practices developed during the dustbowl and depression years of the 1930's. Many of the practices developed, and much of the work done during that time, were funded by Federal and State governments. For this reason, many of the names associated with early reclamation of mined lands -- McKell; Bjugstad; Power, Sandoval, and Ries; Aldon; Plummer; Richardson and Farmer; and Hodder -- are also names from the Soil Conservation Service, the Agricultural Research Stations, and land grant universities. Early mine reclamation was so associated with agriculture that reclamation and revegetation were considered virtually synonymous.

While some agricultural emphasis continues today, the technology has expanded greatly to embrace soils, hydrology, wildlife, and land use. Reclamation science has responded to legal requirements, reconstruction of endangered habitats, revitalization of damaged environmental systems, and establishment of wetlands. Reclamation methods are used to minimize the impact of human development in housing subdivisions, on ski slopes, and in highway reconstruction.

Early reclamation investigations in the arid and semi-arid Western United States were based on research trials for replacing materials suitable for plant growth and re-establishing vegetation. Cook et al. (1974), Power et al. (1976), the SEAM program (1979), and DePuit and Coenenberg (1981) are good examples of earlier efforts that continue today in work by Schuman et al. (1993). Plant materials centers and agricultural research stations continue to provide tools for reclamation efforts (e.g. Ries et al. 1976, Aldon 1981, Bjugstad 1984, and Majerus et al. 1985).

Researchers such as Shroeder (1985), Toy (1983), and Toy and Parsons (1987) produced research on geomorphic processes such as erosion, infiltration, and sediment yield, while Beauchamp (1973), Dollhopf (1978), Berg (1983), and Halvorson and Doll (1985) investigated spoil and soil in the reclaimed environment. A great deal of applied research has been conducted by mining companies interested in seeking new solutions to reclamation problems. Much of this work is reported in the annual reports required by State agencies for each active mine.

Postovit (1981), Hingtgen and Clark (1984a and 1984b), Yoakum (1984), Clark and Medcraft (1986), and Medcraft and Clark (1986) studied the effects of mining on wildlife populations. Olendorf et al. (1981) and Nelson et al. (1978) described techniques for wildlife habitat restoration. Methods and classification for reconstruction of stream channels are being developed by Wesche et al. (1993) and Rathburn et al. (1993).

There are many works that suggest technologies of various kinds, report on field trials, and recommend plant species for use in reclamation. However, almost thirty years after the earliest trial efforts, a considerable body of practical knowledge has been developed by the specialists responsible for compliance with State and Federal statutes and regulations governing reclamation of mined lands. For the most part, this knowledge is not formalized elsewhere than in this handbook.

This Second Edition of The Handbook of Western Reclamation Techniques represents significant cooperative effort between the mining industry, industry professionals, the academic community, and regulatory agencies. It documents field-proven reclamation methods and demonstrates the diversity with which similar objectives can be accomplished. Some of the methods were developed through trial and error; some were developed from scientific studies and have matured over time. Many of the authors began as reclamation specialists and have moved onward to other positions; some have now retired. The legacy these professionals leave behind is a tribute to the ability of humankind to manage its environment for the better. Their efforts will always be appreciated.

Many people contributed to the second edition of this handbook, particularly Phil Dinsmoor and Robin Carlson. In addition, the support and determination of Wanda Burget and Laurel Vicklund were instrumental in its production. Bj Kristiansen, as always, is to be commended for his fine efforts on the web production. Any errors that have crept into the second edition as a result of editorial tinkering are the sole responsibility of the editor. The fine works otherwise presented remain the products of the authors identified in each subsection

D.G. Mickey Steward, coordinating editor
Gillette, Wyoming
December 2006

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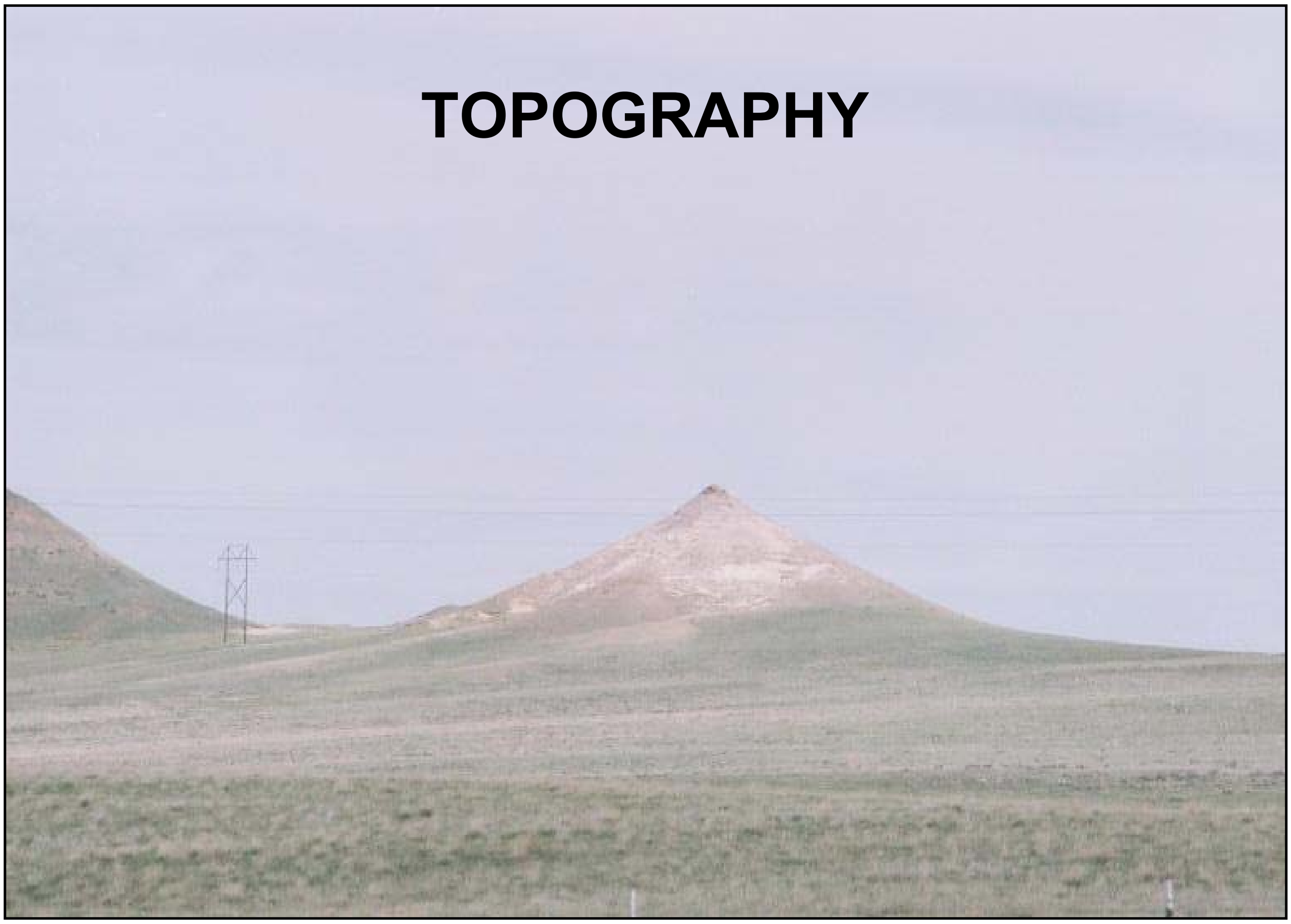
TOPOGRAPHY



Section Editor: Bob Stowe

Handbook of Western Reclamation Techniques Second Edition

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Section 1: Topography

A. Introduction

Section editor: Robert R. Stowe

Reclamation of western lands can be enhanced with some forethought about how the reclaimed topography will look and how it will function with the proposed postmining land use. When land is being reclaimed from surface mining or other surface disturbance back into grazing land and/or wildlife use, adding some macro- and micro-relief structures can be of benefit to both livestock and wildlife. Semi-arid conditions frequently mean few or no trees and strong winds. When there is little or no topographic relief to protect livestock and wildlife from the summer sun and the winter winds, animals suffer and may perish. Topographic relief can provide the protection required in addition to augmenting the postmining land use.

In areas where reclaimed lands will become farm land, topographic design is also important. In these situations, minor hills and slopes, as well as drainages, should be designed so that runoff from precipitation and snowmelt will not inundate land to be farmed, and the reconstructed drainage-ways will not be overly erosive.

The following subsections discuss methods of shaping hillslopes in order to provide topographic diversity for wildlife and livestock while minimizing erosion. A discussion of procedures used to compare the pre-mining and postmining slope regime is also included.

B. Hills/Slopes

1. Hillslope Shaping and Morphology

Section editor: Robert R. Stowe *Subsection authors: Christopher D. Lidstone/C. Marty Jones*

Applicability

Landform stability is a critical element in the reclamation of mined lands. The hillslope is the uppermost unit of the basin watershed and is typically responsible for the production of sediment to the watershed. Concentrated flow or flowing water transfers this sediment to the first and second order stream channels and ultimately delivers the sediment to receiving waters outside the mine permit area. Where surface runoff remains unconcentrated, little sediment movement and virtually no transfer of sediment off-site will occur.

The intent of mining regulations is to minimize off-site production of sediment and to reestablish a hydrologic system that will behave in an erosionally stable manner equal to or better than that which existed prior to mining.

The hillslope component of reclaimed basins is the upper watershed and valley sideslopes that deliver runoff to the smallest (first order) designed drainages in the reclamation plan. Where slope gradients or slope length exceed some threshold value, surface water runoff will concentrate, producing rill and gully erosion. Hillslope shaping, and an understanding of slope morphology and processes, will reduce surface erosion on reclaimed hillslopes.

Special Considerations

Decisions regarding landform shaping must balance mine planning, mining methods, geomorphic processes, and economics. The operator must consider the locations and elevations of haulage roads, ramps, spoil piles, pre-existing and postmining basin outfalls and drainage divides.

For example, mine production features such as haulage ramps and roads can often become components of the postmining drainage system. In these areas, backfill costs can be reduced if postmining drainages are restored to incorporate a portion of the ramp or road alignment.

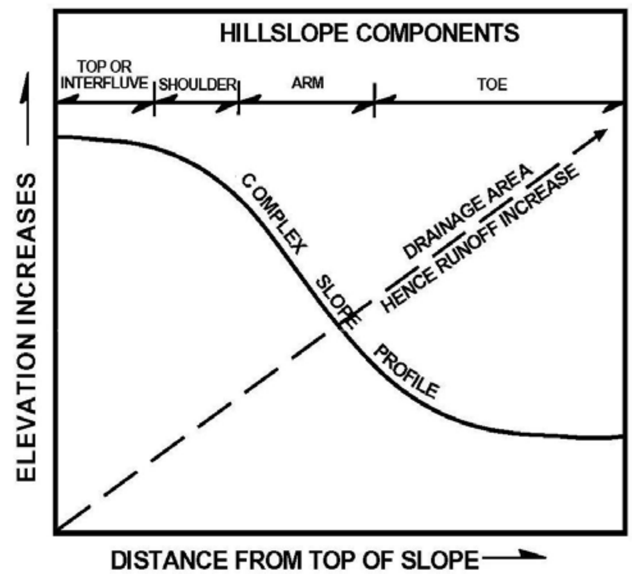
Similarly, out-of-pit overburden stockpiles and/or dragline spoil dumps can be formed into the upper elevation or hillslope component of the drainage system. In doing this, the operator can minimize "double handling" and reduce hauling costs. Pit backfill sequencing should incorporate the final reclamation topography and address not only final drainage design but also final hillslope design.

The overall reclamation plan and hillslope design must reflect such critical variables as postmining basin outfalls and the topography of adjacent lands. Reclamation planning should consider basin or hillslope aspect. Final topography can be adjusted to accommodate the harsher conditions associated with aspect and slope, which influence solar and wind exposure. Experience suggests that there is a significant improvement in reclamation success on protected slopes. Increased moisture retention is required on southern exposure slopes. This can be accomplished by flatter slope angles and a more roughened final reclamation surface.

Techniques

a. Hillslope

The hillslope is defined by a minimum of four subunits and is described with standard nomenclature (after Perrens, et.al. 1984) as shown on the adjacent figure. These particular units were first developed by agronomists in recognition of the importance of position on a natural hillslope with respect to soil genesis. Soils that develop near the shoulder and arm of the slope are transported by both water and gravity to the toe of the slope. In nature, soil horizons are thickest at the toe of the slope and thinnest at the shoulder.



Hillslope Components

(From Perrens, et. al., 1984)

When replacing topsoil on a reclaimed hillslope, it is typically replaced to a uniform depth. As natural erosion and deposition occur on the reclaimed hillslope, translocation of topsoil will take place and over time the thicker zones will occur at the toe of the slope. Recognizing that these processes will occur, yet designing the slope to minimize the movement of topsoil by accelerated processes such as rill and gully erosion, is a critical design consideration.

Hillsope should recognize the value of rainfall infiltration and the liability of direct surface runoff. Water retention on the hillslope will promote revegetation success, and by so doing will stabilize the reclaimed land surface. Where runoff occurs in a concentrated manner, excessive shear forces may occur, resulting in rill and gully erosion. Minimizing slope length and excessive slope gradients will prevent the concentration of direct surface runoff on the hillslope.

(1) Hilltop or Interfluve

As a rule of thumb, the acreage of the hilltop should be maximized and the overall slope length minimized. The hilltop should be formed to retain the maximum moisture onsite with minimum delivery of runoff from the hillslope. In the field, this translates as grade staking the top of an overburden stockpile or dragline dump to ensure the flattest possible configuration (20H:1V or flatter) while maintaining an overall positive drainage. Leaving the regraded surface in a roughened condition will enhance its water retention capabilities.

Immediately prior to the replacement of topsoil, the overburden should be "deep-ripped" or scarified. The topsoil can be replaced directly on the rough overburden backfill surface (at variable thicknesses) and/or the replaced topsoil can be manipulated by mechanical farming methods. Reclamation success has been achieved with "pitting", which is a mechanical means of constructing actual soil pits or divots within the topsoiled surface. Pitting is accomplished simultaneously with drill seeding during final reclamation. Similarly, the construction of small intermittent dozer basins has successfully achieved water retention goals and aided in the development of small playa-like features.

Where a greater acreage of interior drainage is required or desired, the replacement of well-drained soils is essential to prevent the unwanted accumulation of salts. Although natural playas and interior drainage features exhibit predominantly clay soils, the elimination of salt accumulation will enhance revegetation efforts during the critical initial years of bond release.

A final consideration in the geometry of the hilltop is an assessment of the basin area contributing to the receiving drainages. Basin divides can be manipulated to increase the watershed area and peak flow hydrology of one basin while decreasing the watershed area and peak flow hydrology of an adjacent basin. If channel slopes are excessive in one basin, part of the basin runoff can be diverted to another basin, thereby decreasing the overall peak flow hydrology of that basin.

(2) Hillslope: Shoulder and Arm of Slope

To the extent possible, slope length and the slope steepness should be controlled to eliminate excessive erosion. Initial slopes on mine dumps typically range from angle of repose to 1.5H:1V. Minimum reclamation slopes are often controlled by equipment accessibility and the ability to "farm along the contour". Although minimum "farmable slopes" may range from 2.5H:1V to 3H:1V and are dependent on the farming equipment, revegetation is often most successful on 4H:1V or shallower slopes.

In arid and semi-arid climates, slope aspect plays an important part in vegetation success; 5H:1V or flatter minimums are found to be successful on south aspect slopes. North-facing slopes can be slightly steepened and 4H:1V minimums have proven to be successful. Wherever possible, flatter slope gradients are highly recommended and will increase rainfall infiltration and decrease concentrated flow. Such uniformity of terrain enhances vegetation cover and production but may reduce vegetation diversity and will certainly decrease wildlife diversity and cover for livestock during adverse weather conditions.

Slope length and slope shape are also critical design considerations. The slope shape and slope transitions should be designed to promote unconcentrated flow and to minimize the offslope delivery of sediment. Where the combination of critical slope characteristics (slope length, slope steepness and contributing area) will result in concentrated flow, runoff and sediment should be collected into a first-order channel and be delivered in a controlled manner offslope. Small drainage reconstruction is discussed in the Hydrology section of this handbook.

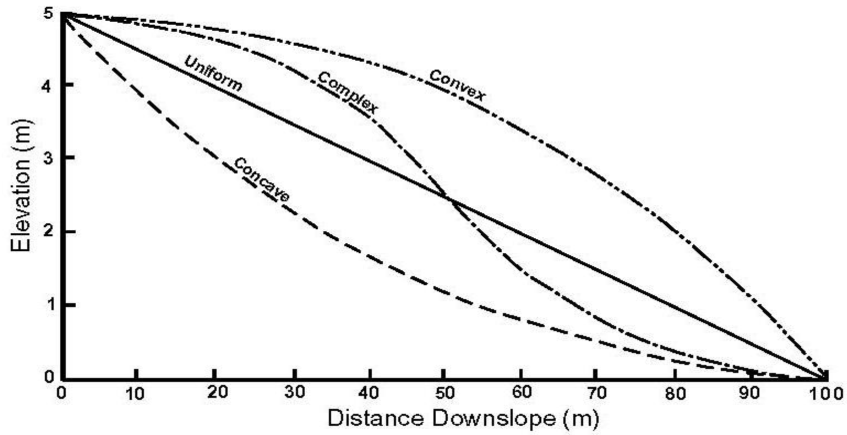
Practical experience has shown that slope lengths in excess of 50 to 100 feet at gradients of 4H:1V or steeper may result in rill and gully erosion. At 5H:1V slopes, lengths in excess of 150 feet or more may be erosive. Of course, vegetation density, soil type, and storm intensity and distribution are important variables in this analysis. Coarse textured soils and/or successfully vegetated slopes allow more latitude in slope length than do fine-textured, poorly vegetation hillslopes.

Cross-slope ditches or furrows can be incorporated into hillslope reclamation to achieve the required slope lengths. Such ditches should be small and unobtrusive and should be constructed oblique to the contour.

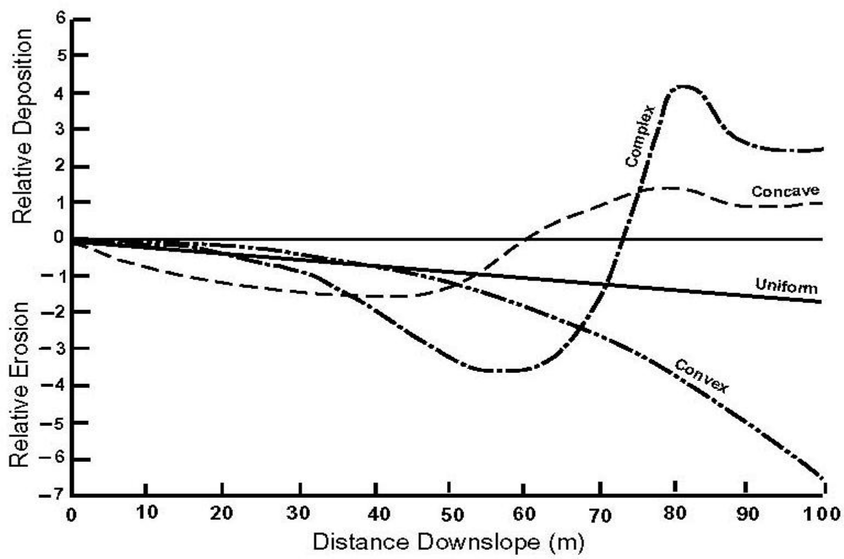
In order to reduce the probability of ditch failure, a minimum gradient of four percent should be established for all cross-slope ditches. Flatter ditch slopes and contour ditches are difficult to construct, and tend to collect water in low spots created by settlement of the fill or poor staking/construction practices. These low areas do provide micro-habitat that leads to vegetation and terrain diversity.

Figures B-1-2 presents typical hillslope shapes and a mass balance of erosion and deposition along the hillslope. The movement of sediment within the hillslope component is a function of both water and gravity. From a practical standpoint, uniform and concave slopes are most often employed in mined land reclamation. Of these two slopes, the concave slope provides a more stable land surface as seen in Figure B-1-2.

Complex slopes are the most common found in nature. These slopes exhibit increased erosion along the center or medial portion of the slope and increased deposition at the toe of the slope. If designed properly, a complex slope can be a stable entity within the overall reclamation scheme and provide diversity in the overall reclamation topography.



Typical Hillslopes

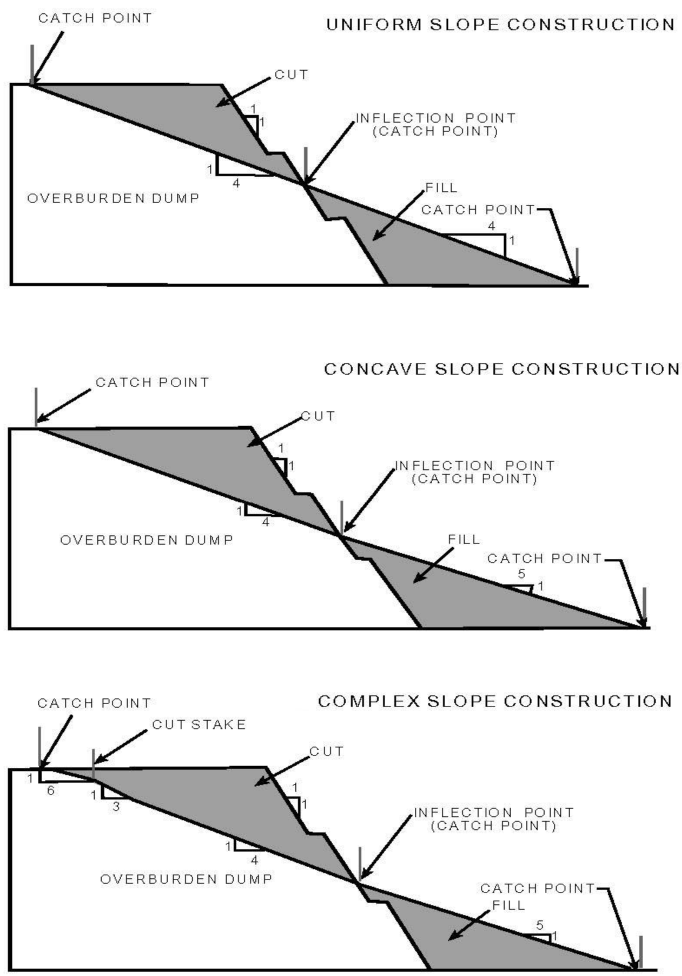


Erosion/Deposition Mass Balance

(From Perrens, et. al., 1984)

Figure B-1-2

Uniform slopes are the easiest to stake and construct in the field. The slope configuration provides few depositional sites within the hillslope. However, where excessive slope lengths occur, offslope transport of sediment (erosion) can be anticipated. Where uniform slopes are staked in the field, flatter gradients and adequate transitions at the toe must be incorporated. Figure B-1-3



Reclamation Slope Construction

Figure B-1-3

presents a 4H:1V uniform slope. Depending on slope length, basin aspect, and transition requirements, a flatter slope such as a 5H:1V or 6H:1V may be recommended.

Concave slopes may require additional staking and construction supervision, but provide better control of sediment movement and a more stable land surface (Figure B-1-3). The lower gradient portion of the slope allows water velocities to decrease, thereby enhancing deposition. The increased staking and construction supervision responsibilities required to construct concave slopes may offset long term maintenance responsibilities.

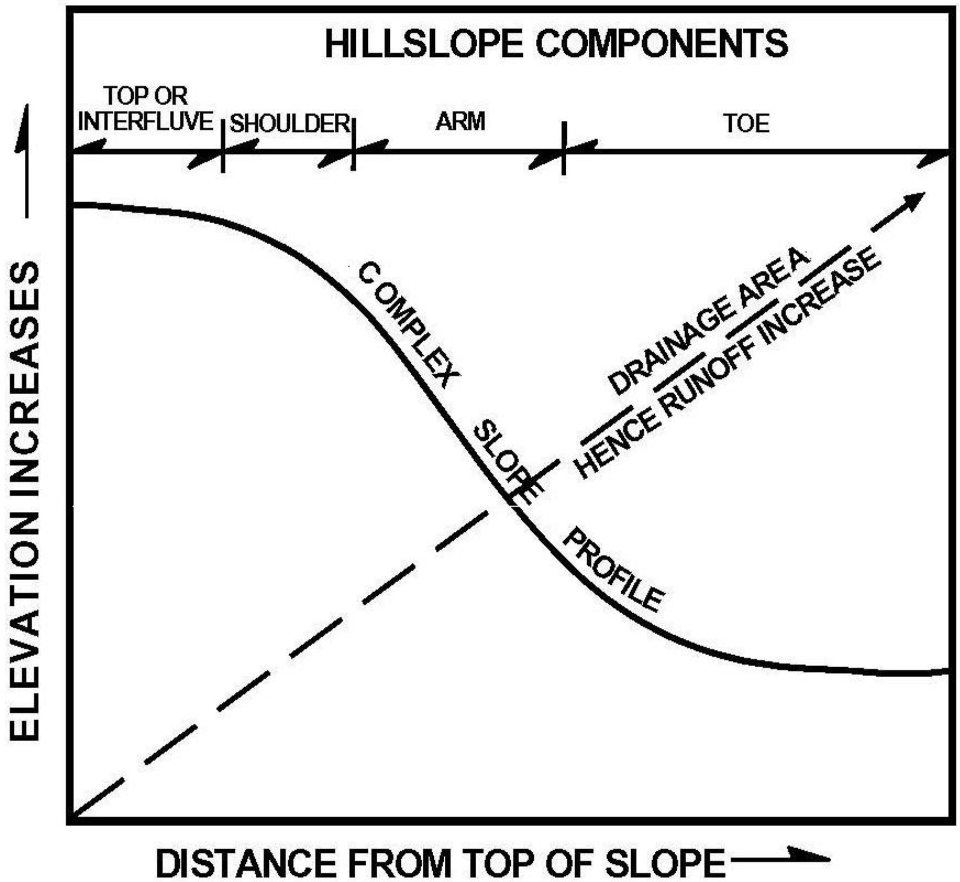
A variation of the concave slope might entail a 4H:1V slope from the interfluve to the arm of the slope and a 5H:1V slope from the arm through the toe section of the slope. Practically speaking, in a multiple-benched mine dump, the upper lifts would be graded to a 4H:1V slope. The cut material would be relocated to the base of the dump and the 5H:1V toe slope would be created (Figure B-1-3). The point of inflection between the 4H:1V and 5H:1V slope (intermediate catch point) would be established based on an earthwork balance.

Complex slopes require intermediate cut stakes as well as the staking of each catch point (Figure B-1-3). Typically the construction of a complex slope may require additional earthwork, although there will be certain earthwork savings in the steep upper "shoulder" reach. The upper reaches of a complex slope provide maximum surface area for rainfall infiltration and minimum runoff. The arm of the slope is the steepest portion of the slope, yet will have limited drainage area contributing to direct surface runoff. Where runoff does occur, the hillslope gradients are the most gentle and velocities will be reduced.

(3) Hillslope: Toe of Slope

The construction of the toe of the slope is often the most essential aspect in hillslope reclamation. Too often the toe of the slope will be left in a convex or over-steepened form. This condition will often result in erosion, since the hillslope drainage basin area is the greatest at the toe of the slope. Because runoff increases with increased drainage area (Figure B-1-4), it is essential that the slope gradient decreases at the toe of the slope. The design intent is to maintain unconcentrated flow and promote infiltration. The lower gradients will also promote the deposition of hillslope sediment, thereby reducing sediment contribution to receiving drainages.

A second element in the construction of the toe of the slope is the smooth transition of the hillslope into the adjacent reclamation valley. A low gradient toe, which transitions into a stream valley, will allow lateral movement of a reclamation channel against the hillslope. If the slope enters the stream valley in an over-steepened condition, erosion and undercutting of the toe is likely to occur.



Hillslope Components

Figure B-1-4 (From Perrens, et. al., 1984)

b. Summary of Hillslope Morphology

Hillslope design should maximize the opportunity for rainfall infiltration and minimize the opportunity for surface water runoff and flow concentration. The movement of sediment within the hillslope form is an essential geomorphic element in natural slope processes. Minimizing offslope movement via rill and gully erosion is critical, and will result in a reduction in sediment contribution to the receiving drainages.

Figure B-1-3 presents the three slope shapes discussed above and the minimum construction staking requirements. Although all three slope shapes are presented, the concave slope design best balances the economics of material movement with the design philosophy discussed above.

c. Construction Practices

Construction requirements are relatively simple and much work can be completed with a dozer. If dozers are used in construction, catch points should be staked in the field and adequate compaction be required near the toe. If scrapers are used in construction, additional staking to define cuts may be helpful.

Some compaction of the fill portion of the hillslope is essential to prevent or eliminate settlement, and in some cases failure of the fill. Concern with compaction is not as pronounced when construction by scrapers is employed. When backsloping a fill against a highwall, the fill must be keyed. In certain instances where ground water is encountered, drainage below the fill must also be incorporated into the design.

C. Backfill Grading Observations

Section editor: Robert R. Stowe *Subsection author: Frank K. Ferris*

Applicability

Relief techniques are an important tool in controlling erosion and cost. Planning a watercourse for drainage will facilitate preparation for the flow and reduce erosion on reclaimed lands. Costs can be controlled by planning for the placement of backfill and having the backfill dumped to grade as much as possible. The incremental haulage or handling cost of $ 0.05 per yard is very economical compared to the $ 0.25 to $ 0.50 (1996 dollars) per yard cost of rehandling backfill.

Special Considerations

Backfill will settle differentially, up to ten feet on a rare occasion; three feet is not unusual. Constructed topographic features must be massive enough to function even with settling in critical areas. Plan ahead to know your desired topography. This will allow for maximum use of mine equipment for placing and grading backfill while that equipment is in the area. Finish grading of frozen backfill will likely take two to three times the equipment hours as compared to thawed backfill.

Techniques

a. Dump Slope Grading

Dump grading can be made more economical by the selective placement of loose dumps and through dump grade control (Figure C-1). Dump grading volume can be reduced and maintained with several methods.

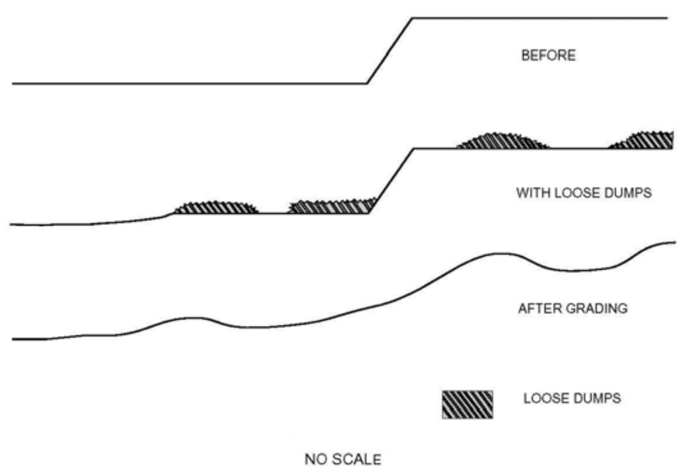


Figure C-1

(1) Decreasing the dump height by five to seven feet (loose dump height).
(2) Sloping the dump grade to be lower at edges and high where needed.
(3) Placing loose dumps at the toe area, dump top, and ridge spots to reduce dozing needs and create micro-features and drainage control.

b. Second Bench

A second bench reduces reclamation grading volume by 70 percent (see Figure C-2). In this example, the volume was reduced from 48 yards^3 to 14 yards^3 per linear foot of dump face with a 50 percent reduction in push length.

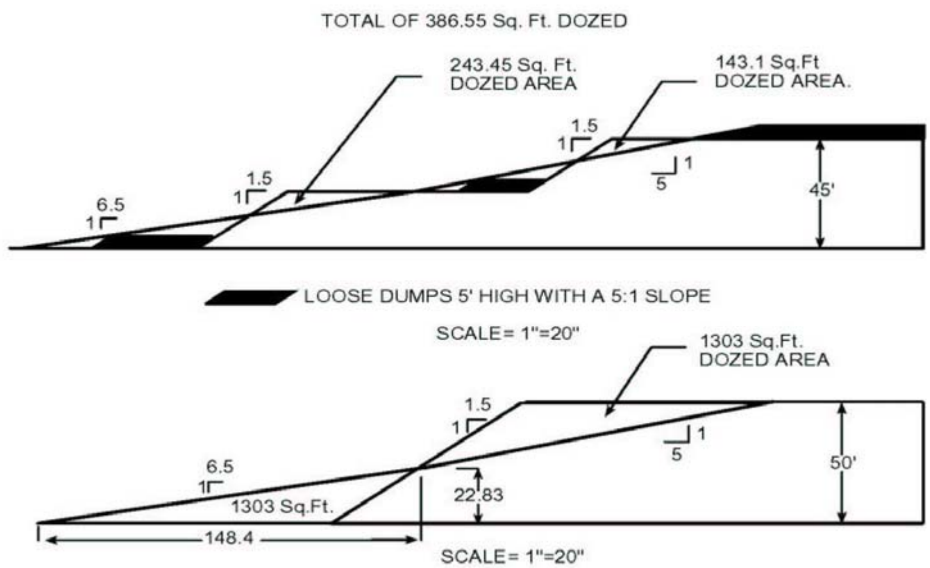


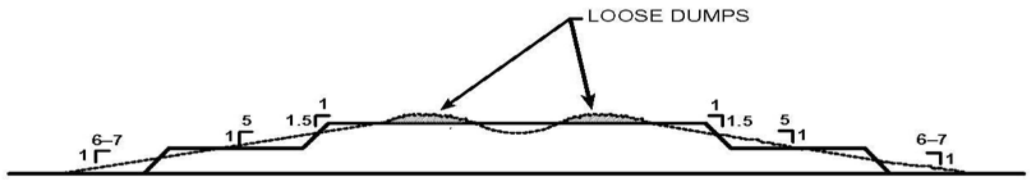
Figure C-2

The second bench can be built between or after the main dump. However, if it is built first, it will reduce the overall cycle time of the haul trucks because they will not have to climb to the top to dump all loads of dirt. After the lower dump is in place, the toe limits of the second (top) dump can be established on the second bench. This construction methods will required additional dump dozer activity during backfilling.

c. Dump Top Reclamation

"Small Drainage Waterway Construction" in the Hydrology section of this handbook can be reviewed for dump top reclamation. It is extremely important to limit the flat areas above slopes because concentrations of runoff down the slope will cause slope erosion. Generally there are two options, depending upon the width of the dump:

(1) Grade to a hill with interior drainage (Figure C-3)



(2) Grade to a hill

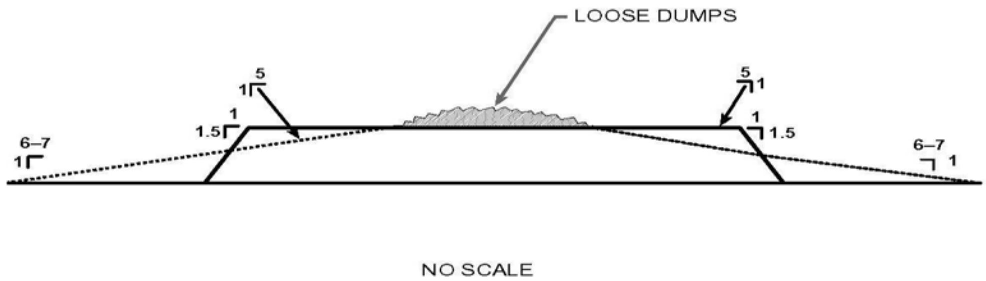


Figure C-3

d. Long Slope Grading

For information on Long Slope Grading, review "Small Drainage Waterway Construction" in the Hydrology section of this handbook.

D. EVALUATION AND COMPARISON OF TOPOGRAPHIC DESCRIPTIVE METHODS

Section editor: Robert R. Stowe *Subsection author: Robert R. Stowe*

Applicability

Reclamation of mined lands and other major surface disturbance requires a comparison between premining and postmining slopes. This comparison ensures that the postmining topography will support the desired postmining land use. Reconstructed land must blend with native land and postmining slopes must be neither much steeper nor much flatter than original slopes.

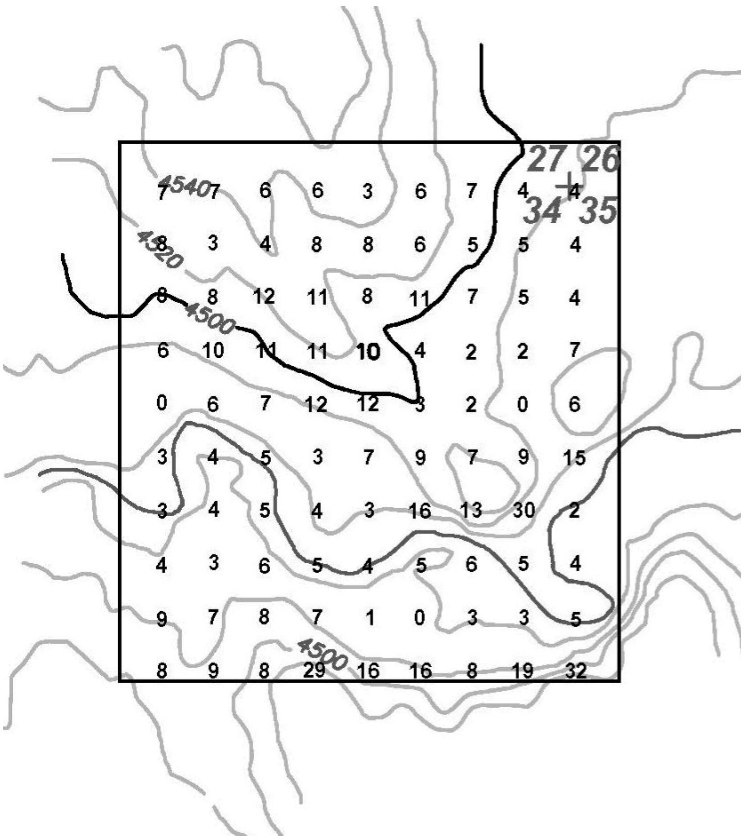
Special Considerations

Slope comparisons generally divide the land surface into a number of grid cells in order to calculate the slope, or rise divided by run, at the grid cell node. This information can then be mapped in several ways. Three methods for evaluating and comparing topography techniques are outlined below.

Techniques

a. Evaluation and Comparison of Topography Techniques

From any of the following three techniques, tables and histograms can be generated to evaluate the percentage of topographic surface with certain slopes or features. Tables and histograms are especially useful when comparing two surfaces, for example, premining and postmining topography. Many engineering firms are available to conduct these evaluations. Special engineering software packages are also available to make these calculations and comparisons.



(1) Elevations

Slope value and optionally, slope direction, which yields a vector, must first be plotted for each grid node. The nodes for the grid and search radius should be selected so that averaging or smoothing between nodes conceals variability in the underlying topography. In one particular form of this method, slopes are calculated by first estimating elevation values into a 100-foot grid from irregular contour data. These grid values are then subtracted from the nearest neighbor to provide a change in elevation in each cardinal direction.

Elevation differences in north and south directions are added, then divided by the total difference between grid values (i.e. 200 feet), to provide a slope in the north-south direction. The same is done for the east-west direction. These component slopes are then added, via vector analysis, to yield the slope magnitude in percent and direction in degrees at the node being analyzed. Vectors may be drawn from each node pointing downslope, with the length of the vector denoting the steepness of the slope.

The above analysis is typically performed every 300 feet to separate posted data values sufficiently for plotting purposes (postmining values at 100-foot spacing would require a very large map with no gain in accuracy or precision).

Slope isopleths may be drawn by contouring the slope magnitude from the slope data on 300-foot centers. Slopes are calculated within projected disturbance limits only, and both pre- and post-mining slopes are calculated on identical 300-foot centers to allow direct comparisons. These values are then posted on a screened topographic base map (Figure D-1). This dynamic map can provide insights about potentially erosive areas and where deposition is likely to occur in a drainage

(2) Isopleth Map

A second method is to contour the points of equal slope in an isopleth map. The contours on this map show the areas of increasing or decreasing slope. A plain with little relief would show few isoslope contours, whereas a quickly steepening bluff would be depicted by many isoslope contours. Water will flow perpendicular to the isoslope contour lines. This is illustrated in Figure D-2.

(3) Mapping Geomorphic Features

A third method of evaluating topography is to map geomorphic features such as hills, slopes, ridges, saddles, valleys, and scarps on a topographic base. This map will show areas where the various geomorphic features are located. Materials used to identify geomorphic features include a premining topographic map of scale 1"=1000' and numerous composite air photographs. Abandoned meanders shown on the premining landforms map are identified using USGS topographic maps of 1"=2000'. Meanders shown are those that were apparent on more than one map source and appear to be within the limits of the most recent terrace deposits. This is more of a qualitative map than either of the two previous maps, as seen in Figure D-3.

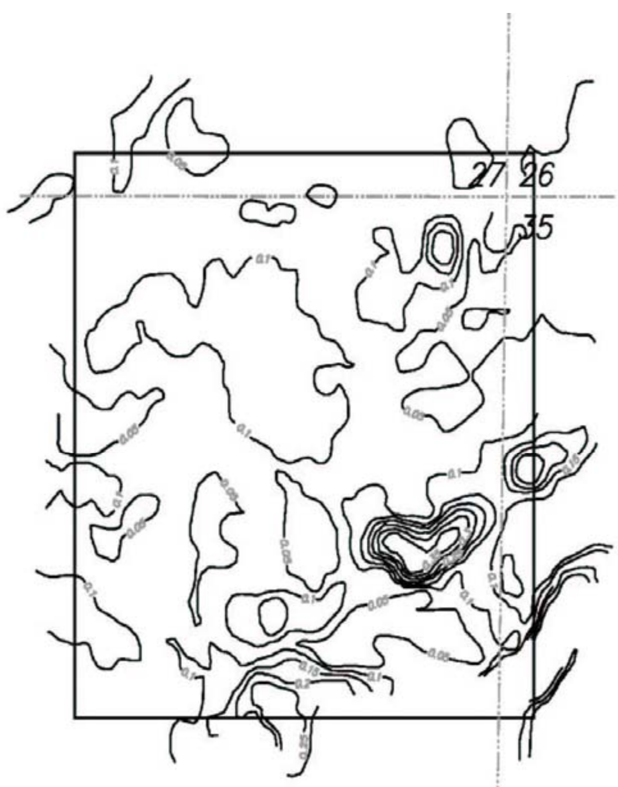


Figure D-2

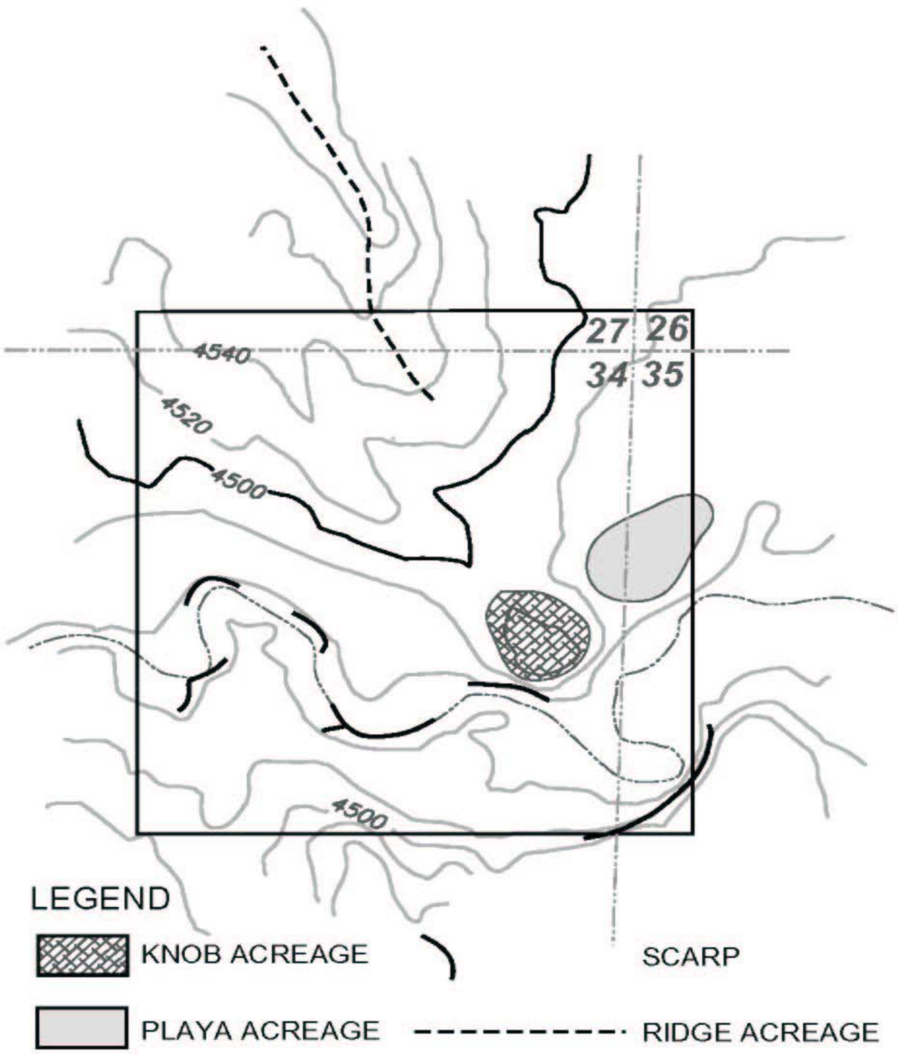
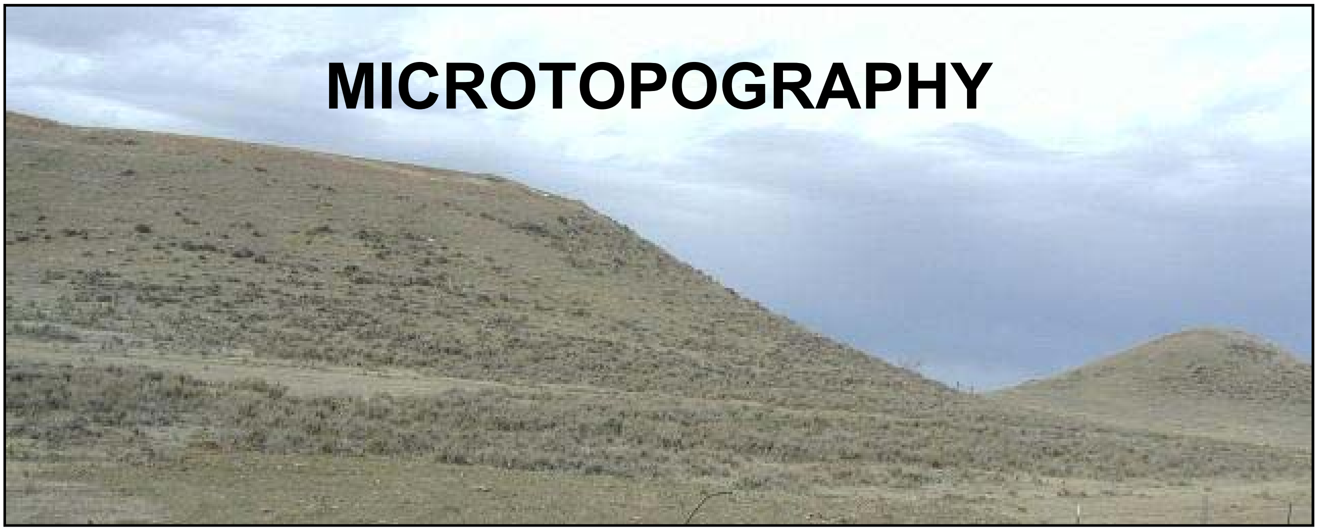


Figure D-3

D. References

Perrens, S.J., G.R. Foster, D.B. Beasley. 1984. "Erosion's Effect on Productivity Along Non-Uniform Slopes" In: Erosion and Soil Productivity; Proceedings of the National Symposium on Erosion and Soil Productivity; December 10-11, 1984 (New Orleans, LA). ASAE Publication 8-85. American Society of Agricultural Engineers, St. Joseph, Michigan.

MICROTOPOGRAPHY



Section Editor: Phil Dinsmoor

Handbook of Western Reclamation Techniques

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Section 2: Microtopographic Construction

Applicability

Microtopographic construction creates specific landform features within the broader reclamation topography in order to provide and enhance topographic diversity and relief. Such finer landform features do not significantly alter the reclaimed topography, but add topographic relief to what otherwise could be a rather sterile landscape having uniform slopes and surfaces. Microtopographic features may be described as mounds, ridges, knobs, knolls, bowls, scarps, banks, rock piles, and rock outcrops, just to name a few.

Microtopographic features enhance the landscape of permanently reclaimed land and provide additional wildlife habitat and cover. Specific reclamation techniques such as use of site specific seed mixes and variable topsoil replacement depths can compliment microtopographic construction in promoting plant community diversity and desired species composition in the reclaimed environment.

Special Considerations

Microtopographic features should generally be configured and sized to accommodate topsoil replacement, and yet conform within accepted grade or contour tolerances of the reclaimed topography.

When incorporating microtopographic features into the overall reclaimed topography, local drainage conditions and patterns and the potential for erosion should be carefully considered. Site- specific erosion control measures may be necessary until vegetation is well established.

Techniques

Ideal construction would be to mimic native undisturbed landforms – those natural features that are erosionally stable and the result of centuries of wind and water erosion and climatic events. But economic considerations, equipment limitations, and unconsolidated soil conditions largely limit our capabilities to imitate Mother Nature's work.

With creativity and visualization, microtopographic features may be free-formed during final grading of rough topographic features. Or with advanced planning, construction of microtopography may occur concurrently with general grading or backfilling operations.

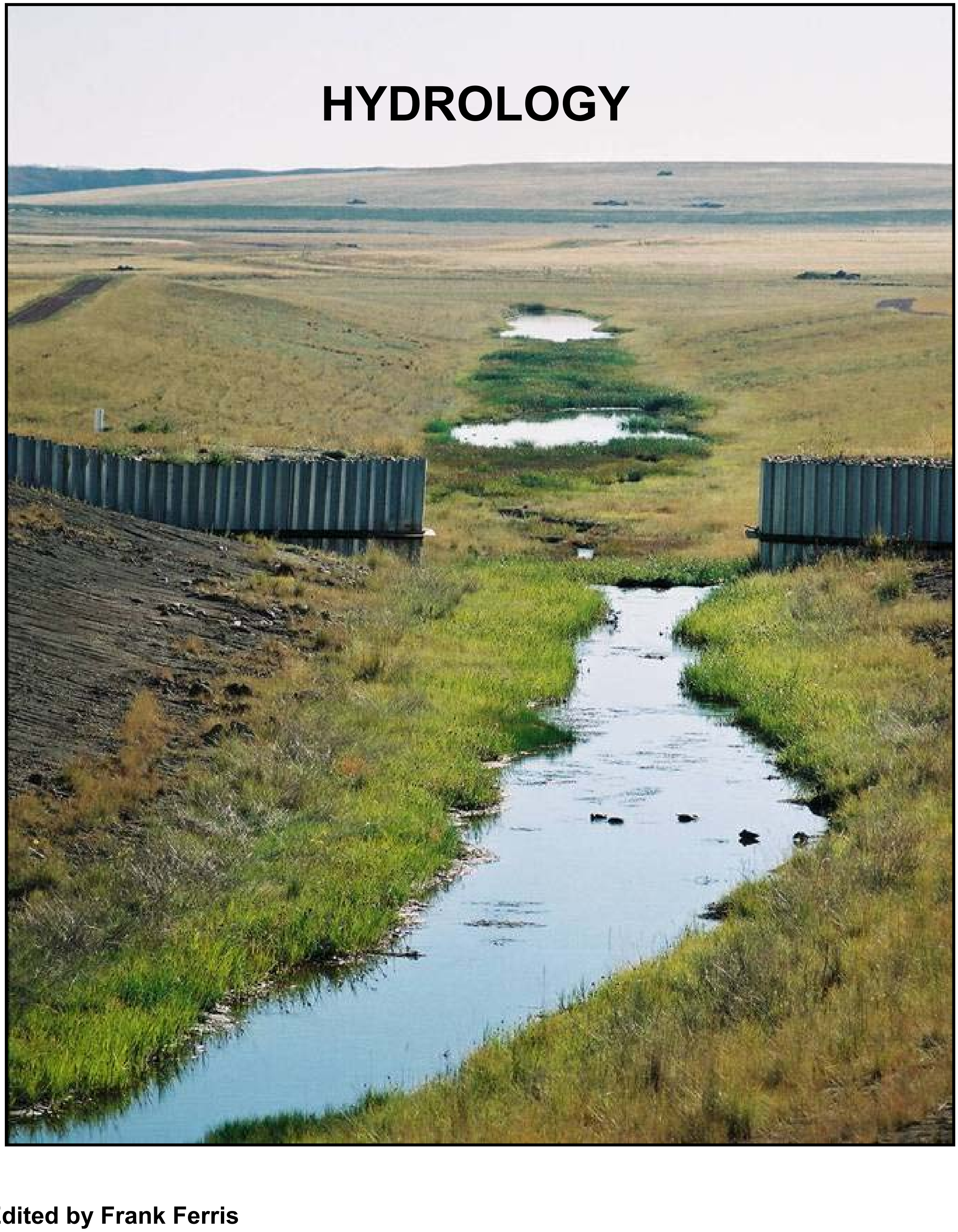
Strategic placement of truck loose dumps on level graded surfaces may be shaped into mounds, knolls, or ridges for permanent reclamation. In some instances, residual dumps or rough surfaces merely require some smoothing to provide topographic relief in upland or lowland locations.

Irregular topographic configurations present opportunities for construction of microtopographic features on slopes during final grading. With some amount of cut/fill earth movement, bowl shaped features and ridges can be created to enhance topographic relief on reclaimed slopes.

A most effective way to create or enhance microtopographic relief is the use of large rocks or boulders encountered during mining or other excavating activities. Placement of boulders on reclaimed land provides wildlife habitat and cover and effectively enhances the landscape of reclaimed land. The ways in which boulders may be placed or configured is limited only by the creative imagination.

Boulder placement along ridge crests, rock caps on knolls or mounds, in random rock piles, random singular placement, placement in linear windbreak configurations, rock outcrops on slopes, along reconstructed stream banks, or within constructed reservoirs, are some of the possibilities. Construction of rock outcrops on final graded slopes is particularly effective in providing microtopographic diversity. Boulder features may be emplaced before or after topsoil replacement operations.

HYDROLOGY



Edited by Frank Ferris

Handbook of Western Reclamation Techniques Second Edition

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SECTION 3 HYDROLOGY

A. INTRODUCTION

Section editor: Frank K. Ferris

Control of water and sediment in disturbed areas is important for practical and legal reasons. One of the most important post-disturbance features is the reconstruction of drainages, which control erosion and restore the surface hydrologic function. Even with the best planning, design, and construction practices, disturbed and reclaimed areas are very susceptible to erosion until vegetative cover can be established.

The techniques in this section cover some common water control structures, sediment control, and reconstructed drainages that have been implemented at various mine locations. The following aspects should be considered when implementing any design:

1. Proper installation is critical to the success of any project. In hydrology, it is extremely critical because once water has bypassed or undermined your structure, the effectiveness of the structure is compromised and structural failure is likely.
2. If the problem or project is too complicated or too large, get experienced help. It is not unusual for an inexperienced person to have several failures prior to solving a hydrology problem.
3. Match the method to the site condition. For example, hay bales may not be effective in a steep draw.
4. Match the method to the climate. For example, a grass filter will take longer to establish and is less likely to be successful in an arid environment.

Self-functioning sediment reservoirs are a relatively new addition to the reclamation toolkit. This type of reservoir is designed to discharge water through a sand filter that is part of the embankment. Self-functioning reservoirs operate without pumping, sampling, or logistical activities in all weather and all conditions at all times of the day and night. Periodic maintenance is required to remove sediment from the reservoir side of the sand filter.

If built according to appropriate designs, the discharge from a self-functioning sediment reservoir will be cleaner than required to meet limits for suspended solids, so sampling may not be required. This should be authorized by the appropriate regulatory agency prior to permitting and construction. Self-functioning reservoirs, as with any regulated structure, should be designed by a properly qualified professional. Passive sand filter sediment reservoirs have been in use for several years.

B. Control Structures

1. Sediment Control Basin Design and Construction

Section editor: Frank K. Ferris *Subsection author: Richard C. Warner*

Applicability

Sediment control basins have been used extensively for storm water management and sediment control throughout the mining industry. A variety of dam/impoundment types have been utilized which include excavated basins, embankment dams, and, more recently, infiltration basins. Sediment basins are used to reduce peak flow, trap sediment, and meet effluent limits.

This subsection presents design and construction considerations for storm water and sediment control basins. Actual design and construction procedures are readily available elsewhere (SCS National Engineering Handbook, Section 19 (SCS, 1985); Earth Manual, Department of the Interior (Bureau of Reclamation, 1974); and SCS Engineering Field Manual (SCS, 1984)).

Special Considerations

The current wet-weather effluent limit widely used in the mining industry is 0.5 milliliters per liter settleable solids at peak discharge. The Imhoff cone test is used to determine the settleable solids concentration at the discharge point from a sediment basin. In addition to meeting the required effluent concentration, basins are used to minimize the hydrologic impact of mining by reducing the peak flow, often to pre-mining conditions.

The National Pollutant Discharge Elimination System (NPDES), which may be applicable under dry-weather situations, normally requires effluent limits for Total Suspended Solids (TSS), usually specified in milligrams per liter. To meet NPDES regulations, design criteria not appropriate for the system being protected are frequently needed. This is because current regulations focus on specific criteria, often neglecting key aspects of a particular fluvial system.

Since sediment discharge frequency/duration/concentration relationships influence aquatic invertebrates and multiple use of the receiving waters, the specific criteria approach can have undesirable environmental consequences. A single nationwide standard that disregards the flow and sediment regime of the fluvial system discourages the development of holistic procedures and methods, thereby reducing the incentive to explore more environmentally sound and cost effective approaches.

Technique

a. Design Considerations

Sediment basins are used to reduce peak flow, trap sediment, and meet effluent concentrations. The efficiency of basins to accomplish these functions is directly related to basin design and construction procedures. Additionally, the efficiency of a basin is highly influenced by up-gradient mining activities and control measures. Basin efficiency is also directly influenced by the incoming eroded sediment size distribution.

If up-gradient controls such as check dams, sediment traps, furrows, terraces, etc. are used, the sand fraction of the transported sediment is reduced. Although the overall trap efficiency of the basin will subsequently be decreased by these measures, the need to provide additional sediment storage and/or expensive sediment removal is also reduced.

Regional basin analysis should be used to incorporate runoff, sediment concentration and amount, and eroded sediment particle size distribution information into the design. If characteristics of the receiving stream can be considered as part of the design, regional basin analysis becomes even more valuable.

Basin design parameters include: location, gradient, and stabilization of the inflow channel; length-to-width ratio of the pool measured at the crest of the principal spillway; basin shape and depth; sediment storage capacity; permanent pool storage; location, type, and size of the spillways; passive and active dewatering provisions; use of internal check dams, turbidity curtains, and baffles; and use of flocculation additives. The performance of a basin in reducing the peak flow, capturing sediment, and meeting effluent concentration limits depends on comprehensive design and rigorous adherence to design requirements during construction.

(1) Inflow Channel

Inlet(s) should be located to provide the hydraulically longest flow path between the inlet and outlet. This will help to reduce short circuiting and provide a higher potential for mixing the inflow with the permanent pool, thereby reducing the sediment concentration through dilution and providing a longer residence time needed for settling sediment. The basin inlet should be a channel versus a pipe to reduce concentrated flow and avoid clogging by debris during large storm events. The inlet should be stabilized by geotextiles, rock riprap, or the other means described in the subsection entitled "Drop Structures" in this section of the handbook. The inlet channel should be wide to further enhance mixing.

(2) Length to Width Ratio

The optimum length-to-width ratio of the reconstructed basin is two to one. This ratio reduces dead storage and short circuiting. A ratio of one to one increases dead storage from approximately 20 to 30 percent. Longer length-to-width ratios have not been adequately investigated but should incrementally decrease dead storage and increase trap efficiency.

(3) Basin Shape and Depth

The shape and depth of the basin should provide a storage depth that reduces re-suspension of previously settled sediment. An alluvial depositional fan is seen at the entrance of many sediment basins. This depositional feature reflects the settling characteristics of incoming sediments. A deeper basin will reduce the potential re-suspension of deposited sediment. Thus a relationship exists between length and depth with the two-to-one ratio providing the length needed for settling time and the deeper pond reducing potential sediment re-suspension.

The relationship is complex because the deeper pool allows settling particles to remain in suspension longer prior to reaching the level of previously settled sediment. Thus, sediment in the deeper pond may be discharged while still in suspension. Field experience indicates that, for a pond with a permanent pool, a length-to-width ratio of two to one is adequate. Two to three feet of permanent pool above the sediment storage area provides a buffer to reduce sediment re-suspension and facilitates the tradeoff between sediment settling depth and the potential for re-suspension. Further research is needed on this relationship.

(4) Sediment Storage Capacity

Sediment storage is often sized by a rule-of-thumb such as "X" acre-feet of storage per disturbed contributing watershed acreage. Such simple methods often yield an over-design of the actual needed sediment storage capacity. Rule-of-thumb methods often have no confirmed data base nor do they reflect the erosional and sedimentary processes occurring within the watershed. There are numerous opportunities to contain sediment within the watershed, including the mine pit as a significant portion of watershed precipitation enters the active pit area either as precipitation or runoff directed to the pit.

The judicious use of check dams, sediment traps, furrows, terraces, and numerous other onsite control techniques reduces the need for excessive sediment storage. An alternative method to the rule-of-thumb approach is to estimate the sediment load associated with the 10-year 24-hour design storm event and normalize for average annual sediment yield based on the published annual R-factor.

The Sediment, Erosion, Discharge by Computer Aided Design (SEDCAD 4 Manual, (Warner, Schwab and Marshall, 1998) for further information regarding this method. Another approach is to simply specify the sediment clean out level based on past experience and basin performance in the region. Other methods include estimation using the Soil Conservation Service's universal soil loss equation or its modifications.

(5) Permanent Pool Storage

The size of a permanent pool affects peak flow reduction, sediment trap efficiency and effluent concentration. The primary consideration is how the permanent pool affects the detention time of incoming flow and sediment. The advantage of a permanent pool is that, assuming the water in the basin is clear at the start of a runoff event, it will provide significant dilution, thus reducing the concentration of the effluent. The negative aspect of a permanent pool is that there is usually less space available for detention of the incoming waters (inflow hydrograph), and runoff will be discharged at a faster rate. Additionally, the depth that a sediment particle must traverse to be deposited is increased; thus increasing peak flow, decreasing detention time, and retaining a greater percentage of sediment particles in suspension.

If a permanent pool and a partially dewatered basin system are contrasted, these trade-offs can be readily visualized. The partially dewatered basin has initially less water for dilution of the incoming flow but greater capacity to retain a portion of the inflow hydrograph. Additionally, sediment entering the dewatered system will have an initially smaller settling distance and a greater detention time than one entering the permanent pool basin. Refer to the SEDCAD 4 Manual (Warner, Schwab, and Marshall, 1998) for a more complete discussion and illustration of the efficiency of a passive dewatering system. It appears that the trade-off among all of these design parameters results in the conclusion that dewatering basins provide a higher detention time, greater sediment trap efficiency, a lower peak discharge, a lower peak stage, a smaller basin, reduced embankment height, and lower effluent concentration with respect to settleable solids than the permanent pool situation.

(6) Spillway

Spillway location, type, and size directly influence the performance of sediment basins. A large spillway with little surcharge provides no significant attenuation of the incoming storm. Thus, peak flow will only be slightly reduced, detention time will be minimal, potential sediment trap efficiency will be reduced, and effluent concentration will be higher than alternative spillway techniques. A smaller spillway with the capability of building temporary surcharge will provide peak flow attenuation and improve sediment removal.

(7) Dewatering Provisions

The previous discussion of the tradeoffs between a permanent pool and a partially dewatered basin emphasize the potential increased efficiency of a partially dewatered basin. Methods to achieve dewatering are: (1) perforated risers, (2) perforated risers with tapered holes, (3) perforated risers with rock filters, (4) perforated risers with geotextile filters, (5) trickle tube, (6) slow sand filter, (7) fixed siphon, and (8) floating siphon. Methods 1 through 6 can be passive or made active with the use of a discharge valve. Methods 7 and 8 are normally operated passively but can be operated actively with the use of a pump.

A perforated riser has a higher trap efficiency than the standard drop-inlet principal spillway. Use of tapered holes in a perforated riser facilitates various operational dewatering schemes used to provide storm water storage by varying incremental dewatering times. The addition of a rock filter, for all or part of the height of the perforated riser, increases sediment trap efficiency and reduces effluent concentration. The filtering action of the geotextile further reduces effluent concentration but significantly increases dewatering time. This increase in dewatering time can be partially overcome by only using the geotextile for the lower perforations.

Locating a small trickle tube near the sediment storage volume functions like a single dewatering orifice in a perforated riser but has the disadvantage of releasing sediment deeper in the pond. A fixed siphon tube has similar disadvantages but should reduce sediment concentration due to the forced upward discharge during the siphoning period. The floating siphon tube has the added advantage of always discharging slightly below the surface where sediment concentration is low. Slow sand filters have been installed in Pennsylvania and Ohio to dewater basins at landfills. The effluent concentration is lower than for any other dewatering method observed to date. Research is currently ongoing to mathematically model the sediment removal effectiveness of slow sand filters and will be incorporated into SEDCAD+ version 5.

Passive systems function automatically, which is an advantage for remote locations and reduces work load. The advantage of placing a valve on the discharge line of these dewatering systems is to utilize contained water for fugitive dust control or other mining uses and to discharge lower sediment concentration after a longer settling time has elapsed.

(8) Check Dams, Turbidity Curtains, and Baffles

Internal check dams are provided to accomplish numerous functions: (1) provide a chamber for sediment storage of the larger size sediments, (2) facilitate sediment clean out, (3) provide detention and slow release through previously deposited sediments for small storms, and (4) distribute runoff more uniformly throughout the width of the basin to reduce potential short circuiting and dead storage. The internal check dam should have a rock trench drain beneath it to facilitate dewatering of the first chamber to the second chamber of the sediment basin.

For high flows that completely fill both chambers, the internal check dam may exacerbate trap efficiency by actually creating a short circuiting of the inflow by raising the sediment-laden water over the internal check dam to a higher elevation. Further research is needed. Turbidity curtains function to lengthen the flow path between the inlet and outlet. The turbidity curtain should direct flow beneath and to the sides of the curtain. These curtains should be relatively porous such that some flow can also be transported through the curtain.

(9) Flocculants

Flocculants can further increase the effectiveness of sediment basins and may, when used with dewatering techniques, further reduce basin size. Flocculants are predominantly being used in Texas and western Canada to achieve higher trap efficiencies and lower effluent sediment concentrations.

b. Construction Considerations

Several construction elements are discussed in the subsections entitled "Special Considerations in Planning and Constructing Permanent Postmining Impoundments" and "Hydrologic Control Structure Tolerances" in this section of the handbook. This subsection will focus primarily on construction quality control during the compaction process, but will address other facets of construction such as clearing and grubbing, excavating the cutoff trench, and constructing the emergency spillway. Large dam construction is considered beyond the scope of this section and will not be discussed.

(1) Soils

Borings, or at least test pits, should be made throughout the pond area with particular attention paid to the location of the embankment. Soils suitability depends on the ability of the soils to be compacted, thus developing a relatively impervious basin base and embankment. Silty clay loams and sandy clay loams are excellent potential soils for pond and embankment construction.

The purpose of foundation studies is to assure that a stable support of the embankment will be provided during saturated conditions and that necessary elements exist to prevent excessive seepage through the key way. Clearing and grubbing is necessary to remove vegetation, soils with root growth, and soils that are unsuitable for construction. Cutoff trench excavation is an extension of the clearing and grubbing operation. The cutoff trench functions to reduce seepage beneath the embankment. Its width should be that of a dozer or compactor to facilitate operations.

Prior to compaction, standard soil tests need to be conducted primarily to determine the density-moisture content relationship. Scarifying the foundation soils will help bond the compacted lift to the foundation. Additionally, scarification between lifts will also reduce the overall permeability of the soil layers. Lift thickness should relate to the construction equipment. If only a dozer is used, a lift thickness of four to six inches will provide adequate compaction effort (rubber-tired equipment will provide better compaction than a track dozer). The use of a compactor and six inch lifts will increase compaction effectiveness and ensure a better embankment.

(2) Construction Quality Control

The key elements for construction quality control are scarification of the previous lift, lift thickness control, soil lift mixing and blending, and, most importantly, proper control of the compacted moisture content. The Proctor test, in conjunction with a permeability test, will provide information necessary for proper compaction needed to assure a low permeability soil liner and embankment. A range of moisture contents and densities needed to provide an acceptable permeability will emerge from these tests.

Providing air-tight bags containing soils at moisture contents below, at, and above the target moisture content readily assist operators in recognizing the correct soil conditions during the construction phase. Furthermore, equipment operation provides an immediate feedback regarding proper moisture content during construction. A properly trained compactor operator can readily determine by the "feel" of the equipment and observation of the equipment foot print if sufficient moisture content exists and needed compaction has been achieved. The compactor should "walk out" after four to seven passes in a properly compacted soil. The inspector should be able to roll the soil between his/her hands into a long tube if the moisture content is near optimum. Too dry and the soil will not hold together; too wet and the soil will smear in the hands rather than rolling.

All of this compaction testing may not be necessary for every embankment. An adequately compacted embankment and pond surface may be achieved given proper soils, a relatively close moisture content, and passage of construction equipment over the embankment such that the equipment effectively compacts the entire width of the embankment. The level of needed compaction dictates the degree of construction quality control that is necessary for a given operation.

(3) Emergency Spillway

The emergency spillway should use the original ground if practical; otherwise excavation of the inlet channel and exit channel will be required. The emergency spillway should be constructed such that no flow will be conveyed against the embankment. If this is not practical then rock riprap, with a bedding stone blanket and/or geotextile, should be used for protection of the embankment. Spillway dimensions should be selected to convey the design discharge.

As a practical consideration, it is advisable to over-design the emergency spillway to convey the 100 year or larger design storm. On small dams, the cost of this over design is usually minor with respect to the safeguards that it provides. A rule-of-thumb used by the Soil Conservation Service (SCS) is that the maximum width of the bottom of the emergency spillway should not exceed 35 times the design depth of flow. This is to preclude potential accumulation of deposited material and debris and to reduce the potential for establishing meandering flow through the spillway.

2. Diversion Design and Construction

Section editor: Frank K. Ferris *Subsection author: Richard C. Warner*

Applicability

Diversions are used throughout mining to intercept and convey runoff. Some diversions used to convey runoff from non-disturbed areas around active mining sites preclude commingling of runoff waters and reduce the quantity of runoff to subsequently be controlled by sediment basins. Diversions take on many design forms depending upon the quantity of runoff and slope of the channel. Classically, as the quantity of runoff increases, there is a progression from bare earthen to grassed waterways to rock riprap channels.

Numerous commercial products can be used to stabilize diversions. Lower flow velocities can be controlled by excelsior mats and geotextiles. As flow increases, grouts, gabions, and concrete filled fabric forms can be used. If properly designed and constructed, diversions perform the duel functions of conveying runoff and remaining stable, i.e. non-erosive. Poor construction techniques and inadequate time for stabilization prior to a significant discharge event can cause temporary failure of the diversion and create recurring cost.

Special Considerations

In the design of diversions, the development of a stable channel for a rather large design storm appears to be the primary consideration. If diversion channels are built on too flat a slope, they can fail due to blockage by accumulated sediment or “blow-outs” in low spots. Often diversions can accommodate the large storm event, but failure to consider potential sediment deposition from intermediate events, and subsequent loss of conveyance capacity, sometimes leads to failure of the control structure. In the case of terraces, the failure of an up-gradient terrace causes the failure of all down-gradient terraces. Diversion failures can occur due to construction procedures that do not adequately provide the needed measure of construction quality control.

An aggressive field inspection of the diversion during construction can reduce the propensity of potential failures by assuring that proper slope, depth, freeboard, and channel transitions have been established. Failure to give adequate attention to a stone blanket and/or a geotextile during the placement of rock riprap creates the potential for undercutting beneath the rock layer, erosion and transport of sediment, and ultimately failure of the control structure to function properly. Inadequate design information exists for steep slope rock riprap design, i.e. slope greater than 15 percent. The placement and distribution of rock riprap (Dmax, D50, and D10) along the rock riprap diversion also creates less than adequate construction conditions.

Technique

Methods will be outlined in this subsection and reference will be made to standard practices. The techniques will emphasize how to avoid failures and the expense of diversion reconstruction. Since the design of terraces for surface mining has not been adequately addressed in literature, design considerations will also be outlined for terraces. Additionally, techniques for which no published information is available but seem to work well in the field will be discussed. Such informal technology transfer provides a vehicle of information exchange to the extent necessary for others to try the techniques, and through gained experience improve upon the ideas.

(1) Temporary Diversions

Bare soil or spoil diversions are commonly used as temporary diversions. They are relatively cheap to construct but often require significant maintenance. Thus, the tradeoff between initial capital cost and maintenance cost is readily apparent. The limited permissible velocity approach is normally used. The technique is simple. The soil or spoil is linked with a permissible velocity. If in the actual design the permissible velocity is not exceeded, the diversion is assumed to be stable and will convey the discharge without significant erosion.

Many diversion design elements are often ignored with the permissible velocities. For example, permissible velocities listed in literature are limited and do not readily translate to many spoils. Thus, the initial determination of permissible velocity is not readily apparent. The development of listed permissible velocities is largely based on intuition and experience gained from relatively stable cut channels that areused for irrigation. Often, both cut and fill are necessary in mining operations, and the fill soils can not be sufficiently compacted to withstand the permissible velocities.

The effect of a design near the critical slope is often ignored. Uniform flow at or near the critical depth is unstable. A slight irregularity in the construction or deposition in a reach of the diversion can cause a shift in the Mannings' "n", thereby developing an unstable condition. Uniform flow at or near the critical depth is observed to create a sort of standing wave which can cause an appreciable change in flow depth and in some circumstances, exceed the diversion capacity. Earthen channels often meander, causing erosion and deposition. Where sediment deposition occurs along channel reaches overflow conditions can exist.

(2) Diversion Stability

<u>(a) Rock Check Dams</u>

Besides these design conditions, it should be realized that for many soils and storm conditions for various regions, runoff from a very limited acreage can be controlled by earthen diversions. Physical constraints sometimes require that a diversion channel be constructed with a slope that is too steep (i.e., the velocity at the design flow exceeds the permissible velocity for the type of soils encountered. All of this appears to be bad news. How can earthen diversions be salvaged? Promising techniques use check dams made of durable rock. This is illustrated on the following page (Figure B-2-1).

The check dam creates a back flow condition, thereby reducing transport velocity and creating a depositional opportunity for transported sediment. Thus, the potentially erodible channel is transformed to a stable channel. The design of this channel should take into account the needed additional conveyance capacity, assuming that deposition removes a portion of the channel cross sectional area. The check dams are designed as broad crested weirs, or sharp crested weirs for the geotextile check dam. The dams are the flow constriction within the channel.

With the erosion problem eliminated, these check dam-stabilized channels can now accommodate much larger drainage areas and higher peak flows than the standard limited velocity methodology. Check dam spacing is a function of slope. A conservative approach is to have the back water of each dam reach the up-gradient check dam. These designs have been successfully installed in the Piedmont area of South Carolina and in the Mississippi Delta region, where highly erodible soils are common.

<u>(b) Grassed Waterways</u>

Grassed waterways are often used to increase diversion stability and therefore convey larger runoff quantities. The classic design of grassed waterways is based on retardance classifications, which enable the design for conveyance, under long grass conditions, and stability, under short grass

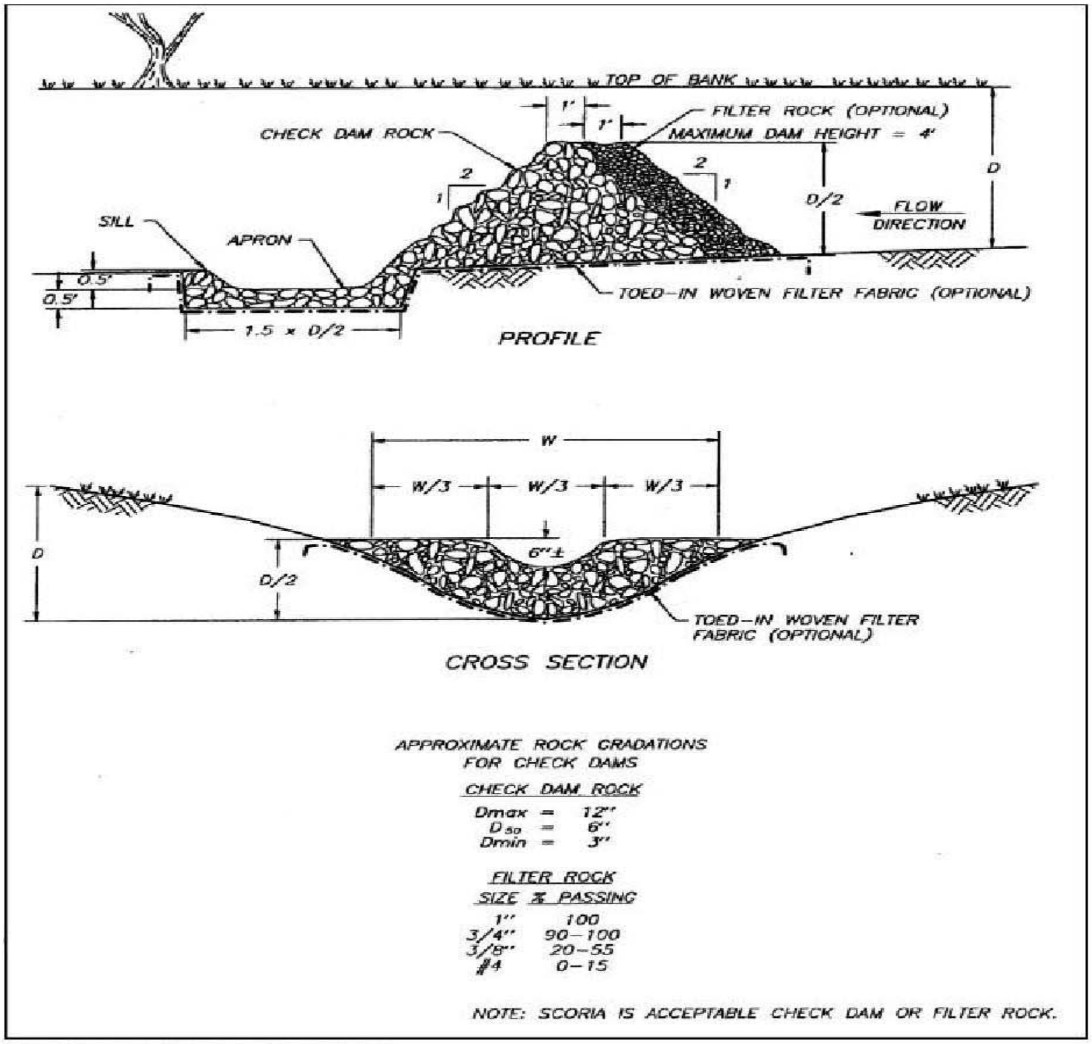


Figure B-2-1 ROCK CHECK DAM

conditions. To perform satisfactorily, grassed waterways are dependent upon climatic conditions that are favorable to vegetative establishment and growth.

To successfully establish grassed diversions, many options exist but few are actually employed. The channel can be stabilized by: small check dams as previously described; commercially available products utilized to protect the channel and assist vegetal establishment; construction of the diversion in advance of actual use; use of a rock center section of a low flow channel; or diversion of runoff during establishment.

In practice, operators usually design diversions to be stabilized with vegetation, construct them, apply seed and mulch, and then accept the risk that a runoff-producing event may occur before the vegetation can become established. Required repairs following such an event may entail partial or complete revegetation. Season of construction and an element of luck will affect the success of the project. Detailed design procedures are provided in SCS-TP-61, Handbook of Channel Design for Soil and Water Conservation (SCS, 1947).

(c) Rock Riprap

Rock riprap diversions can convey large quantities of runoff on steeper slopes than can be considered for earthen or grassed diversions. As previously stated, the data base for designs is based on typical stream gradients and is limited for steeper channels. Thus, extrapolation is the design method for diversions greater than approximately 10 percent.

Numerous methods have been developed to predict the D50 rock size. These vary from simply solving Mannings' equation, by estimating Mannings' "n", to methods that compare resisting moments to overturning moments and are linked with a safety factor. Analysis has been completed for a stream approximately 20 feet wide and of trapezoidal shape which compared eight methods. Most of the methods predicted a D50 within +/- 3 inches. Thus for channel slopes less than 10 percent, and for relatively small streams, numerous methods may be comparable.

It is recommended that alternative methods be used to develop a feel for the probable D50 size and, as always, practical experience gained from field applications that actually work is the most valuable design asset available. Unfortunately, the applicable range of various methods is not explicitly documented.

Angular durable rock should be placed by a backhoe or trackhoe to avoid segregation of rock sizes from dumping and pushing with a dozer. The riprap must be well graded as uniformly-sized rock will not pack and is less effective for erosion control

(3) Terraces

Terrace designs have been predominantly developed for agriculture. Terraces fail in mining reclamation due to deposition of sediment within the terrace or undercutting by flow at the soil-terrace interface, which sometimes produces a vehicle for piping beneath the terrace. Perhaps the most common mode of failure is collection of runoff water in a low spot, which overflows the terrace and causes a “blowout” in the berm.

Terraces constructed with a shallow slope and with a terminus in a pond or established drainage will provide better results over a longer time than terraces built on a contour. Animal bore holes also sometimes contribute to undercutting terraces. Designs must address both sediment and storm water. If terraces are to function as lateral sediment traps, either by design or by practice, then sediment deposition must be determined by erosion and transport models. The quantity of sediment expected to be deposited should be predicted and additional capacity provided.

The terrace slope and outlet control are predominant design parameters. The outlet should be designed to rapidly discharge larger runoff events while storing a portion of the runoff from these events. Smaller runoff quantities can be more easily detained through a passively dewatered outlet. The benefit of retaining a portion of the runoff is for establishment of vegetation. Use of small internal check dams located along the length of the terrace can provide runoff storage and also reduce the failure of down-gradient terraces if an up-gradient terrace fails. The SEDCAD 4 program can readily assist in the design of terraces, bare earthen diversions, grass waterways, and rock riprap channels.

3. Drop Structures

Section editor: Frank K. Ferris *Subsection authors: C. Marty Jones/Christopher D. Lidstone*

Applicability

Drop structures are typically constructed at locations where the "design" or "as-constructed" channel gradient is too steep, resulting in excessive flow velocities and the need for channel protection. A drop structure can accommodate the required channel fall over a relatively short, protected channel reach, while providing for the construction of a long section of lower gradient unprotected channel upstream and downstream of the structure.

Drop structures can also be located at sediment pond inlets and outlets to enhance the stability of the dam structure during flood overtopping (spillway) events, or the stability of the upstream channel during typical runoff events. Some states and non-coal regulatory agencies allow drop structures in the reclamation plan as a permanent structure.

Special Considerations

Drop structures should be located in a straight channel section where the fluid forces are steady and uniform. It is recommended that the structure be located at least 100 feet upstream or downstream of any bends in the channel, and a minimum of 100 feet upstream or downstream of channel confluences. Minimizing excavation, earthwork, and rock costs should be considered in the location of the structure.

Many regulatory agencies have guidelines or requirements which dictate the design life, hence hydrologic design event for channel protection structures. Design life may also reflect the level of risk acceptable to the designer or owner of the facility. Peak flow estimates for such design events are generally developed with computer models, which utilize SCS methods to predict the peak discharge. These include the: U.S. Army Corps of Engineers, HEC-HMS Hydrologic Modeling System; QTR-55; Sedimot; and others.

Technique

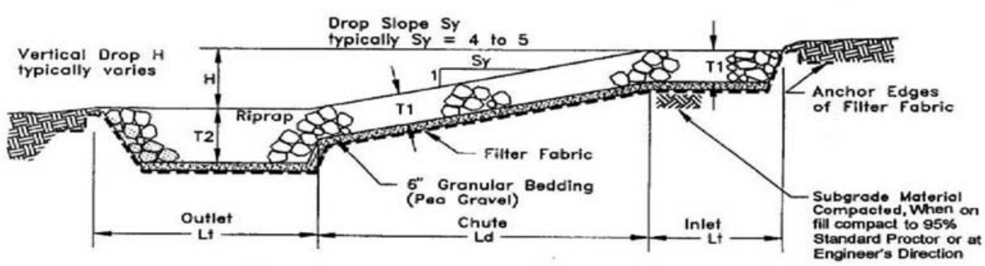
There are three main types of drop structures: concrete drops, rock riprap drops, and wire enclosed rock riprap drops (gabions). Concrete structures can be sloped chute structures or vertical drops. Rock riprap structures are typically constructed as sloped structures, and gabions are usually constructed as stepped structures. Rock riprap structures and gabion structures, which are more cost effective and are utilized more often than concrete drop structures, will be discussed in this section.

(1) Rock Riprap Drop Structures

Figure B-3-1 presents a typical profile of a successful drop structure. The basic parts of the structure are the inlet, chute section, and outlet. The rock riprap is sized to be stable during the design flow event. Various procedures are available to estimate the rock diameter or rock weight to ensure stability. This subsection will not present design procedures for sizing the rock riprap, but a listing of references to find design procedures has been included at the end of this section.

The function of the inlet and outlet section of the drop is to ensure a smooth flow transition entering and exiting the structure. The length of the inlet and outlet section should be five times the uniform flow depth of the downstream channel section or 15 feet, whichever is greater (refer to the "Design Manual for Water Diversions on Surface Mine Operations" listed in References). The chute section typically has a drop slope of approximately 4H:1V.

In some cases where the design discharge is large, the drop slope may be set at a flatter grade (5H or 6H:1V) to ensure the stability of the rock riprap. The design of the chute and drop height (H) should ensure that a hydraulic jump does not occur at the exit section of the structure. Based on the authors' experience with various structures, it is recommended that the Froude number should not exceed 4.0 in any section of the chute, and that the overall drop height (H) should not exceed 12 to 15 feet.



. Typical Rock Riprap drop Structure – Profile View

Figure B-3-1

A cross section of a drop structure is presented in Figure B-3-2. The design capacity of the structure must pass the design flow event with a minimum of one foot of freeboard. Freeboard allowance should be increased wherever possible, particularly where turbulent forces are anticipated; e.g. at the bottom of the structure. The side slope Z of the structure should be no steeper than 2.5H:1V and should be flatter under larger design discharges. The bottom width of the structure should be similar to the bottom width of the upstream channel. Similarities in channel geometry will make construction easier and improve the hydraulics through the structure. Bottom widths of the drop structure typically range from eight to sixteen feet. Anything less than eight feet in width is more difficult to construct. Most structures typically have widths varying from 12 to 16 feet.

Two of the most important factors in constructing a sound rock riprap drop structure, include: (1) obtaining rock with a proper gradation and shape, and (2) utilizing a durable and sound rock type. The rock size for the structure is based on median rock diameter, D50. The rock should be angular, blocky and have a uniform gradation to ensure that the individual rocks will interlock with minimum void space. The gradation is based on the D50 diameter:

D100 = 1.5 to 2.0 times D50

D20 = 1/3 to 1/4 times D50

Rock sizes for the gradation are usually specified by one-quarter foot increments, i.e. D50= 0.5 feet (6 inches), D50=0.75 feet (9 inches), D50=1.0 foot (12 inches). A median rock diameter greater than 2.0 feet (24 inches) with the proper gradation is difficult to obtain from most quarries. Generally, the rock riprap for drop structures will have D50 diameters less than 1.5 feet (18 inches). Good quality rock is essential for the long term success of the structure. The following rock properties are recommended:

(a) The rock should be durable;
(b) The rock should have blocky-angular shape;
(c) The rock source should be free of organic material, clay, shale seams, or other structural defects;
(d) The riprap should have a specific gravity of at least 2.50.

Lesser quality rock may by used in site specific situations, where the design flow is relatively small and/or the structure has a small drop. In some instances sub-standard rock can be anchored by vegetation or may be installed in a structure with a relatively short design life or at a site with minimal adverse consequences of failure. Standard construction specifications (ASTM) will provide rock testing requirements. Riprap sources which do not meet these properties may be utilized, but design modifications may be required. The designer will need to ensure that the rock quality will not compromise the stability of the structure.

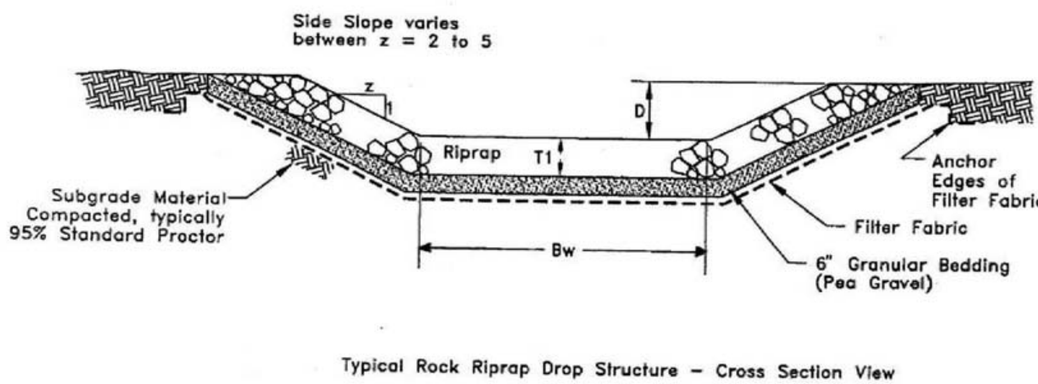


Figure B-3-2

Some measure of protection is required below the drop structure, to prevent failure or winnowing of the underlying soils. This can be accomplished with a graded granular filter or a granular bedding used in conjunction with a geotextile fabric (Figure B-3-2). Frequently the granular bedding is a pea gravel overlying the geotextile fabric. The fabric will protect the bed material from being "washed out" from below the structure and the granular bedding will protect the geofabric, as angular rock is being placed on the fabric.

There are some guidelines that should be observed during the construction of a rock drop structure. The construction inspector will need to ensure that the rock has a gradation corresponding to the design specification. He will also need to ensure that when the rock is handled (stockpiling and placing), segregation of the rock does not occur. The structures should be constructed from the bottom to the top to minimize the potential of rock segregation.

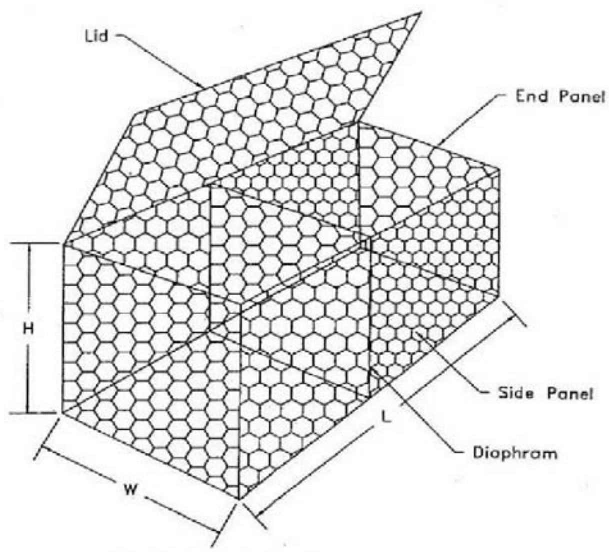
(2) Gabion Drop Structures

Gabions are wire enclosed baskets filled with rock. The combined weight of the rock in the enclosed structure can withstand higher flow velocities and hydraulic forces when compared to individual stones within a "loose" rock riprap structure. A gabion structure often can utilize on-site rock recovered during mining operations. A range of basket sizes available for construction are listed in Figure B-2-3.

A typical layout for a gabion drop structure is presented in Figures B-2-4, 5, 6, 7, and 8. As indicated in the figures, the structures are typically constructed with a stepped profile in both the longitudinal and lateral direction. When the gabions are placed, each basket should overlap no less than one-half the length of the underlying basket. The baskets will also need to be adequately keyed into the channel bank and bed to prevent failure of the structure by cutting or breaching. An inlet and outlet transition section, similar to that required for rock riprap drops, should be constructed. The individual baskets are also bound to each other with wire fastenings.

Design criteria for the gabion structures are typically based on channel velocity, depth of flow, or the ability of the gabion to withstand the force of the flowing water. Specific gabion manufacturers should be contacted regarding design criteria for each basket size. The allowable flow velocity and shear stresses are based on the basket thickness, rock size, and rock specific gravity. For example, and according to manufacturer's recommendations, a basket with a thickness of 1.6 feet, filled with rock with a D50=7.5 inches and specific gravity of 2.5, should remain stable for flow velocities less than or equal to 10 feet per second.

Figure B-3-3



Wire Thickness for the Gabion Baskets ~0.09"

Typical Gabion Basket Dimension

L(ft)	W(ft)	H(ft)
6.5	3.25	3.25
9.75	3.25	3.25
13	3.25	3.25
6.5	3.25	1.67
9.75	3.25	1.67
13	3.25	1.67

Detail of Typical Gabion Basket Sizes

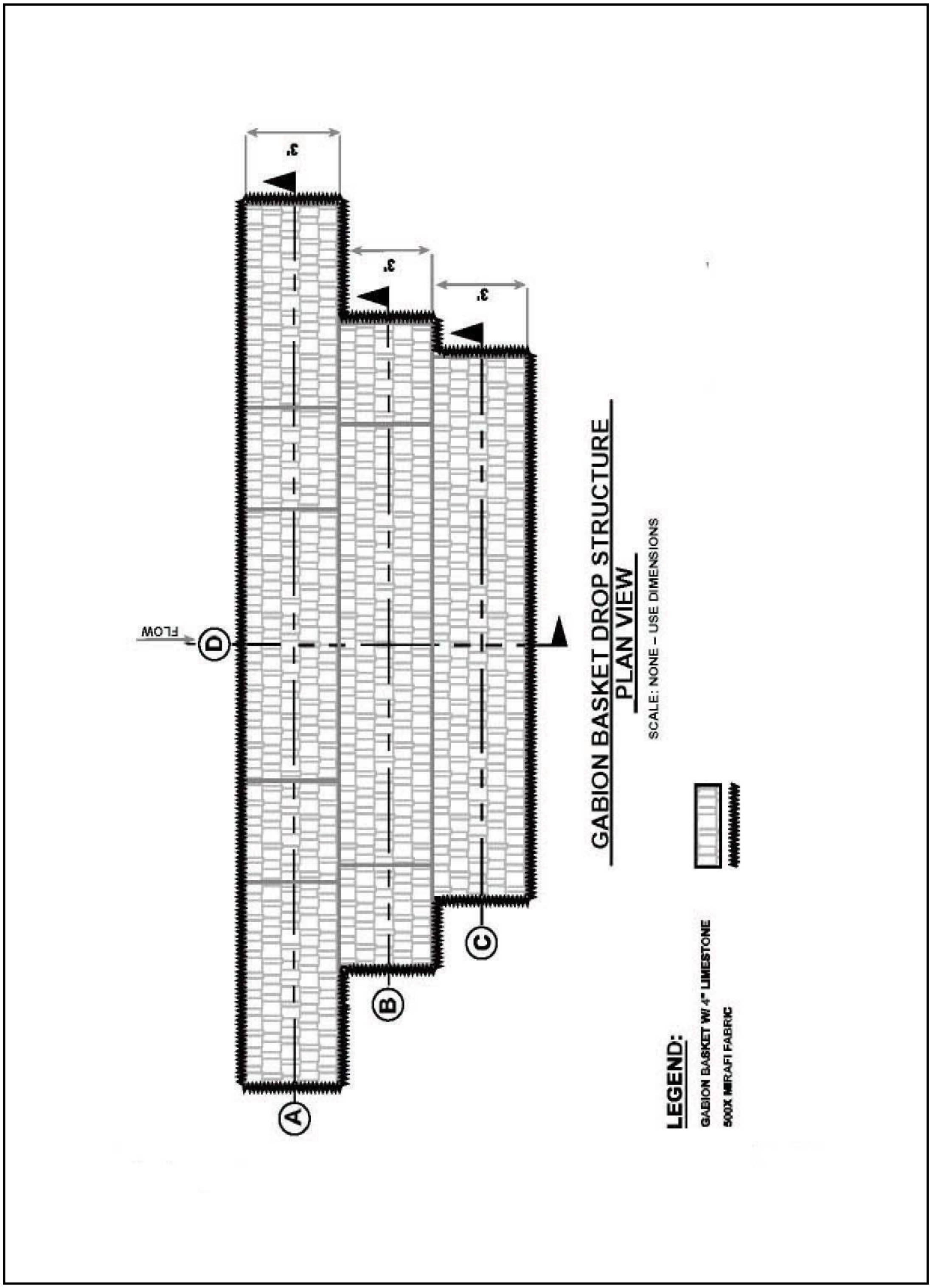

3'
3'
3'
FLOW
A
B
C
D
GABION BASKET DROP STRUCTURE
PLAN VIEW
SCALE: NONE – USE DIMENSIONS
LEGEND:
GABION BASKET W/ 4" LIMESTONE
500X MIRAFI FABRIC

Figure B-3-4

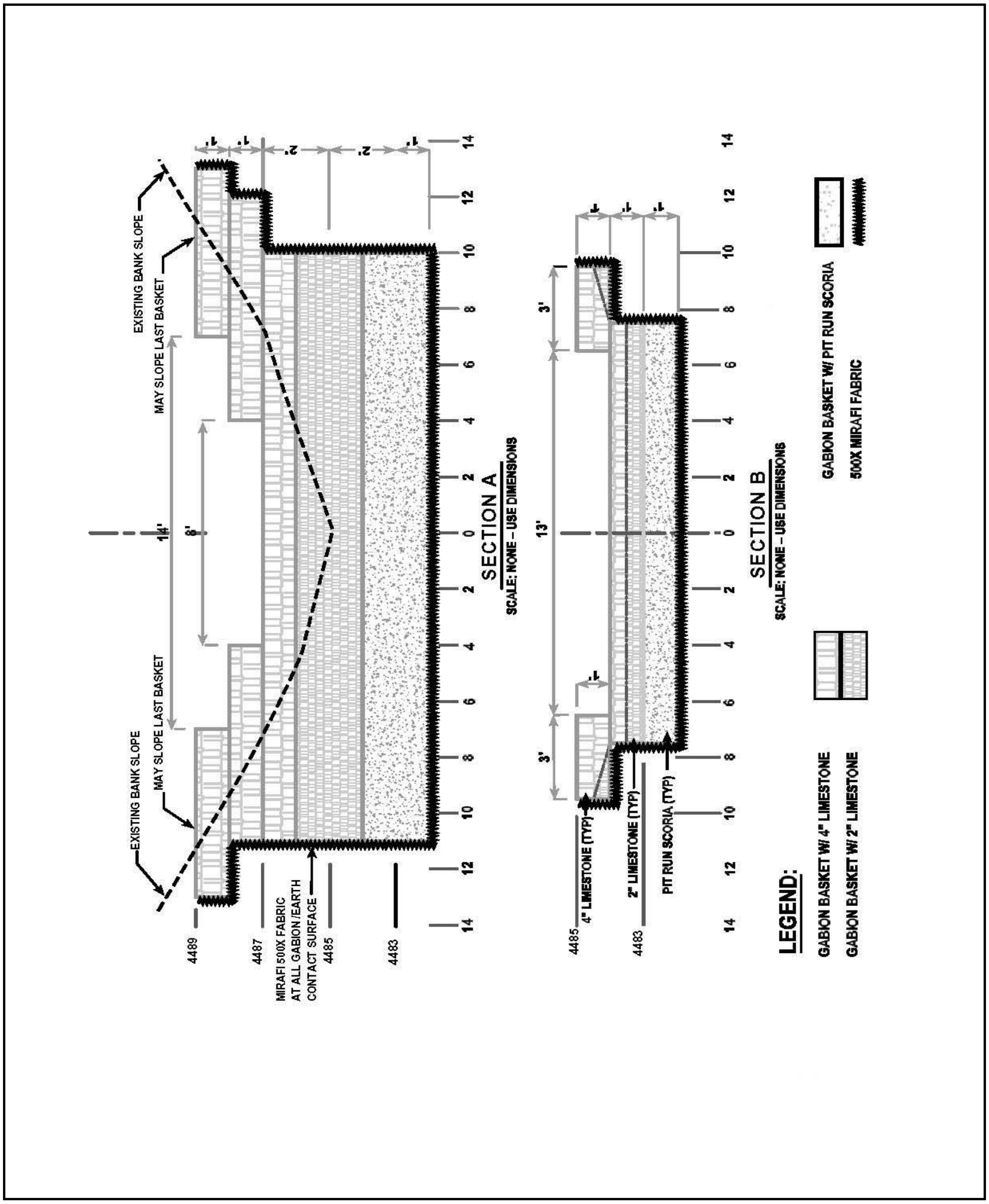

EXISTING BANK SLOPE
MAY SLOPE LAST BASKET
4489
4487
4485
4483
MIRAFI 500X FABRIC
AT ALL GABION/EARTH
CONTACT SURFACE
14'
8'
SECTION A
SCALE: NONE – USE DIMENSIONS
3'
13'
4" LIMESTONE (TYP)
2" LIMESTONE (TYP)
PIT RUN SCORIA (TYP)
SECTION B
SCALE: NONE – USE DIMENSIONS
LEGEND:
GABION BASKET W/ 4" LIMESTONE
GABION BASKET W/ 2" LIMESTONE
GABION BASKET W/ PIT RUN SCORIA
500X MIRAFI FABRIC

Figure B-3-5

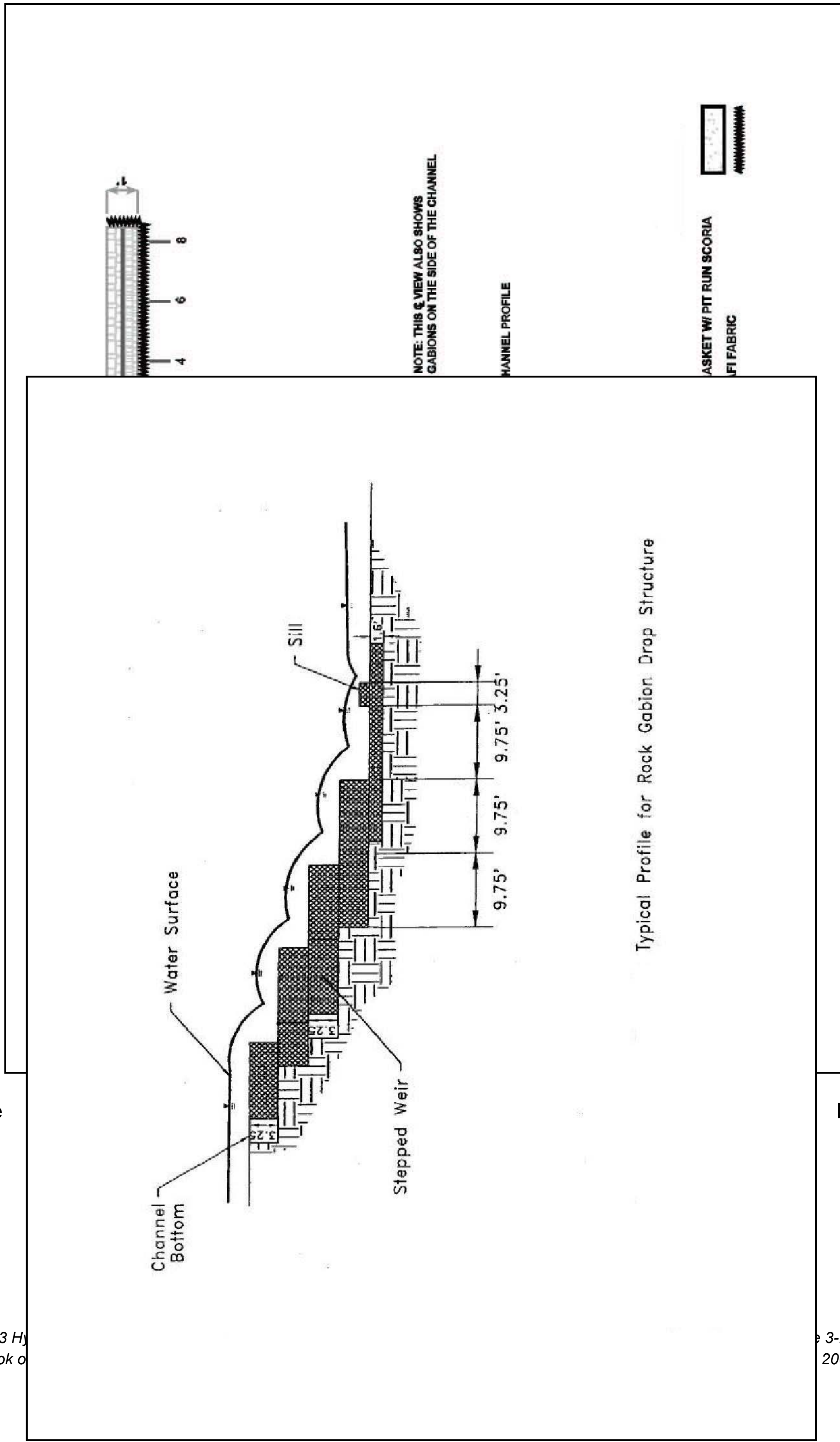

NOTE: THIS ℄ VIEW ALSO SHOWS
GABIONS ON THE SIDE OF THE CHANNEL
HANNEL PROFILE
ASKET W/ PIT RUN SCORIA
FI FABRIC
Water Surface
Sill
1.6'
3.25'
9.75'
9.75'
9.75'
3.25
3.25
Stepped Weir
Channel Bottom
Typical Profile for Rock Gabion Drop Structure

Figure B-3-6

Figure B-3-7

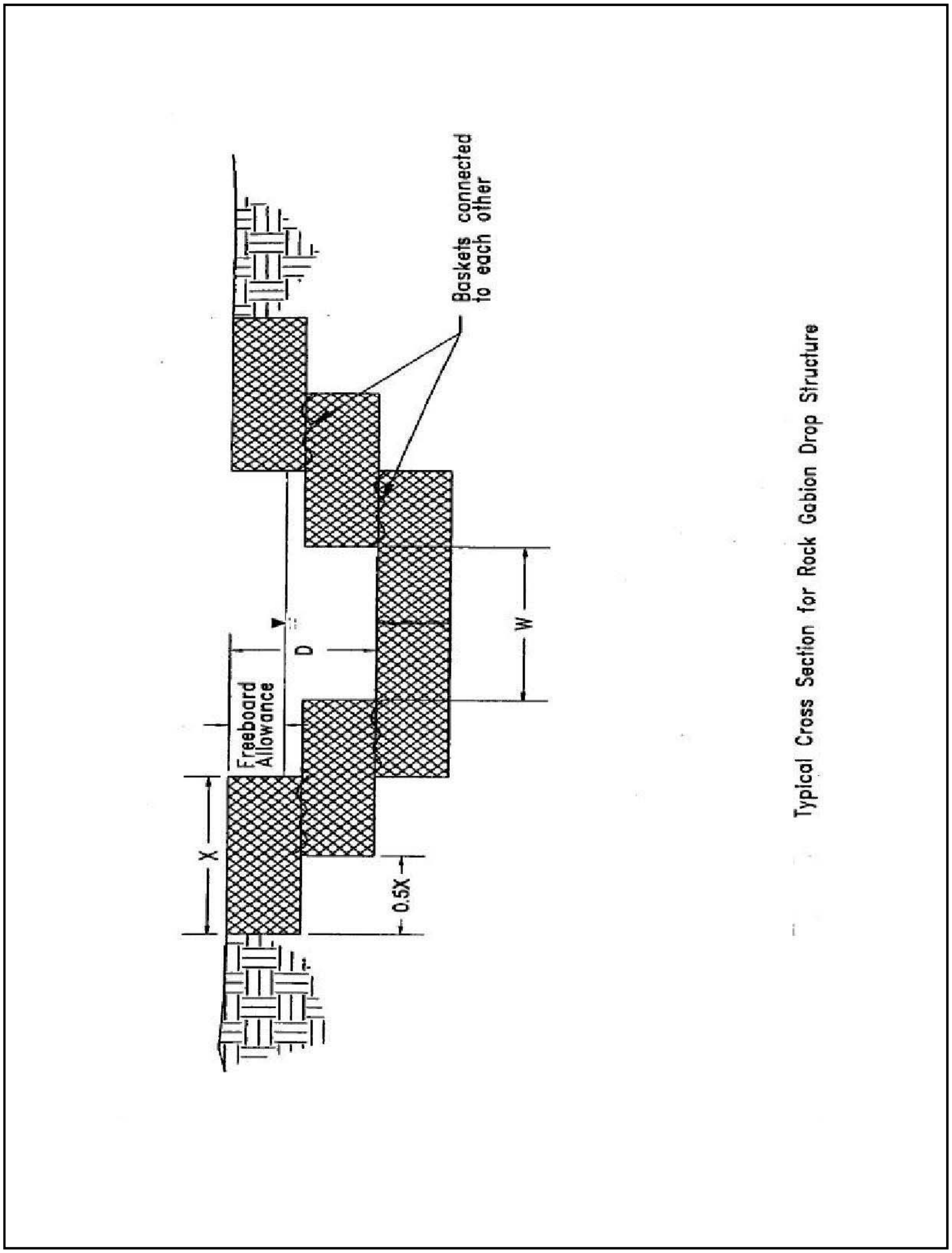

Baskets connected
to each other
Freeboard
Allowance
D
W
X
0.5X
Typical Cross Section for Rock Gabion Drop Structure

Figure B-3-8

One of the advantages of gabions in drop structure design is the ability to use "on-site" rock for the construction of the structure. However, the rock used to fill the basket should still meet the following criteria: (1) diameter of 5-10 inches; and (2) be durable and free of any structural defects. The designer should be aware that certain rock types, like "clinker" or "scoria", have relatively low specific gravity and poor durability. When utilizing sub-standard rock, structure design (basket size and rock diameter) and placement of the individual baskets should address the limitations of the rock. If low specific gravity rock is utilized, a larger basket thickness and/or larger individual diameter rock will be required to achieve the same level of protection at the individual structure.

For typical applications, galvanized, coated gabion baskets meet most design requirements at a lesser cost. If the structure is placed on corrosive soils or exposed to caustic waters or acid drainage, use of polyethylene coated basket wire will extend the design life of the basket at an increased cost. High Density Polyethylene (HDPE) baskets are also available at an even greater cost. HDPE baskets have higher puncture resistance, longer durability, and are easier to transport and assemble. The increased unit cost must be weighed against design intent, transportation costs, and labor factors.

(3) Rock Riprap Sizing

There are numerous sources and procedures available for determining the rock size requirements for a drop structure. Listed below are three sources that present different procedures for sizing rock riprap:

"Design Manual for Water Diversions on Surface Mine Operations" Prepared for the Office of Surface Mining, Fort Collins, CO. (Simons Li & Associates, Inc., 1982). This publication presents sizing criteria based on a design flow rate and the channel geometry.

"Rock Riprap Design for Protection of Stream Channels near Highway Structures, Volume II Evaluation of Riprap Design Procedures" (Blodget & McConaughy, 1986) This publication presents numerous design procedures for sizing rock riprap developed by the Army Corps of Engineers, Federal Highway Administration, State Department of Transportation and the Bureau of Reclamation (USBR).

"Hydraulic Design of Stilling Basins and Energy Dissipaters" (Peterka, 1958) presents an analysis of existing USBR installations and includes a design nomograph, which sizes riprap based on bottom velocity versus weight of rock.

When reviewing a procedure to size rock riprap for a drop structure, the procedure must be valid for the intended application. For example, if the design procedure was developed for rock placed on channel banks, it may not be applicable for sizing the rock riprap placed on the chute section of a drop structure. Some design procedures assume a specific gravity of 2.65 for all rock. Many otherwise suitable rock types, including limestone and leucite, have lower specific gravities. In these cases the rock may be "up-sized" to account for its lower unit weight.

4. Backfill Impoundments

Section editor: Frank K. Ferris *Subsection author: Frank K. Ferris/Patrick T. Tyrrell*

Applicability

Water structures are needed on a mine site for water treatment and storage. Impoundments created in backfill voids are usually more cost effective than impoundments on unmined areas.

Special Considerations

Uncompacted backfill slopes may not be stable enough to support equipment if the slopes become saturated.

Techniques

a. Design Considerations

Incised backfill impoundments are created by leaving a void area in the backfill and grading the slopes. Though simple, the following basic design features need to be considered: size, shape, cells, inlet structures, Mine Safety and Health Administration (MSHA) criteria, stability, location, function, and construction. The function of a reservoir will determine the extent that the design incorporates features for water treatment (shallows, cells, flat slopes, length approximately four times width) or water storage (deeper, steeper sides, length to width ratio variable).

In general, reservoirs should be designed with water treatment in mind, as good water quality is important for any function, and the incremental cost of a treatment reservoir is low compared to reworking or repairing any features of an inexpensive water storage reservoir. Backfill impoundments primarily intended to store water can be deeper, with shape dictated more by available topography, and with a reduced high-water line area to minimize evaporation.

(1) Size

The structure must be large enough to handle the design runoff event plus any pit or process water, and may include additional capacity for dust control or to provide a convenient location to hold excess runoff and minimize offsite discharges. Backfill impoundments with at least 100 acre-feet of water storage are commonplace for large surface mines. This large capacity provides flexibility in pumping and holding large volumes of water in the structure until a discharge is convenient or can be avoided. A larger size reservoir is more conducive to treatment and recycling of water from washing operations. Such a reservoir provides the treatment and storage capacity for dry periods when other sources of water become less reliable.

(2) Shape

If water treatment is the primary purpose of the reservoir, it will be the most effective in a long, shallow (two to three feet deep) reservoir with the inlets as far as possible from the water discharge location. This assures the shortest distances for sediment to drop to the bottom, and limits short circuiting (inflow water traveling directly to the pond outlet). As a guide, a backfill reservoir intended primarily for water treatment should average 5 to 30 feet deep, 200 to 500 feet wide, and 500 to 4000 feet in length, depending on the volume to be treated. Side slopes should be 3H:1V to 4H:1V to accommodate access by people and wildlife (Figure B-4-1). Angle of repose slopes 1.5H:1V that become saturated will likely fail. Mobile heavy equipment should be kept off the saturated, uncompacted slopes characteristic of this type of impoundment.

(3) Cells

Cells should be strongly considered to control any oil spill that might enter the reservoir, limit wave fetch, and eliminate short circuiting caused by temperature inversions (i.e. warm plant water). The connections between cells typically would be culverts installed below the water surface.

All cells should be designed to be at the same elevation regardless of the reservoir volume. Because the base and sides of the reservoir and the dividing embankment are not compacted, cells with differing water levels will likely have piping or seepage from cell to cell. As the soil settles, failure between cells is likely. Impoundments constructed primarily for water storage reservoirs do not necessarily need a dividing embankment.

(4) Inlet Structure

Inlet structures must be considered for any reservoir that is expected to function more than one year. Surface or pipeline water that is released above the high-water line and washes down an unprotected slope will cause significant erosion in one season, and more quickly if there is a continuous water flow. The washing of slope soil into the reservoir bottom will quickly fill the lower reservoir volume up to, or possibly clog, a connecting culvert or pump culvert, and will compromise the already marginal stability of the uncompacted slope.

One option is a culvert to deliver inflow below the water surface. If the pipeline inlet is on the reservoir floor, it will generally stir up sediment and decrease the reservoir's water treatment effectiveness. Using the same culvert for inflow and outflow can be done, but should only be considered if the quality of the source water is very clean. Pumping sediment-laden water into the pump culvert will cause pump problems (Figures B-4-2, 3, and 4).

Figure B-4-1

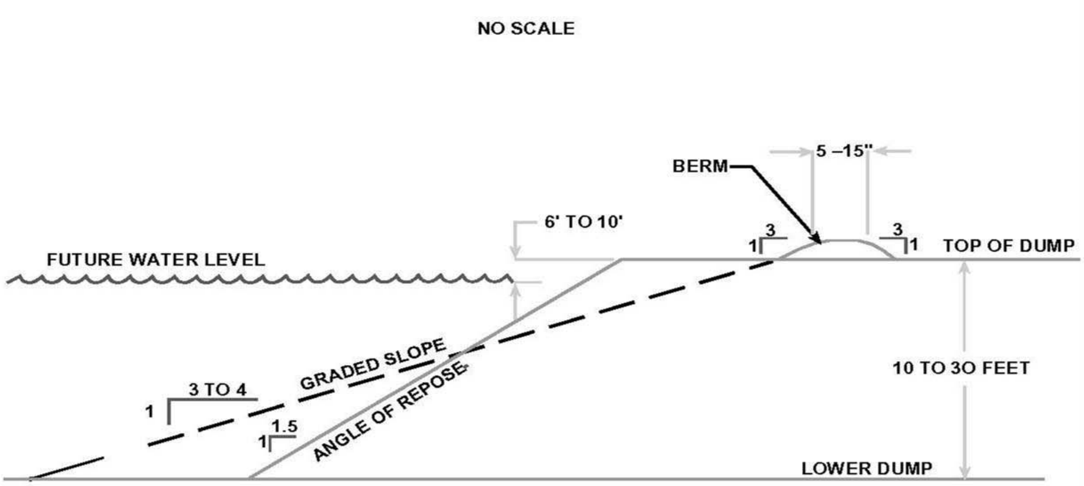


Figure B-4-2

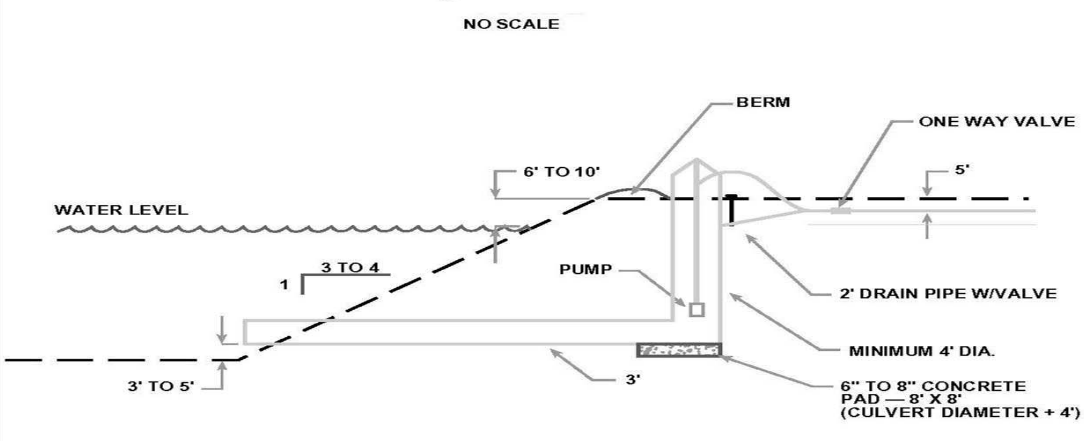


Figure B-4-3

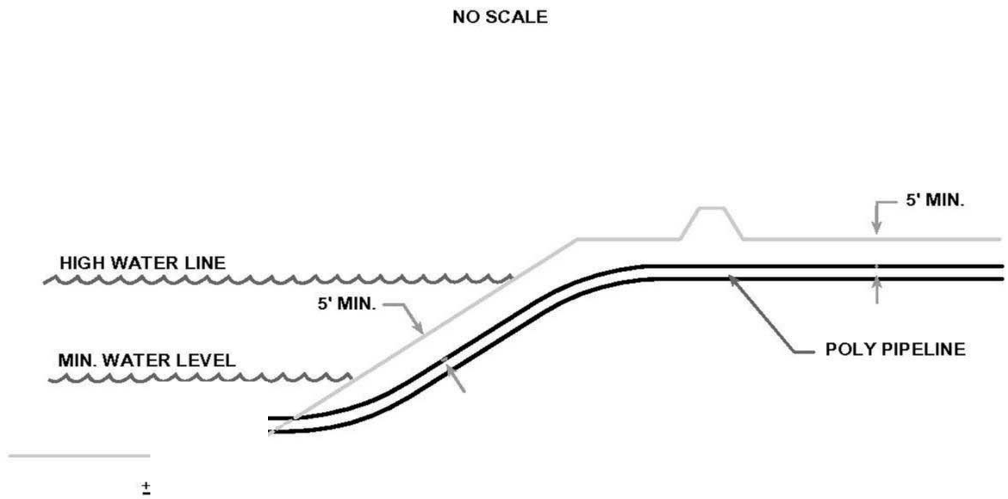
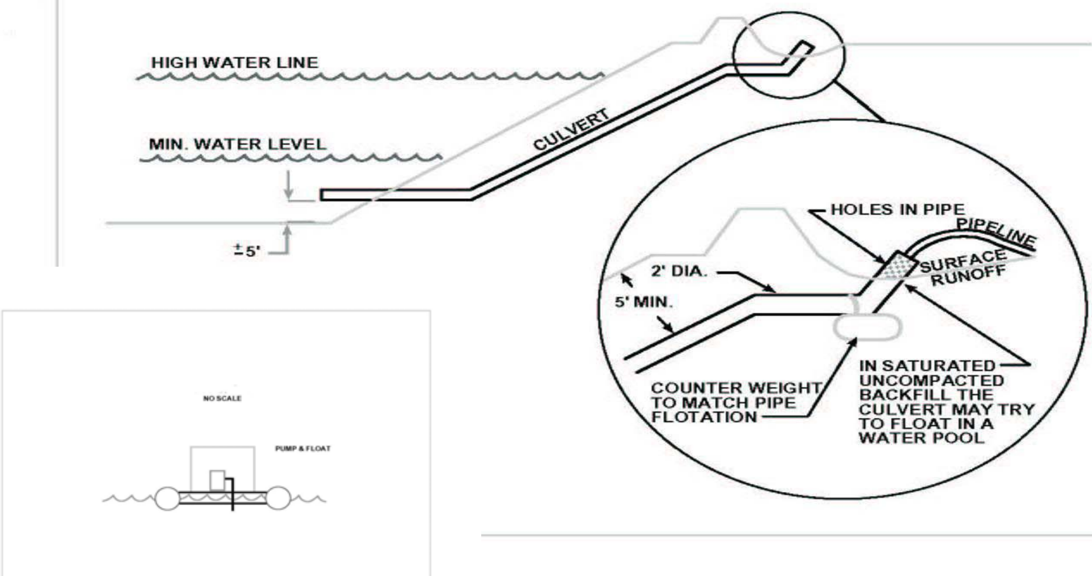


Figure B-4-4



(5) MSHA

Generally, MSHA has jurisdiction over any water structure that stores 20 acre-feet or more of water or slurry behind an embankment that is five feet or higher, as measured from the upstream toe to the emergency spillway, or has an embankment that is 20 feet or higher. A 100 acre-feet or larger reservoir normally falls within these criteria.

An incised backfill reservoir does not have a compacted embankment storing water above the surrounding ground level. This generally eliminates such impoundments from MSHA jurisdiction. MSHA and the mines have used the following rule of thumb to qualify the reservoir as incised: backfill 200 to 300 feet wide between the reservoir and the pit, and higher than the reservoir. In 1993, MSHA qualified this by stating that for a structure to be incised and not require design approval, the minimum backfill slope from the high-water line to the pit floor had to be at least 10H:1V.

(6) Stability

Uncompacted, saturated backfill is usually unstable when used to contain water or support weight. When used with very flat slopes such as MSHA suggests (10H:1V), stability should not be an issue.

The reservoir site must be conducive to water retention. This means the side slopes and reservoir bottom must be soils that exhibit low permeabilities. Zones of sand or waste coal in or in close proximity to the base or side are likely to cause significant water loss through seepage. A very porous soil backfilled to the reservoir may generate a seep on a backfill bench, if one is nearby.

(7) Location

The location should be chosen to maximize life and assure stability. The longer the reservoir is used, the more cost effective it is. Designing an impoundment to be non-MSHA is a major help in timing and cost. Position the reservoir where MSHA jurisdiction is not required, and the saturated backfill does not become a future obstacle to mining.

(8) Function

Multiple functions of water treatment, water storage for dust suppression, wildlife use, and postmining land use should be considered in the given priority.

(a) Water Treatment

Water Treatment for pit, plant, or disturbed area water sources is usually the primary concern. This reservoir is not likely the final treatment, but the initial step to reduce the Total Suspended Solids (TSS).

(b) Water Storage

A second concern is water storage for use during dust control activities, for storage of water awaiting treatment, or for simply providing a holding area to minimize discharges or provide a water source in extended dry periods.

(c) Wildlife

A reservoir can be made to have some wildlife features at a minimal cost (the subsection entitled "Wetlands"). These features should be included to show compatibility of the mining operation with wildlife.

(d) Postmining Land Use

It is an added bonus if the structure (or part of it) can be made part of the postmining land use. Keep in mind that water sources may deposit coal fines that should be covered before final reclamation. You may want to design the reservoir to be partly buried by final reclamation to cover unsuitable sediment.

(9) Construction

The construction cost-saving in this structure is the use of uncompacted fill for water containment. Sides are dumped in and dozed to final slope (Figure B-4-1). Berms are required by MSHA to prevent a vehicle from entering the impoundment. A spillway needs to be installed to provide six to ten feet of freeboard. Freeboard is from the high-water line when spilling to the top of the containing backfill bench.

Do not consider a compacted embankment on top of uncompacted backfill. Differential settling of the backfill will negate the purpose of the compaction and possibly cause failure of the embankment. For reservoir access, an old haul road ramp is good (if one is present) for skid mounted pumps or other equipment, because the base will remain firm. Compaction (minimum 90 percent standard proctor is suggested) should be performed around dewatering pipe stands.

(10) Dewatering

a Gravity Discharge

The simplicity of gravity discharge should be considered because no pump is required. The downside is that it may not always provide surge capacity, there may not be a good way to shut the system off, and a pump may be required to load water trucks or recycle water. Also, gravity discharge is often not possible because the reservoir is usually lower than the surrounding area.

b. Pumps

Installation of two pumps should be considered to maintain reservoir capacity and discharge system reliability. Pumps with durable, slower speed impellers are better because they will last longer. Existing pump stock may dictate the pump to be used. Pumps that are in continuous use for long periods should be electrically driven, if power is available, because of the lower maintenance and cost compared to diesel engine driven pumps.

Figure B-4-4 illustrates a desirable pump evacuation method for longer duration installations and the float and pump method, which is usually much cheaper for up to three years duration. Access, safety, winter ice, and maintenance make the land-based design much more desirable when it must be used for many years.

C. ALTERNATIVE SEDIMENT CONTROL

1. Straw or Hay Bale Check Dams

Section editor: Frank K. Ferris *Subsection author: Doyl M. Fritz*

Applicability

Use straw or hay bale check dams when temporary sediment or erosion control is needed for one season or less.

Special Considerations

The channel slope is the most critical aspect, and should be twenty percent or less.

Technique

a. Definition

Straw or hay bale check dams consist of standard agricultural bales placed end-to-end in rows across a sloping area of land.

b. Function

Straw or hay bale check dams provide a simple, inexpensive method for temporarily controlling sediment by reducing the velocity of runoff and filtering sediment from the runoff.

c. Useful Life

These structures are short-lived and should only be utilized in temporary applications. The useful life of a straw or hay bale check dam is dependent on many factors, but is typically only a few months.

d. Design Recommendations

(1) Location

Use bale check dams in locations where the bales are not likely to be overtopped by runoff (i.e. small drainage basins with shallow to moderate relief). Do not install bale check dams in areas of highly concentrated flow, such as steep, narrow channels and ditches.

(2) Placement

Place bale check dams along a contour or in shallow swales. Extend both ends of the check dam in an uphill direction so that the elevations of the bottoms of the two end bales are at or above the elevation of the top of the bales that are placed along the contour. Place bale check dams on sloping land in accordance with the following table:

Slope, percent	Maximum slope length above a single bale check dam or between successive bale check dams
2 or less	250
5	100
10	50
15	35
20	25

e. Installation Recommendations

Install straw or hay bale check dams as shown on Figure C-1-1. Do not install straw or hay bale check dams in areas where rock or rocky soil prevents full and uniform depth anchoring of the bale check dam.

(1) Contouring (optional)

If bale check dams are placed in a graded channel, such as a roadside ditch, it is sometimes advisable to place the check dams just downstream from a shallow basin created with the scraper used to build the channel. Such basins provide sediment storage space, reduce maintenance, and also temporarily pond water. This enhances vegetation and provides temporary habitat for certain species of birds and wildlife.

(2) Double Rows (optional)

A second line of bales offset behind the first can also be very effective.

f. Maintenance Recommendations

(1) Inspection

Inspect each bale check dam after every runoff event and at intervals not exceeding one month.

(2) Repair

Reset, stake, and backfill any dislodged bales. Repair all undercutting of the anchor toe with compacted backfill materials.

(3) Sediment Accumulation

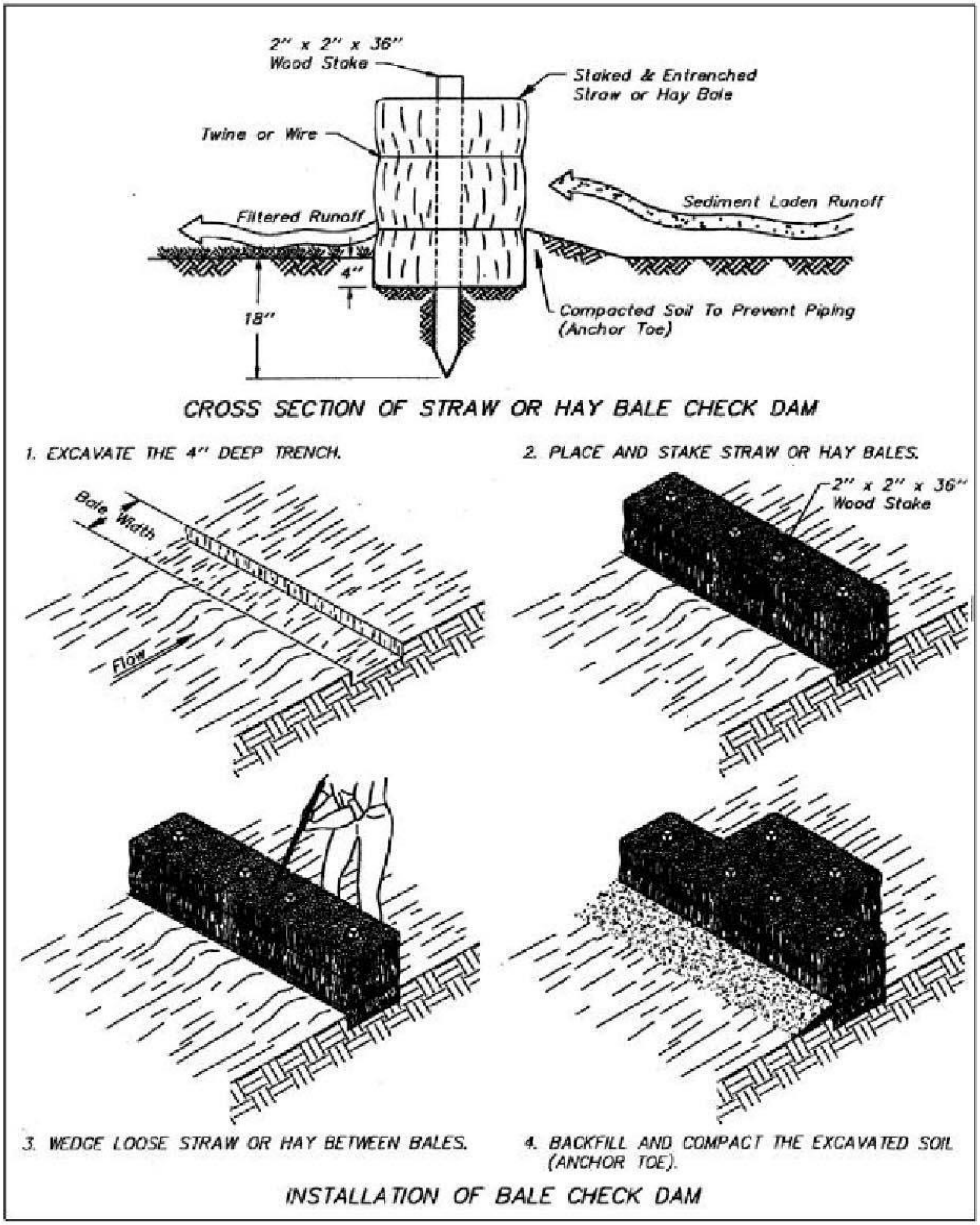
Replace bales that have become damaged or clogged with sediment. Remove accumulated sediment as required when uniform accumulations reach one-third the height of the bale check dam.

2. Rock Check Dams

Section editor: Frank K. Ferris *Subsection author: Doyl M. Fritz*

Applicability

Rock check dams should be used in steep, defined drainages when reduction of channelized runoff flow velocity and filtration of sediment from channelized runoff is required for one year or more.



STRAW OR HAY BALE CHECK DAM

Figure C-1-1

Special Considerations

Failure to control the flow velocity of channelized runoff on disturbed or newly reclaimed land can result in significant head-cutting in channels. Rock check dams may be used where flow is channelized and flow velocity is too high for the use of other stabilization and sediment control methods, such as straw or hay bale check dams or sediment fence. In addition, they may be used when the duration of stabilization is needed for more than one season/event.

Technique

a. Definition

A rock check dam is a low, porous, loose-rock embankment that is intended to slow the velocity of channel flow but not to impound water.

b. Function

Rock check dams control the flow velocity of channelized runoff and filter some sediment from the runoff, thereby reducing erosion and transported sediment. They are usually constructed in steep terrain and are most appropriate in narrow channels and ditches.

c. Useful Life

Indefinite.

d. Design and Construction Recommendations

Design and construct rock check dams as shown on Figure C-2-1.

(1) Placement

Place rock check dams across a swale, ditch, or channel, perpendicular to the direction of flow. Space rock check dams in series along a channel, as required, or in accordance with the following equation:

$$D = H/(0.5S)$$

D = distance between successive rock check dams, in feet,
H = height of rock check dam, in feet, and
S = slope of channel, in feet-per-feet.

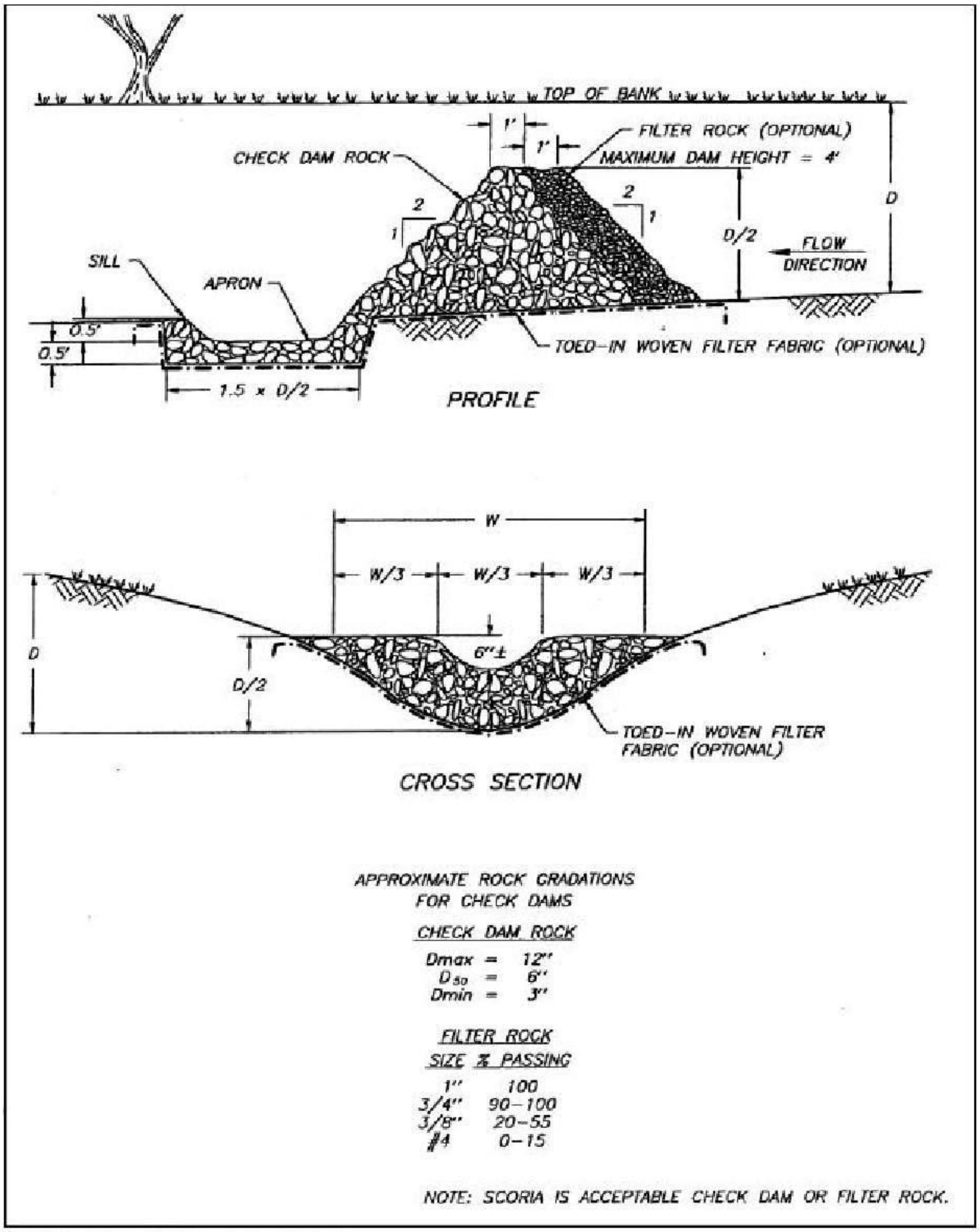
(2) Materials

Install toed-in woven filter fabric before placing rock check dams for those structures intended to remain in place for an appreciable length of time. Construct rock check dams with check dam rock alone if the sole purpose of the dam is channel stabilization. Construct rock check dams with both check dam rock and filter rock if increased check dam sediment removal capability is desired.

e. Maintenance Recommendations

(1) Sediment Accumulation

Remove accumulated sediment from immediately upstream of a rock check dam at or before the time when the depth of sediment reaches one-half the height of the check dam. Remove and replace rock check dams if they become completely clogged with sediment.



ROCK CHECK DAM

Figure C-2-1

(2) Removal

Rock check dams may be removed or left in place if they have successfully served their purpose. In grass-lined ditches or swales, rock check dams may be left in place when the grass has matured sufficiently to protect the ditch or swale from erosion. If it is desirable to remove the check dams, the areas exposed by removal of rock check dams should be immediately seeded and mulched.

3. Sediment Fence

Section editor: Frank K. Ferris *Subsection authors: Doyl M. Fritz/John D. Berry*

Applicability

Sediment fence should be used when sediment control is needed for one year or more.

Special Considerations

Sediment fence may be installed as an alternative to straw or hay bale check dams. Sediment fence may have a longer useful life than straw or hay bale check dams.

Technique

a. Definition

A sediment fence is a low geotextile fabric fence placed across a sloping area of land.

b. Function

Sediment fences control the flow velocity of overland runoff and filter sediment from runoff without impounding water, thereby reducing erosion. The sediment removal efficiency of sediment fence is typically high but varies depending on sediment particle sizes and the quality of sediment fence installation and maintenance. Like straw or hay bale check dams, sediment fences may be placed in series to increase sediment trapping efficiency.

c. Useful Life

The useful life of sediment fence may be indefinite, depending on flow magnitude and the rates of sediment accumulation and fabric degradation due to weathering. Frequent maintenance may be required to maintain the integrity of sediment fence that is left in place during numerous major runoff events.

d. Types of Sediment Fence

Sediment fence is produced by most major geotextile manufacturers. It may be purchased as prefabricated fence with preassembled posts, as fence fabric with regularly-spaced pockets into which the purchaser places posts, or as fabric with a reinforced top edge and no pockets for posts. Sediment fence fabric is available in varying widths (i.e. fence heights), typically ranging from 2 to 3.5 feet.

e. Design Recommendations

(1) Support Structures

Support structures should be sturdy enough to withstand a considerable amount of hydrostatic and sediment load pressure, particularly before vegetation has become established. The fabric must be backed with support of some kind to keep the water and sediment from pushing the bottom of the fabric out, causing a failure underneath the fabric. Steel posts and wooden snow fence make an excellent support structure. The steel posts can be placed in the bottom of a trench cut with a motor grader and the snow fence is then wired to the posts with the bottom of the snow fence in the trench.

Bracing should be added to the back of the support structure to ensure it will not be pushed over by water, sediment accumulation, or wind. Bracing can be accomplished by using steel posts placed at an angle behind every other upright post. It is helpful to use a cutting torch to cut small notches in the uprights to accept the angled braces. The braces should be pounded into the ground a minimal amount to keep them from sliding and should be wired to the upright posts at the top.

(2) Fabric Quality

The sediment fabric should be high quality and UV resistant. The additional cost of quality material will be more than made up for by additional labor required to replace fabric that has deteriorated before sediment control release has been obtained. The bottom of the fabric panel should be extended out from the support structure in the trench at least one foot. The fabric can be wired directly to the snow fence at five foot intervals or lathe can be wired to the side of the fabric opposite the snow fence. The lathe keeps the wire from pulling through the fabric, which can happen in areas prone to wind. The flap of fabric in the trench is covered with soil once the structure is completed, to ensure water and sediment do not run under the fence. This can be accomplished by using the motor grader to gently push the material removed from the trench back over the fabric and refill the trench.

(3) Installation

Place sediment fence along a contour. Extend both ends of the sediment fence in an uphill direction, so that the elevations of the bottoms of both ends of the fence are at or above the elevation of the top of the fence that is along the contour. Sediment fences installed in areas of concentrated flow, including channels, ditches, and swales, should have small drainage areas.

(4) Design Parameters

Place sediment fence on sloping land in accordance with the following table:

Slope, percent	Maximum slope length above 12 to 18 inch high sediment fence	Maximum slope length above 24 to 30 inch high sediment fence
2 or less	250	500
5	100	250
10	50	150
15	35	100

Slope, percent	Maximum slope length above 12 to 18 inch high sediment fence	Maximum slope length above 24 to 30 inch high sediment fence
20	25	70
25	20	55
30	15	45
35	15	40
40	15	35
45	10	30
50	10	25

f. Installation Recommendations

Install sediment fences as shown on Figure C-3-1. Do not construct sediment fences in areas where rock or rocky soil prevents the full and uniform anchoring of the fence toe.

Where the ends of sediment fence fabric come together, overlap, fold, and staple the two overlapping ends.

g. Maintenance Recommendations

(1) Inspection

Inspect sediment fence and repair as required after every significant runoff event.

(2) Sediment Accumulation

Remove accumulated sediment at or before the time when the depth of accumulated sediment reaches one-half the height of the sediment fence.

(3) Repair

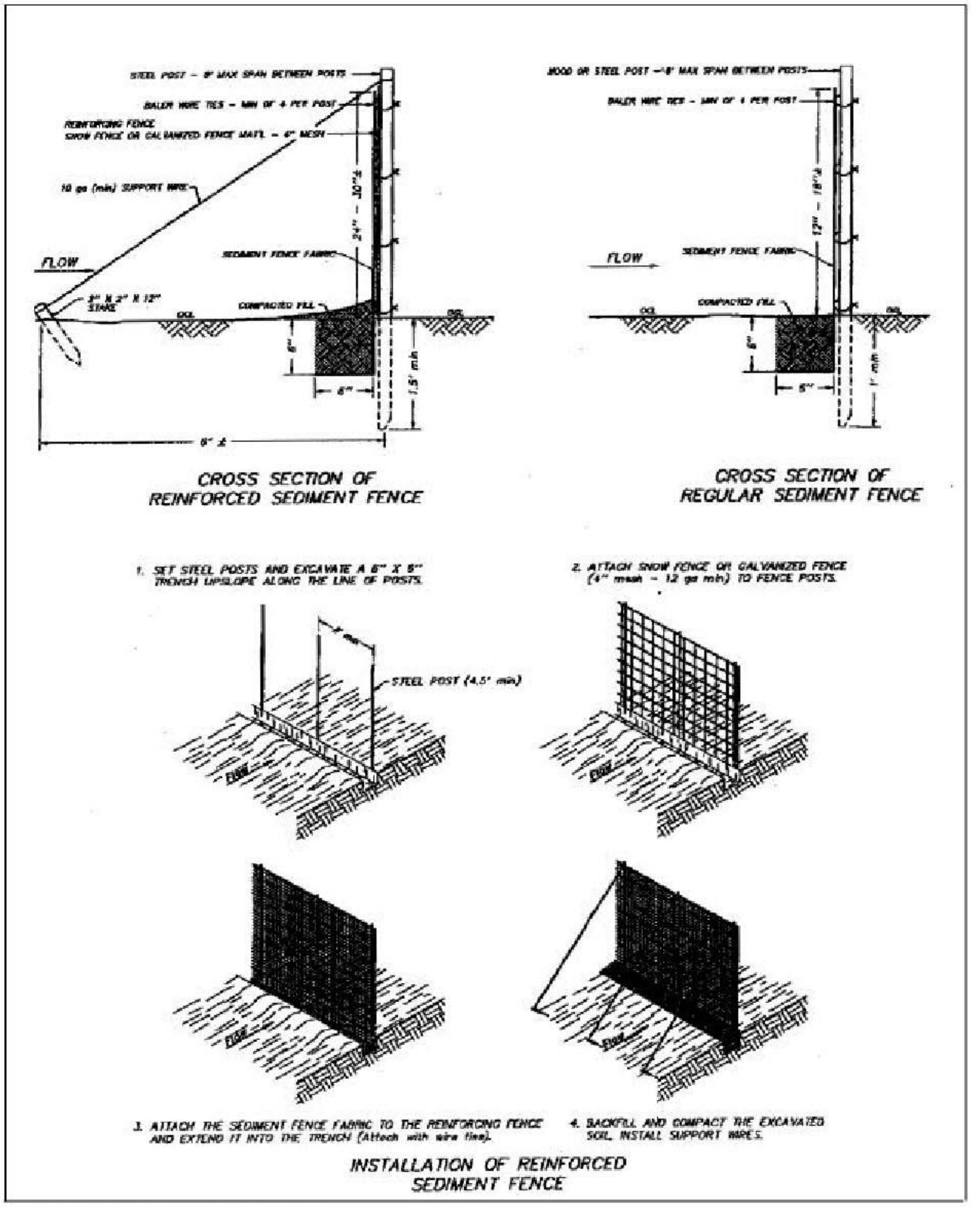
Immediately repair with compacted backfill all undercutting or erosion of the sediment fence toe anchor. Replace sediment fence that is degraded by weathering in accordance with the manufacturer's recommendations.

4. Gabion Baskets

Section editor: Frank K. Ferris *Subsection author: Doyl M. Fritz*

Applicability

In high velocity, high volume, or long duration circumstances, gabion baskets should be considered. Reduction of flow velocity or protection from erosion due to high flow velocity in channels is sometimes required during mining and reclamation. Gabion baskets may be used to construct check dams, drop structures, or pipe outlet aprons which are capable of withstanding and/or reducing relatively high-velocity flow.



SEDIMENT FENCE

Figure C-3-1

Gabion basket structures are relatively simple to install and are generally more durable than comparable loose-rock structures. They allow the use of much smaller rock than could be used under similar flow conditions without the wire baskets. They also offer an advantage over rigid concrete structures because they are flexible and can conform to changes in subgrade conditions caused by erosion and settlement.

Special Considerations

Generally, baskets with a thickness of less than one foot should be avoided. Fabric under the basket and sufficient rock gradation within the basket are necessary to assure minimum flow velocities against the soil under the basket. Otherwise, erosion may undercut the baskets.

Technique

a. Definition

Gabion baskets, which are constructed of wire panels that are shipped to the installation site disassembled, are assembled on-site with hog rings, filled with rock, and staked in place at the construction site.

b. Function

Figures C-4-1 through 3 provide examples of gabion structures. Gabion baskets are used to construct check dams, drop structures, and pipe outlet aprons that are intended to withstand and/or reduce relatively high flow velocities. Construction of gabion basket structures is relatively simple and requires no special construction skills. Gabions can also be used to line temporary diversion channels where flow velocities exceed 5 feet-per-second (e.g., cross section C-C' on Figure C-4-2 and cross section A-A' on Figure C-4-3).

c. Useful Life

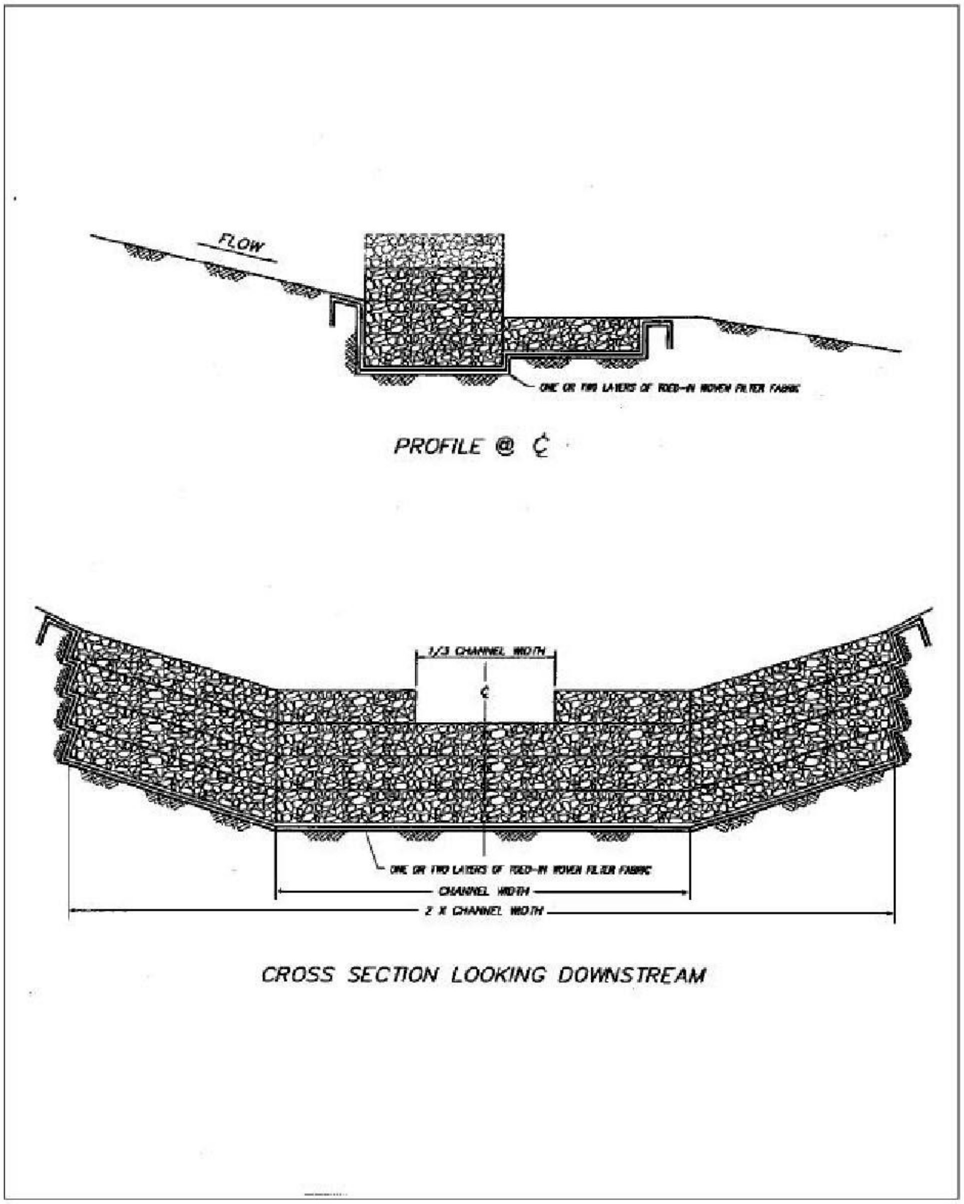
Gabion baskets last indefinitely. The useful life of a gabion basket structure is usually longer than that of a comparable loose-rock structure, and they may outlast rigid concrete structures in some applications. Their durability is dependent on the quality of the rock and wire used in construction. The use of durable rock and heavy gage, corrosion resistant baskets will provide the longest useful life.

d. Design and Construction Recommendations

Design and construct gabion basket structures as shown on the figures.

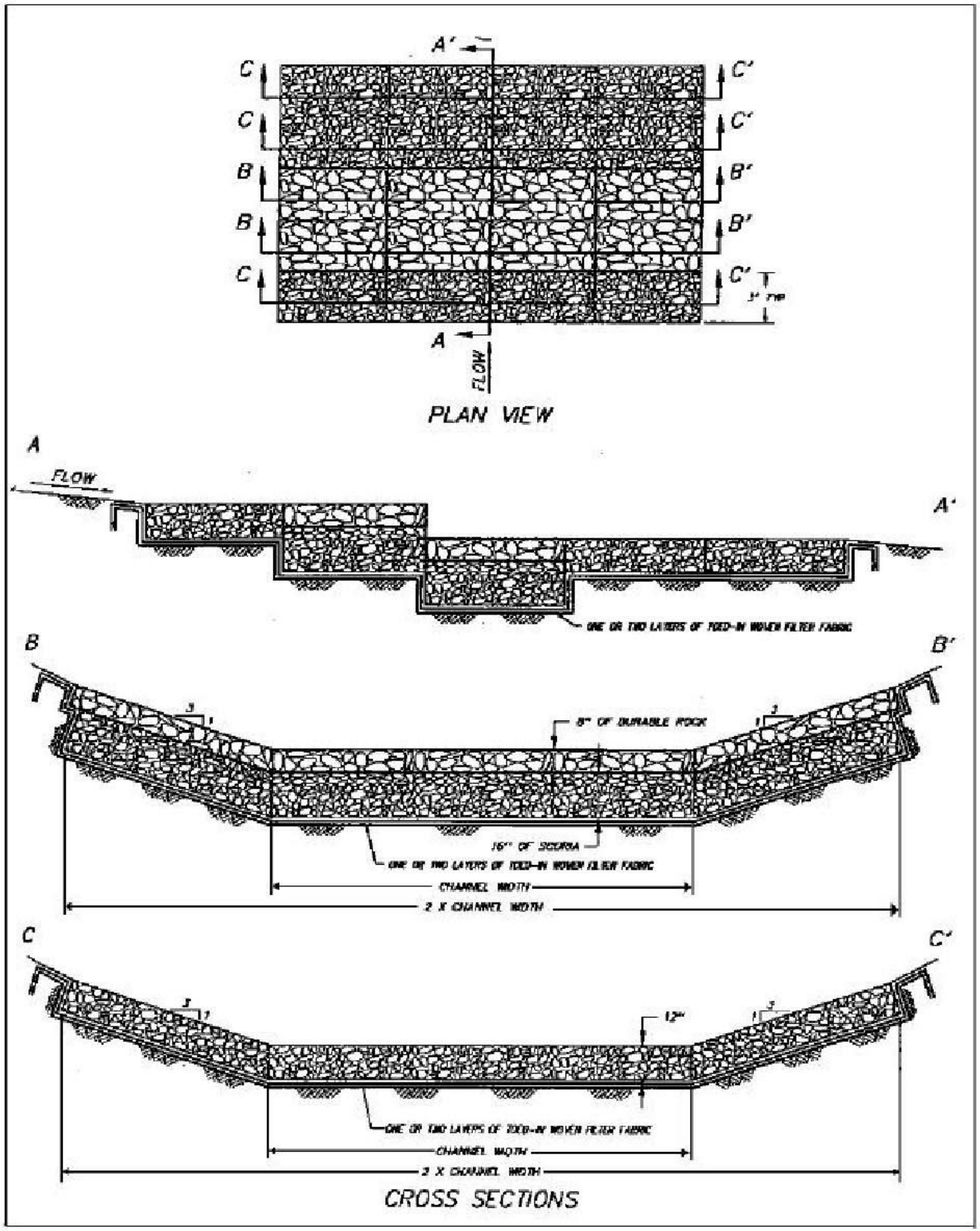
(1) Design Parameters

Gabion basket structures should be designed in accordance with the parameters recommended in the following table:



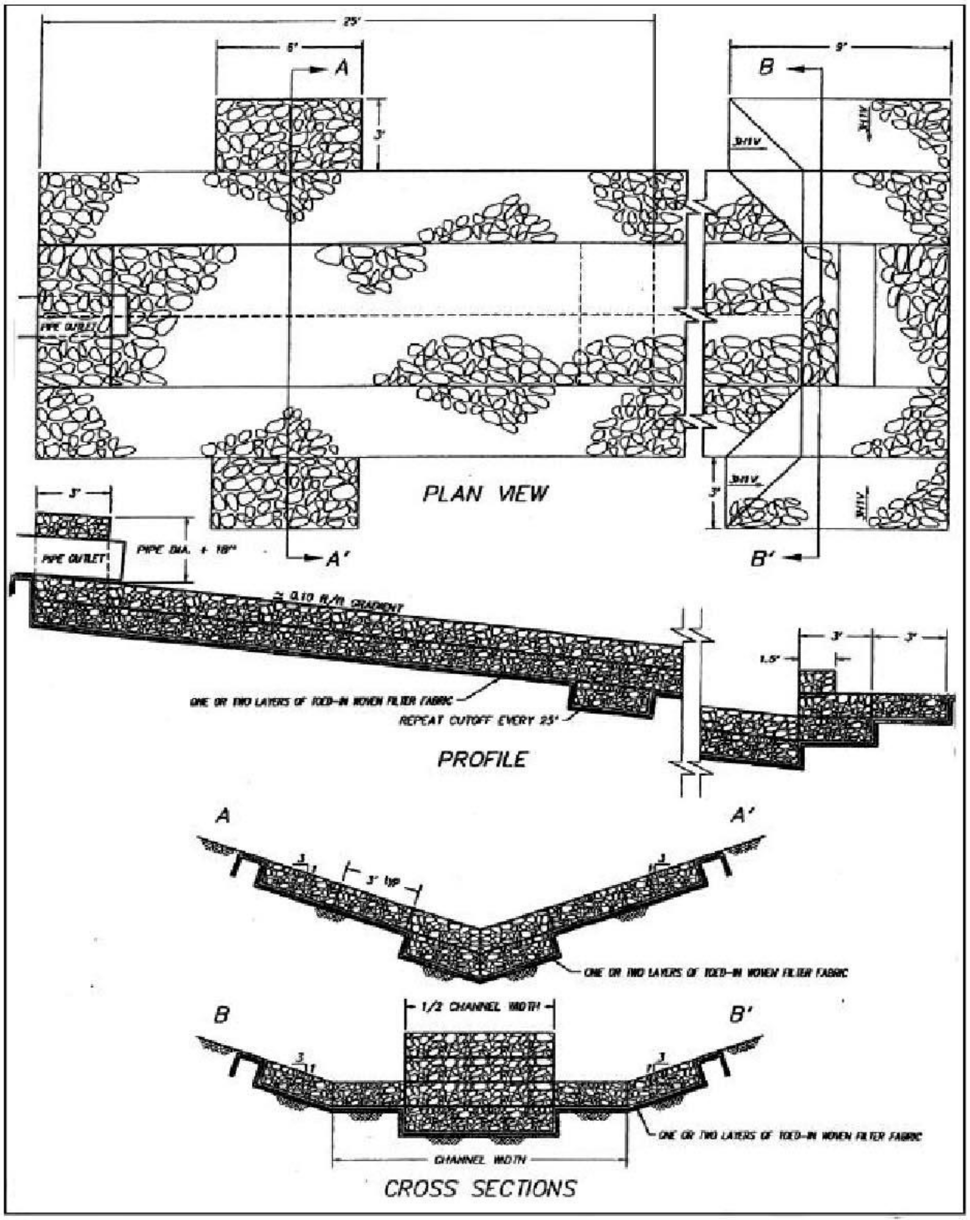
CABION BASKET CHECK DAM

Figure C-4-1



GABION BASKET DROP STRUCTURE

Figure C-4-2



GABION BASKET PIPE OUTLET APRON

Figure C-4-3

Type	Manning's "n"	Thickness (inches)	Rock fill gradation (inches)	Permissible flow velocity (feet/second)
Reno mattress	0.025	6	3 - 6	13.5
Reno mattress	0.025	9	3 - 6	16.0
Reno mattress	0.025	12	4 - 6	18.0
Gabion	0.027	18 +	5 - 9	22.0

(2) Materials

Durable rock such as limestone or granite should be used to fill gabion basket structures that are intended to remain in place for extended periods of time. Scoria rock may be used in temporary gabion basket structures, but longevity and permissible flow velocities may be reduced by use of the less durable scoria rock. One or two layers of woven filter fabric may be used to protect underlying soils. Two layers of fabric will provide additional protection in case the top layer is punctured or torn during installation.

e. Maintenance Recommendations

(1) Sediment Accumulation

Remove accumulated sediment from immediately upstream of a gabion basket check dam, at or before the time when the depth of sediment reaches one-half the height of the check dam.

(2) Repair

Repair broken wire baskets and replace lost or displaced rock as necessary.

(3) Removal

Remove temporary gabion basket structures when their useful lives are completed. In grass-lined ditches or swales, gabion basket check dams may be removed when the grass has matured sufficiently to protect the ditch or swale from erosion. Immediately seed and mulch areas exposed by removal of gabion basket structures.

5. VEGETATIVE FILTERS

Section editor: Frank K. Ferris *Subsection author: Richard C. Warner*

Applicability

Vegetative filters have been investigated as a sediment control mechanism for protection of streams. They have been predominantly used as riparian buffer strips in agriculture (Dillaha et al., 1989, Parsons et al., 1991) and have been analyzed, in experimental settings, for a surface mine (Barfield and Albrecht, 1982), and a construction site (Hayes and Harrison, 1983). Sediment trap efficiencies reportedfor these experiments ranged from 70 to greater than 90 percent. Grass filters have been designed to achieve these high efficiencies only when overland flow has been established and directed towards the filter.

Special Considerations

For grass filters to function at high efficiencies, runoff entering the filter must be maintained as overland flow. Dillaha (1989) concluded that the effectiveness of vegetative filter strips in removing sediment and nutrients from cropland runoff were relatively ineffective due to concentrated flows entering the filters. Sediment-laden waters approaching a vegetative filter are slowed through backwater effects and deposition occurs up-gradient of the filter and in the upper portions of the filter. Dillaha found that after deposition occurred, later runoff events would be transported along the previously deposited sediment barrier until a low spot was reached and then pass as concentrated flow through the filter, thus significantly reducing the effectiveness of the filter. Also, natural depressions in the landscape further exacerbated the problem of developing concentrated flows. For vegetative filters to function properly, overland flow must be established and maintained.

Technique

Hayes and Dillaha (1991) developed procedures for the design of vegetative filters. Coarser particles are deposited by settling in the reduced velocity created in the up-gradient portion of the filter, whereas finer particles are removed through infiltration at the lower portion of the filter. From this basic knowledge, primary design parameters can be determined. Overland flow must exist. Thus grass density should be high and the selected grass must be able to resist flow without bending to the ground. The drainage area generating runoff must be relatively small and situated such that overland flow proceeds to the filter without concentrating. The filter length should accommodate deposited sediment and be sufficiently long to enable time for infiltration of runoff. The selected soils should have a relatively high infiltration rate if the smaller size fraction of sediment is required to be captured.

For mining applications design considerations seem to restrict the use of grass filters to ideal conditions. How can these restrictions be relaxed? If only settleable solid trapping is needed, the length of the filter can be significantly reduced. Dillaha used vegetative filters in the range of 15 to 30 feet. Overland flow must be established and maintained. This is difficult in a natural setting because of the tendency to deposit sediment up-gradient of a filter. It is my recommendation to use vegetative filters in conjunction with a sediment filter fence. The silt fence accomplishes these functions: (1) changing concentrated flow to overland flow as discharge is contained behind the silt fence and subsequently transported through the filter, (2) a large portion of coarser particles are settled behind the sediment fence thereby reducing the need for storage capacity within the vegetative filter, (3) discharge through the silt fence will be low and relatively uniform which enables infiltration, and associated capturing of the finer sediments to be accomplished, and (4) maintenance, i.e. sediment removal, is easily conducted. Thus, the vegetative filter functions as a secondary treatment system which will further reduce effluent concentration entering the fluvial system.

Ideal application areas are along lateral developments such as haul roads, railways, etc., where directing runoff to sediment basins may be economically infeasible. The SEDCAD+ program has a vegetative filter predictive algorithm which will assist in determining the sediment trap efficiency and reduction in flow as a function of filter input parameters for a design storm event.

D. Reconstruction of Hydrologic Features

1. Small Drainage Waterway Construction

Section editor: Frank K. Ferris   Subsection authors: Frank K. Ferris/Christopher D. Lidstone/C. Marty Jones

Applicability

Concentrated flow from small drainage areas usually causes the most erosional problems because a waterway of some type has not been provided.

Special Considerations

When runoff is generated from a small area as unconcentrated flow and is routed over a steep area, the flow coalesces and becomes concentrated flow. The erosive energy of this concentrated flow increases as additional water is added to the system or as it gains energy traversing the steeper slope. Rills, gullies, and headcuts are formed, where no designed channel existed. Anticipating where the flow will coalesce into concentrated flow and "cutting a waterway" will eliminate or reduce rill and gully erosion.

Contributing drainage basin area is an important consideration in small drainage waterway construction. A rule of thumb may suggest that a small drainage will form for every three to seven acres of contributing basin area. However, there are many variables which affect the development of lower order drainages, including: contributing basin area; basin slope; length of overland flow; slope aspect; and soil or parent material. Many operators collect adequate baseline geomorphic data to assist in prediction of where a small waterway will form. A standard geomorphology text will assist the operator in the selection, measurement, and analysis of relevant morphometric parameters. Specifically, drainage density (total channel length divided by basin area), frequency of first order channels (total number of first order channels divided by the basin area), and the constant of channel maintenance (number of acres of contributing basin area to establish a first order channel) are important parameters.

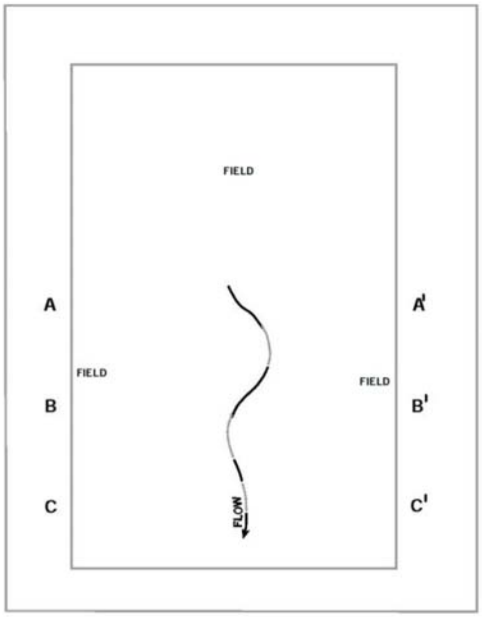
Technique

The two aspects of waterway design that need to be considered are the channel water and the inflow from adjacent areas. A flat bottom channel (10 to 12 feet wide) with gentle side slopes reduces flow depth, decreases water concentration, and increases the wetted perimeter. These factors help reduce water velocity which helps control erosion. The channel provides enough water concentration to help sod formation.

Reclamation grading needs to occur with a focus on the water flow from the reclaimed surface. Waterways need to be constructed to the main channel. The waterway grade should continue to get flatter along its route to the design channel. There are three general types of areas that should have waterways.

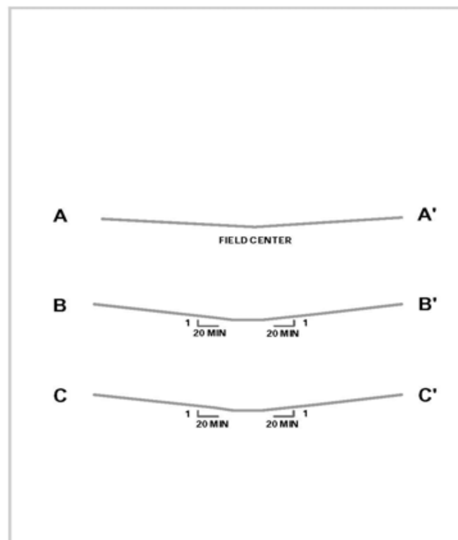
(1) Flat to Gently Sloped Fields

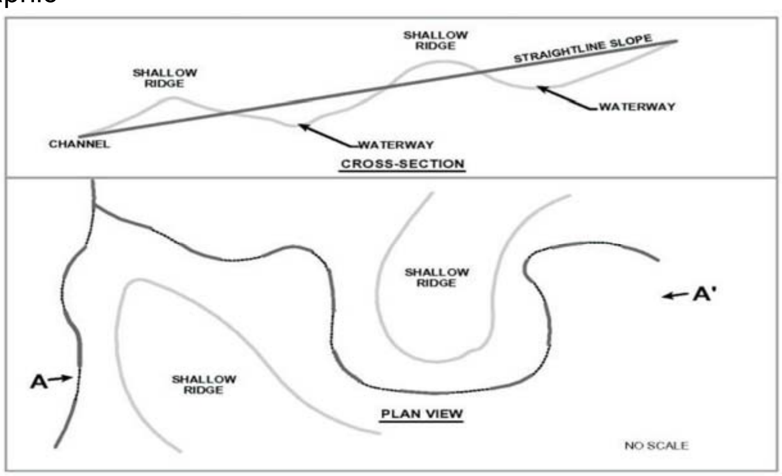
Large fields usually have an area where water ponds, or during large runoff events, ponds and flows in some direction. On reclaimed land where differential settling will occur, it is best to create a waterway to a designed channel. This prevents head cuts where water exits the field and enters the channel. A waterway should start near the low point of a field and go to the design channel. This is illustrated on Figures D-1-1 and 2.



(2) Long, Moderate Slopes

Long, moderate to steep slopes should be broken by shallow ridges and waterways. Because long slopes of expected sheet flow form concentrated flow and gullies, the length of slope and drainage area should be limited to five acres or less. The drainage area is the most critical factor to determine channel stability. Use waterways and ridges in conjunction with other micro-topographic





features to break a slope and concentrate the runoff in areas where sod will form and stabilize a waterway. Figure D-1-3 3 shows this in plan view and cross section.

(3) Backfill Dumps

Large, wide, elevated dumps will require establishing an interior drainage to an access ramp for a shallow gradient waterway off the top of the elevated backfill dump. Otherwise, direct flow over the exterior slopes will cause extensive erosion. If there is a choice, the channel gradient should be almost flat to promote infiltration. Establishing a small playa may also be an option.

The ramp gradient is usually too steep for non-erosive flow. Extensive grading, or routing the channel onto a bench that is 10 to 20 feet lower, is usually needed to get an acceptable channel gradient. Figure D-1-4 shows the interior drainage route from a large elevated backfill dump.

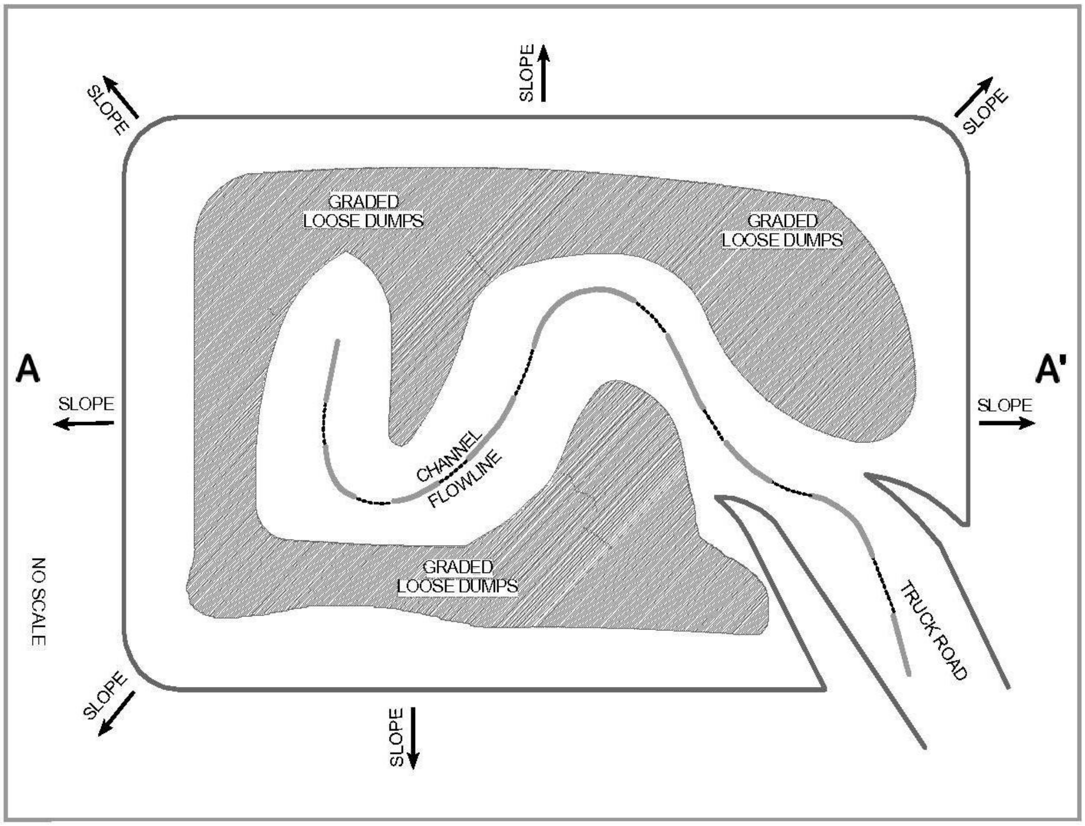

SLOPE
SLOPE
SLOPE
GRADED
LOOSE DUMPS
GRADED
LOOSE DUMPS
A
A'
SLOPE
SLOPE
CHANNEL
FLOWLINE
NO SCALE
GRADED
LOOSE DUMPS
TRUCK ROAD
SLOPE
SLOPE

Figure D-1-4

Figure D-1-5 shows how one can transform the top surface of a dump, using loose dumps and grade control, into an interior drainage system.

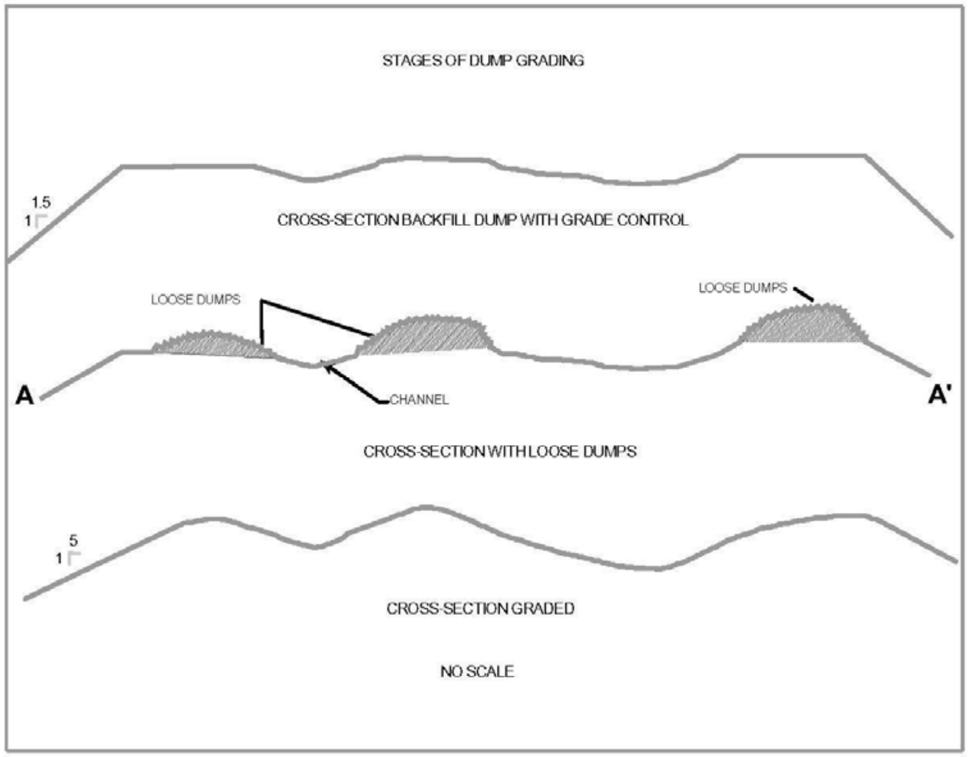


Figure D-1-5

2. Stream Channel Construction

Section editor: Frank K. Ferris *Subsection author: Richard C. Warner*

Applicability

Often mining operations require the relocation and reconstruction of streams or stream modifications to increase discharge capacity.

Special Considerations

An assessment of premining stream parameters and an understanding of flow characteristics necessary for food production, spawning and cover (i.e. habitat) will greatly increase the opportunities for success. Besides stream morphologic parameters, an understanding of stream velocity, depth, and substrate will facilitate construction of a balanced, diverse aquatic ecosystem.

Technique

a. Planning

The development of a successful reclamation plan that addresses stream considerations is based on the acquisition of premining stream data. A base map normally displays a planview of the channel, flood plains, and generalized vegetation documentation. Such data can be readily obtained through aerial photos or the existing channel can be surveyed. A stream longitudinal profile is extracted. This profile displays distance from a specified downstream location, reach segment number, length and slope of each reach, meander characteristics and cross-section measurements for each reach. The meandering pattern as described by wavelength, sinuosity (ratio of valley slope to stream slope), and radius of curvature. Numerous other meander patterns and characteristics can be helpful in stream reconstruction (Gore, 1985). Meandering has been identified as the primary vehicle of dissipating stream energy and is therefore a principle design tool for stream reconstruction.

A vertical profile of channel substrate should be detailed for each stream environment, i.e. pool and riffle. Each layer of the vertical profile should contain particle size composition. Note should be made of stream geometric factors such as cross-section shape, stream pattern (meandering patterns and braided), and pool-riffle patterns. Also location and description of point bars and cross currents should be noted.

b. Stream Habitat Components

To enhance stream relocations, it is necessary to gain an understanding of the interplay among aquatic habitat factors and physical factors of stream velocity, depth, and substrate. In a pool-riffle environment, riffles function as food production and spawning areas. Riffles exhibit relatively shallow depths, higher than average velocity, and coarser substrate than pools. Velocity is the primary parameter describing the distribution of aquatic invertebrates. Velocity in riffles governs the rate of oxygen transfer to properly sized substrate (i.e. rubble, boulders, and cobbles) thereby supplying oxygen and removing metabolic waste products from intergravel areas. Water velocity increases the exchange rate, thereby enhancing respiration and food acquisition. Optimal velocity is subject to debate, but the range for riffle segments for good stream productivity is between 0.5 and 3 feet-per-second (fps) or 0.15 and 0.9 meters-per-second (mps) (Delisle and Eliason, 1961). A narrower design range is 1 to 2 fps or 0.3 to 0.6 mps (Giger, 1973).

Velocity controls substrate size to a large extent. The larger size rocks are associated with riffle areas since sands and silt are removed by the higher current velocity. Benthic invertebrates decrease in number and diversity as substrate is changed from rubble to coarse gravel to fine gravel and sand. Rubble appears to play a key role in the riffle environment. It provides a broad surface for invertebrates to cling to and functions to protect insects from high velocities (Gore,1985). Velocity also functions as the vehicle for drift, which is the movement of organisms downstream by current. Drift supplies the mechanism to acquire food which advances increased population densities and diversity.

Depth controls, to a great degree, the intensity of light which controls photosynthetic production of food. Deeper waters are less productive and contain fewer invertebrates than shallower riffle areas. Depth of highest productivity in trout streams range from 0.5 to 3 feet (0.15 to 0.9 meters), provided that current and substrate are suitable (Gore, 1985).

The parameters of velocity, depth and substrate combine in the riffle environment to provide an optimal habitat for aquatic invertebrates (Gore, 1985). The repetitive pool-riffle succession creates an excellent habitat for food production, spawning, cover, and resting. Stream cover can take many forms. Bank cover is provide by overhanging vegetation and undercut banks whereas in-stream cover is found by aquatic vegetation and the larger substrate. When reconstructing a stream, cover is essential. Elser (1968) found a reduction of 78 percent less trout in a stream having 80 percent less cover.

c. *Structures to Enhance Stream Habitat*

Structures such as current deflectors, low profile dams, and the selective placement of boulders and substrate during channel reconstruction can enhance habitat. Such devices can locally increase velocity, create pools and scour holes, provide gravel trapping areas, remove silt from spawning areas, protect stream banks, enhance pool-riffle sequencing, aerate the water, reduce or increase water temperature, and generally both create enhanced habitat and simultaneously provide bank stabilization.

d. *Current Deflectors*

Current deflectors are structures extending outward from the streambank into the channel. Common terms for these devices are jetties, spur dikes, groins, etc. As with many controls, deflectors have been reported to be both successfully and unsuccessfully employed. Wesche (1985) reviewed numerous applications and reported successes summarized by phrases such as "the number of age 1 and older brook trout had doubled in the modified reach"; "the number of good quality pools had increased from nine to twenty nine, average pool depth had increased by 0.5 feet (0.15 meters), and additional spawning gravel had been exposed"; and "...improved the carrying and reproductive capacity of the reach for trout, was cost effective when compared with stocking, and had their greatest effect on the substrate, increasing the exposed gravel in each reach from 14 to 24 percent". Wesche (1985) also summarized failures such as "...deposition which occurred immediately downstream from the structure negated any habitat gains"; "...deflectors were quite susceptible to damage and needed frequent repairs"; and "flood flows reduced the ability of certain structures to concentrate the flow, while the pools provided little trout cover".

To be effective, deflectors require application of design methodology and rigorous construction methods. Unfortunately, few design aids exist for the proper sizing, location and spacing of deflectors. Consideration should be given to: (1) location along the reach, i.e. locate along a straight or concave (the bank at the outside of the bend) stream section; (2) spacing among a sequence of deflectors; (3) location of riffles; (4) stability of the substrate; (5) ability to anchor the deflector in the bank; (6) bank height and stability; (7) point-bar deposition location; (8) bed transport; and (9) specific deflector design parameters. Important deflector design parameters include the deflectors length, width, height, shape and orientation angle. Selection of these parameters will depend upon the channel width, water depth, and velocity, besides those factors previously mentioned.

For habitat enhancement, the development of scour holes at the tip and along the face of the deflector are also design considerations. It should be noted that design for stability of the stream banks and the deflector itself may be based on a design discharge associated with a specified storm recurrence interval, but the predicted size of a scour hole will remain a highly time-dependant aspect due to the time-variability of stream discharge and sediment transport. Scour holes will progressively enlarge and be partially refilled during the rising and falling stages of the hydrograph. Thus, available habitat scour-hole size will vary throughout the flow regimes experienced by a stream.

Current deflectors influence the creation of primary and secondary scour holes, gravel and sediment deposition patterns, and the stability of stream banks across and downstream of the deflector. Localized, increased flow velocity occurs near the tip of the deflector, resulting in the creation of the primary scour hole. Intermediate vortices occur both upstream and downstream along the deflector face. The size of the primary scour hole is functionally related to water density and viscosity; flow depth and velocity; deflector length, orientation angle with the downstream bank, and side slope; size, density and gradation of bed sediment; and sediment concentration of transported material (Klingeman et al., 1984).

Klingeman et al., (1984) list nine predictive equations for primary scour-hole size near current deflectors. Sediment deposition patterns vary depending upon the orientation angle of the deflector. Generally, deposition occurs slowly in the lee of permeable dikes (Lindner, 1969) but due to decreases in flow velocity, upstream deposition can also occur. To enhance habitat in the lee of the current deflector, it may be designed to prevent overtopping during flood events, thereby facilitating scouring by secondary eddy currents during normal flows.

Orientation angle recommendations are normally perpendicular (90 degrees) to the flow or downstream. Klingeman et al. (1984) notes that the upstream-oriented current deflector, "is more effective in deflecting the current away from the bank than the downstream-oriented dike". That is, a greater distance occurs before the current returns to the downstream bank, thus bank stabilization is enhanced. Orientation angle and deflector length influence scour-hole development. Effective deflector length is the length perpendicular to the bank. As the effective deflector length and the orientation angle increases, the size of the scour-hole increases (Klingeman et al., 1984). The limiting feature is the effective length, since as the length increases the flow section further contracts, thereby creating the potential for an unstable stream bank opposite the deflector. Although no firm design recommendation exists, it is generally recommended that the effective deflector length be less than one half of the stream width.

e. Low Profile Dams

Low profile dams are structures that span the entire width of a stream channel and may be constructed to point upstream, horizontal, or downstream. Low profile dams are also called weirs or check dams, and are usually located along relatively small, headwater streams that have steep gradients and lack adequate pool-riffle environment. As with deflectors, low profile dams provide a broad spectrum of potential habitat enhancements: (1) creation of a pool by raising the water level, thereby inducing upstream deposition of spawning gravel areas, facilitating fish passage, reducing overall channel scour, allowing sedimentation of organic debris, and encouraging the development of riparian vegetation which further enhances bank stabilization and bank cover development; (2) creation of localized scour hole(s) which provides fish rearing areas and temperature regime stability; (3) stream aeration; and (4) formation of gravel bars downstream of the structure. These multifaceted benefits can be enhanced by the proper design, placement and construction of low profile dams.

Design elements encompass weir discharge capability; shape of the downstream face (i.e. vertical, sloped or stepped); structural stability; energy dissipation; seepage control; and creation of the stilling pool by usage of multiple weirs. One relatively overlooked design parameter is the angle of the low profile dam and the influence of the angle on scour hole formation, size, and location. Klingeman et al. (1984) conducted a series of experiments regarding the influence of weir angle on scour hole and depositional area formation. Upstream pointing low profile dams, i.e. with a weir apex angle of less than 180 degrees, created a single scour hole at the center of the channel due to the convergence of flow. The deepest scour hole existed for the 90 degree angle. The 60 and 120 weir apex angles resulted in the formulation of scour holes approximately 15 percent lower in maximum depth than the 90 degree angle.

Overall size (i.e. maximum depth times width times length) was greatest for the 90 to 120 degree range of angles. The other advantage of the upstream facing low profile dam is that the scour hole is located at the center of the stream, thereby reducing potential bank instability downstream of the weir. Downstream facing low profile dams create smaller symmetrical scour holes near the channel banks. The advantage to the downstream facing weir is the creation of a gravel bar at the center of the channel. Thus, depending upon the type of habitat enhancements desired, low profile dams can create various sizes of scour holes, placed either adjacent to the banks or centered in the channel, and can facilitate gravel depositional areas, as well as the other potential benefits previously enumerated.

f. Boulder Placement

Only general guidelines exist for the placement of boulders (Wesche, 1985). Either individual boulders or boulder patterns are commonly used. Clusters of boulders are often placed in triangular or diamond patterns. To increase the potential of boulder stability it should be embedded into the stream bed. Boulders ranging from two to five feet (0.6 to 1.5 meters) have been reported to be successfully used (Wesche, 1985). Boulders should consist of durable rock and placement adjacent to stream banks should be avoided.

g. Substrate Development

The use of deflectors, low profile dams and placement of boulders affects the velocity - depth regime and creates spawning gravel areas upstream of structures and downstream gravel bars. The key component to substrate establishment is the control of localized velocity. What is the proper size gradation of substrate to enhance macroinvertebrate production? A vertical profile of the bed material taken from existing established stream segments will yield representative information that if somewhat duplicated should provide background goals for substrate.

Highest productivity and diversity of aquatic macroinvertebrates are found in riffle environments composted of gravel substrate intermingled with medium size cobbles (Gore, 1985). It is also important to reestablish the sequence of pools and riffles. Although riffles provide macroinvertebrate habitat, alternating pools provide needed areas for fish habitat and benthic deposition. It may be difficult to establish spawning gravel areas if fine sediments are continuously being generated from watershed areas. Techniques previously detailed for the control of upland sediment should be used in unison with substrate establishment.

The stream bed will normally consist of a series of layers. Ideally these layers include a gravel base, fine sediment-gravel seal, gravel scour protection layer, and an armor layer to facilitate stream bed stabilization. Often in stream reconstruction the bottom three layers are replaced by a single layer consisting of a heterogeneous mixture of silt, sands, and small gravel placed in a series of shallow lifts. The upper armor layer then is required to provide the predominant substrate for habitat and for stream stabilization.

3. WETLANDS RECONSTRUCTION

Section editor: Frank K. Ferris *Subsection author: Robert K. Green/Frank K. Ferris*

Applicability

Surface coal mines are required to replace any wetlands removed by mining.

Special Considerations

Wetlands should generally be constructed in reclamation areas low in the topography, such as swales, reclaimed channels, or permanent ponds. Water quality must be adequate to establish and sustain wetland plant species. Wetlands must be designed to function without the support of mine water sources.

Technique

a. General Requirements

(1) Size

Plans for wetlands must include site determinations that the drainage area is sufficient to support the planned size of those wetlands from the projected runoff event. Particularly for those wetlands which are expected to contain standing water throughout the growing season, the projected volume of wetland segments with seasonal standing water should not exceed the equivalent of the regional one- to two-year runoff event from the applicable drainage area. A two-year event of lesser duration (e.g. two to six hours) can have a high probability of occurrence in any given year. This event is often used to size small impoundments such as stock ponds, and can have equivalent applicability to wetlands development.

(2) Depth

Depth variation is necessary for diversity. While areas subject to fluctuating periods of inundation and drying will be useful for development of wet meadow communities, there must be some areas in the wetland that will contain seasonal water throughout most of the growing season to establish emergent vegetation stands.

(3) Hydrogeologic Conditions

Functional hydrogeologic conditions needed to foster wetlands development include clay soil, high water table, and graduated or intermittent flows.

b. Locations

(1) Ponds

During construction of ponds, topographic diversity of the structure bottom and the periphery of the water line commensurate with the wetland sizing determinations can be implemented to enhance wetland establishment (Figures D-3-1 and 2).

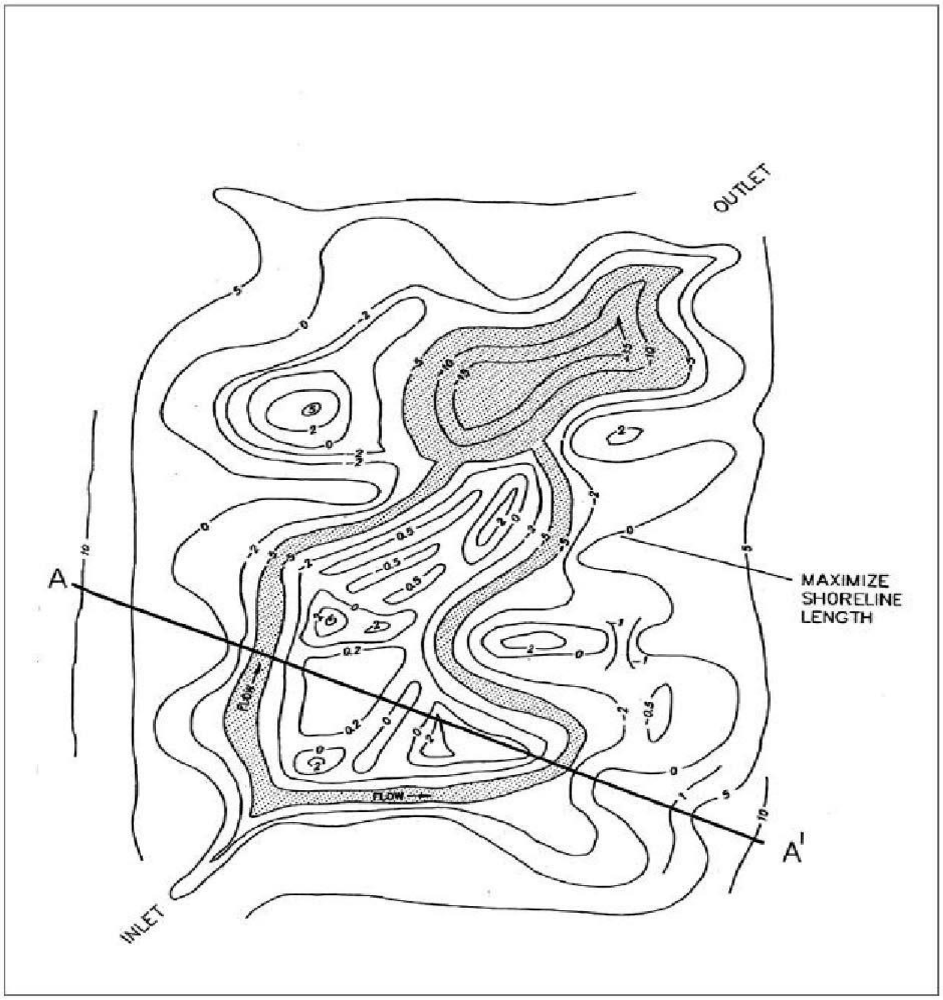
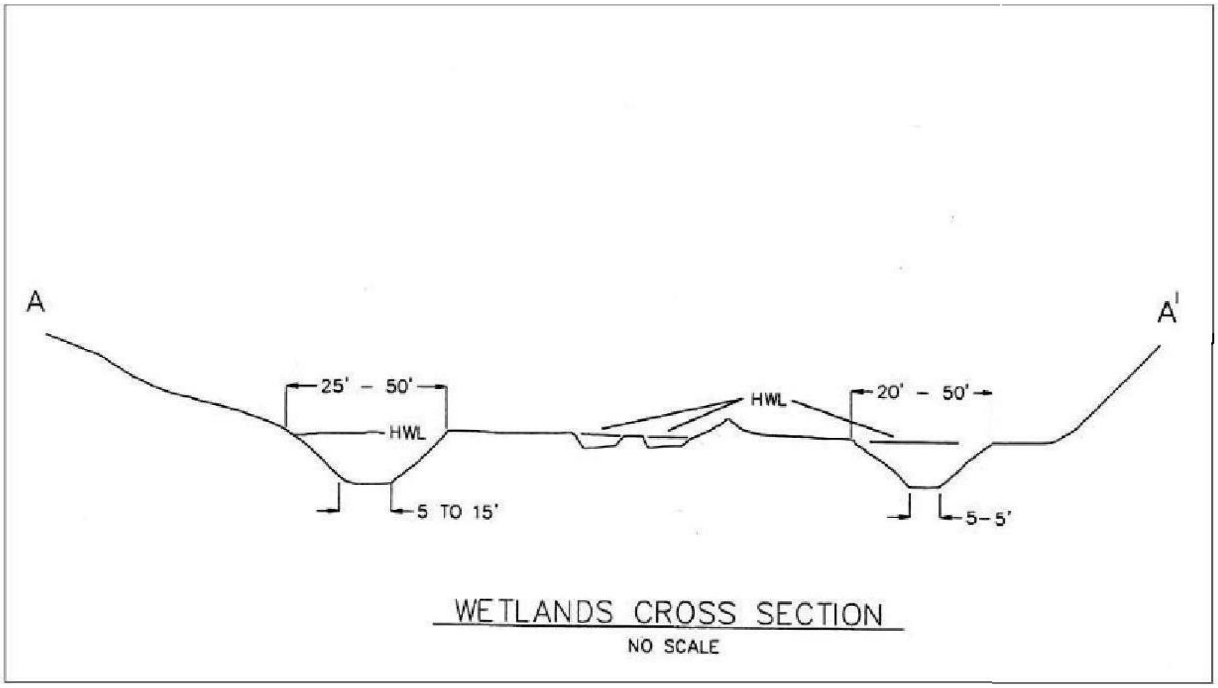


Figure D-4-1

These might include: construction of islands, peninsulas, ridges, and troughs to simulate bars and pools; pitting or furrowing along the contour of the proposed wetland surface to assure extended water retention and soil saturation; or construction of the pond floor at differential elevations. Many of these manipulations can also be applied to existing ponds to enhance wetlands establishment, but generally on a more limited basis due to existing conditions.

Figure D-3-2



Guidelines for establishment of these features include the following:

(a) Depth

Deep areas should be four or more feet deeper than the high water line. If a fish population is desired, more depth is required to prevent winter kill. In a pond with no substantial water flow, 25 percent of the total pond area should be at least 12 feet deep. If there is good water flow, 25 percent of the pond need only be 8 feet deep.

(b) Islands

Waterfowl nesting islands should be one to four feet higher than the high water line, and 200 feet from the edge of the water line where possible.

(c) Bars

Shallows and bars need to be within one-half foot of the normal water line.

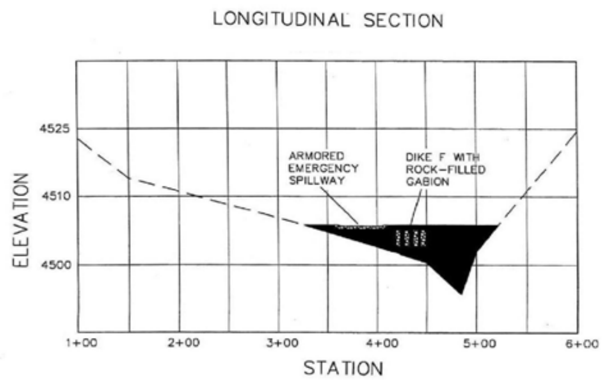
(d) Pitting and Furrowing

Pitting and furrowing should occur in the periphery of the predicted runoff event high water line. These features should be clustered at runoff concentration points, and should have a minimum depth of one foot.

(e) Volume

Predicted water volumes for those areas planned to hold seasonal standing water must be sufficient to address the regional evaporation potential.

(2) Minor Draws



One method of establishing wetlands entails construction of a low profile detention dike, or a series of dikes, across the bottom of a reclaimed drainage course (adjacent figure). The structure is intended to detain flows for sufficient time to create a temporary pool behind the dike. This will allow saturation of the soils and development of wet meadow conditions, while allowing ultimate free flow of the majority of the water. Minor retention pools will form along the upstream side of the dike.

A dike height of approximately five feet is recommended for general application. A top dike width of at least ten feet is recommended to allow construction and access by earthmoving and farming equipment. An average base width of 30 to 35 feet is recommended to provide stability and establishment of gentle slopes on both faces of the dike. Exact measurements will depend upon the size of the drainage, slope, base materials, and other site conditions. The length of each dike will vary as necessary to allow keying into the adjacent topography.

Each dike should have an outlet constructed of paired, rock-filled gabions (Figure D-3-4) to permit the slow escape of water from behind the dike.

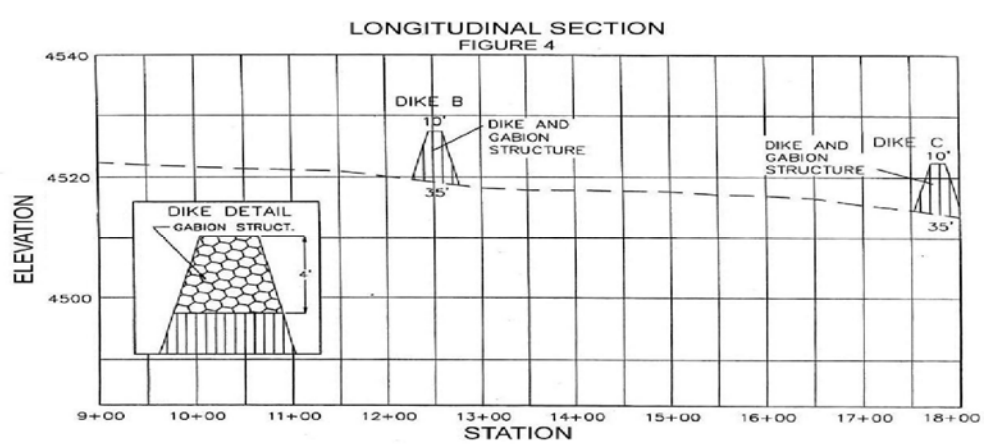


Figure D-3-4

The rock used to fill the gabions should be competent (e.g. limestone) to assure longevity. Periodic flows of water will reduce silt accumulations in the gabions, producing an overall wetlands longevity approximately equal to that of natural stock ponds and drainage pools.

Design planning should ensure minimization of peripheral disturbance to reclaimed lands. Construction timing is generally limited to the driest seasons. Following construction, the dike surfaces are seeded to reduce erosion and ensure stability. Native wheatgrass species are recommended.

(3) Playas

The areas of water concentration in the playa must be small enough to allow water to collect in sufficient depth (6 to 36 inches). The surface soil must be clayey, or have a high water table, to allow water to stand on the surface.

(4) Major Drainage Channels

Major drainage channels generally provide the greatest topographic diversity for construction/installation of such features as deep pools, waterfowl nesting islands, shallow flats and bars, rock structures, and screened channels. These will assist in establishment of varying zones of wet meadow, emergent vegetation, and open water. The guidelines discussed above for establishment of these features in ponds also apply to their implementation in drainage channels.

(5) Final Reclamation

The prospective wetland development areas should be broadcast seeded with a seed mix which will facilitate establishment of wet meadow areas. Select areas projected to hold seasonal water can then be augmented with emergent wetland species either through seeding or transplants. The following mix is recommended to enhance and expedite wet meadow establishment:

Species	Rate
Kentucky bluegrass *Poa pratensis*	4.0 PLS pounds per acre
Reed canarygrass *Phalaris arundinacea*	4.0 PLS pounds per acre
Western wheatgrass *Agropyron smithii*	1.0 PLS pounds per acre

A minimum of .5 bulk pounds per acre of at least two of the following species should also be used:

Prairie cordgrass	*Spartina pectinata*
Streambank wheatgrass	*Agropyron riparium*

Sloughgrass	*Beckmannia syzigachne*
American mannagrass	*Glyceria grandis*
Common rush	*Juncus effusus*
Hardstem bulrush	*Scirpus maritimus*
Cattail	*Typha latifolia*

The basic mix can also be augmented with transplants such as spikerush, sedge, or other wetland species.

4. Planning and Constructing Permanent Postmining Impoundments

Section editor: Frank K. Ferris *Subsection author: Patrick T. Tyrrell*

Applicability

Postmining impoundments are constructed for a variety of reasons. This includes replacement of pre-existing impoundments and construction of new impoundments, where feasible, to take advantage of the resulting reduction in backfill replacement movement. Wetland replacement is another common reason for constructing postmining impoundments. However, wetlands and dam construction techniques are discussed elsewhere in this section. This subsection will deal more with the special considerations faced in planning and constructing permanent postmining impoundments.

Special Considerations

Function of postmining impoundments will be influenced by water supply and quality, chemical characteristics of backfill underlying the reservoir basin, and sediment inflow. From a permitting standpoint, changes in impoundment function or size from premining conditions may trigger a requirement from the regulatory agency to similarly modify postmining land use descriptions in the Surface Mine Control and Reclamation Act (SMCRA) permit prior to approval. Under SMCRA, reservoir feasibility is scrutinized heavily both in design and in performance (via monitoring). If the impoundment is not a replacement feature, the agency likely will request an alternate reclamation plan to be implemented if the structure does not function as planned.

Technique

a. Design and Permitting Considerations

Permanent postmining impoundments are as much a permitting project as a construction project. Typically, permitting and construction of smaller features, such as stock ponds, are not as rigorous or costly as similar work for much larger bodies with a capacity of several hundred or several thousand acre-feet. These larger impoundments are heavily scrutinized from the design and performance standpoints.

(1) Uses

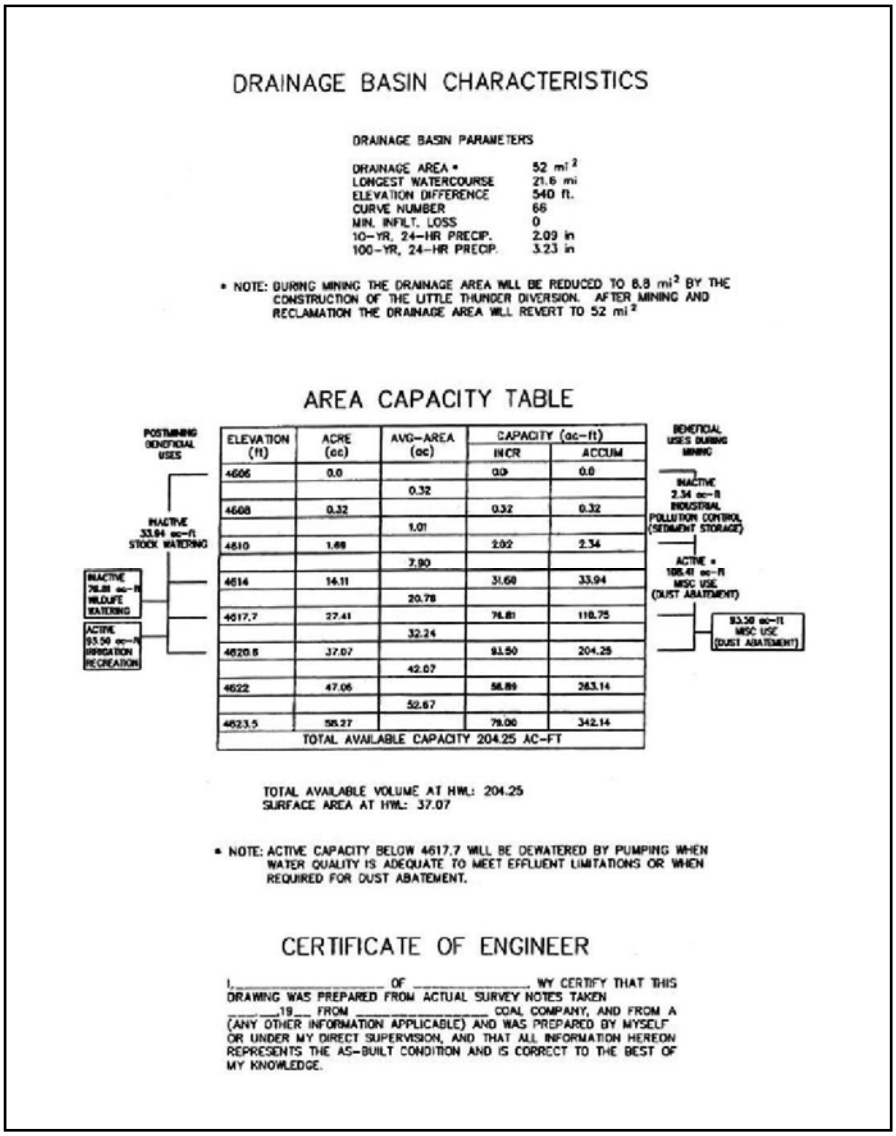
Design and permit the impoundment for its anticipated uses. Larger impoundments intended for wildlife, fish, and recreation, in addition to stock watering, will have different characteristics than small stock ponds alone. Consult established guidelines for appropriate reservoir characteristics prior to design, so you and your management know where you're headed. For waterfowl or fish, for example, guidelines give recommended percentages for littoral zone (shallows), as well as deeper water, to make the impoundment more conducive to healthy populations.

(2) Topsoil

Make sure a reasonable and protective topsoil handling plan is put forth. Without ample topsoil, compliance problems will arise immediately. Typically, for impoundment drainage areas that are actively disturbed or reclaimed but still bonded, the reservoir basin should contain no topsoil below the high water line. This may cause contamination from overland flow.

(3) Water Supply

Permit the impoundment for an expected water supply. Stock ponds can be permitted to contain the mean annual flood (or some other relatively frequent event, to keep fresh water available) estimated by modeling. Larger impoundments may require operational studies to determine a size that will operate properly given the intended use. Assess such parameters as spilling frequency, range of water level fluctuations, and possibly a salt (TDS) balance to evaluate water quality over time and especially during drought periods. These studies will have to take downstream, senior water rights into account, and may result in construction of a low flow bypass or other mechanism (or administrative arrangement) to accommodate those rights.



DRAINAGE BASIN CHARACTERISTICS

DRAINAGE BASIN PARAMETERS

DRAINAGE AREA *	52 mi^2
LONGEST WATERCOURSE	21.6 mi
ELEVATION DIFFERENCE	540 ft.
CURVE NUMBER	66
MIN. INFILT. LOSS	0
10-YR, 24-HR PRECIP.	2.09 in
100-YR, 24-HR PRECIP.	3.23 in

* NOTE: DURING MINING THE DRAINAGE AREA WILL BE REDUCED TO 8.8 mi^2 BY THE CONSTRUCTION OF THE LITTLE THUNDER DIVERSION. AFTER MINING AND RECLAMATION THE DRAINAGE AREA WILL REVERT TO 52 mi^2

AREA CAPACITY TABLE

ELEVATION (ft)	ACRE (ac)	AVG-AREA (ac)	CAPACITY (ac-ft)	
			INCR	ACCUM
4606	0.0		0.0	0.0
		0.32		
4608	0.32		0.32	0.32
		1.01		
4610	1.69		2.02	2.34
		7.90		
4614	14.11		31.60	33.94
		20.78		
4617.7	27.41		76.81	110.75
		32.24		
4620.8	37.07		93.50	204.25
		42.07		
4622	47.06		58.89	263.14
		52.67		
4623.5	58.27		79.00	342.14
TOTAL AVAILABLE CAPACITY 204.25 AC-FT				

TOTAL AVAILABLE VOLUME AT HWL: 204.25
SURFACE AREA AT HWL: 37.07

* NOTE: ACTIVE CAPACITY BELOW 4617.7 WILL BE DEWATERED BY PUMPING WHEN WATER QUALITY IS ADEQUATE TO MEET EFFLUENT LIMITATIONS OR WHEN REQUIRED FOR DUST ABATEMENT.

CERTIFICATE OF ENGINEER

I, ____________ OF ____________, WY CERTIFY THAT THIS DRAWING WAS PREPARED FROM ACTUAL SURVEY NOTES TAKEN ____, ___, 19__ FROM ____________ COAL COMPANY, AND FROM A (ANY OTHER INFORMATION APPLICABLE) AND WAS PREPARED BY MYSELF OR UNDER MY DIRECT SUPERVISION, AND THAT ALL INFORMATION HEREON REPRESENTS THE AS-BUILT CONDITION AND IS CORRECT TO THE BEST OF MY KNOWLEDGE.

A water right should be obtained for the anticipated capacity of the impoundment; but remember that, upon construction, the final as-built capacity cannot exceed the permitted capacity. This is good to know as construction is commencing so no surprises are encountered. A beautiful pond may never function if insufficient attention is paid to water supply.

(4) Freeform Work

As much as possible, leave flexibility in your permitting language to do freeform work in the field. The freedom to add cost-effective shoreline undulations, small islands, riprap extensions, or simply keep working if unexpected conditions are encountered is invaluable if, as a situation arises, you don't have to convene the legislature to continue. But behave yourself; unlimited flexibility is dangerous when it reduces reliance on planning.

(5) Reservoir Characteristics

Pay special attention to reservoir characteristics. Safety must be considered because of the inherent questions about the long-term stability and settlement characteristics of mine backfill. Impoundments in backfill are more safely operated if they are totally incised than if they include an embankment sitting on many tens of feet of uncompacted truck/shovel or dragline spoils. Plus, in the incised case, a much smaller spillway or overflow channel is needed because there is no embankment to protect. Be aware of the safety concerns associated with operating heavy equipment along the banks and shorelines of backfill impoundments as these will be areas of instability when saturated.

(6) Industrial Uses

Make sure the impoundment is permitted for at least some industrial uses. Impoundments can be a convenient water storage feature your production department will want to use, or need to use, at some point. Plus, pit water or disturbed area runoff can enhance the speed with which the reservoir will fill, if it is not to be hydraulically connected to its ultimate drainage area for a period of time. This is a two-edged sword, however. While the extra water can speed maturation of the impoundment, the mining operation must be careful not to introduce unwanted sediment or poor quality water into a structure you hope to be a clean contributor to the postmining environment. Also, the extra water may bias your evaluation of the water balance for the reservoir, if one is necessary to prove its ultimate functions.

b. Construction Considerations

(1) Strip Topsoil

Much work will be going on in the vicinity of the reservoir basin and dam. Because of this, a first step is to remove all remaining topsoil in the dam, spillway, reservoir basin, borrow, and access areas.

(2) Work Dry

Working in wet bottomlands generally can be avoided when creating impoundments in older backfill or small drainages. If you must work in boggy areas, be cognizant of special sediment control measures that may be needed. Also, make sure your equipment operator or contractor can handle the work. In tricky areas, for instance, a floatation dozer may be required. When working in a wet drainage, coffer dams, a temporary diversion, or pumping will be required to keep the active areas workable. In ephemeral channels, most water encountered will be subsurface. A pre-construction borehole grid should awaken you to any potential construction problems.

(3) Survey Control

Maintain good survey control. This is especially important for the as-built drawings, spillway and dam crest elevation confirmation, and high water line delineation. Stake the high water line well in advance of construction to highlight problem areas that may not have been caught when working from maps or photos (i.e. was a power line installed recently, or are there trees that can be salvaged?).

(4) Material Sources and Quantities

Permanent impoundments in backfill environments, particularly the larger ones, will typically require the placement of a layer of "suitable" earth for a specified depth beneath the reservoir bottom. This is material that meets chemical quality criteria agreed to in the permitting process. The suitable zone may be four to eight feet in thickness or more, so a substantial amount must be available. When the time comes that this material is needed, the source quantity and quality must not be in question.

(5) Materials Testing

Do not skimp on materials testing. Since this structure will have to prove its performance during the bond period, and is intended to last many years beyond, thorough testing and documentation thereof is critical. Materials testing will include soil quality (paragraph D above), compaction, gradation (e.g. for riprap), and classification (for embankment zones).

(6) Monitoring

Especially for the larger impoundments, provisions should be made during construction for the water quantity and quality monitoring that will often be required as a condition of approval. This will include, at a minimum, one or more staff gages, survey monuments (for the embankment, and for the reservoir basin if constructed on backfill), and water quality monitoring station locations. Be sure to stash a johnboat in the brush nearby, if access is unpredictable, to allow for bathymetric surveys and depth-integrated sampling in the future. If the structure serves any industrial uses, it will likely end up as an National Pollutant Discharge Elimination System (NPDES) discharge point. In this case, additional equipment will include a controlled lower-level discharge (in addition to the service discharge and emergency spillway) and a flume or other measuring device at the outfall.

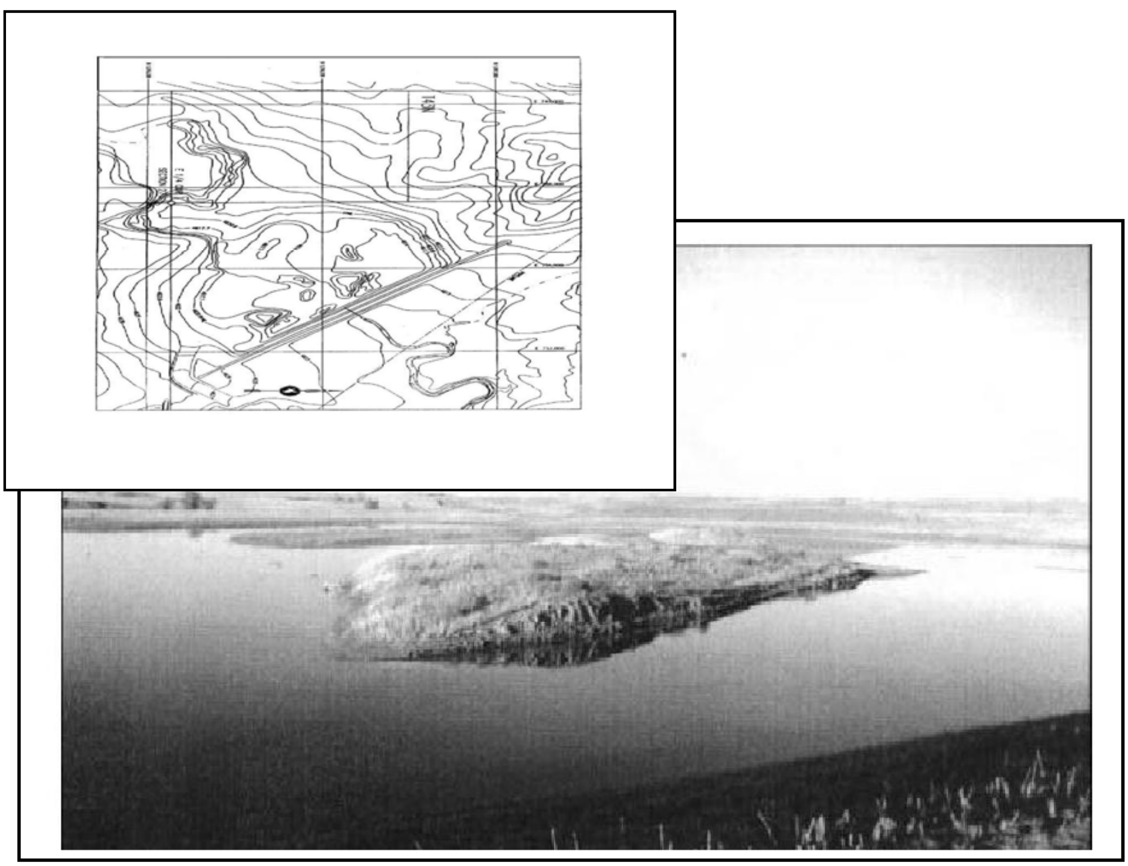
(7) Stabilization

Stabilize areas that will be affected by flowing water. Spillways, outlet channels, inlet channels, downwind shorelines, embankments, and mechanical outlet works should all have erosion protection in place and functional before they are needed. Especially steep sections, such as in inlets to incised structures and embankment slopes, will probably require durable riprap. Other areas can adequately be stabilized with vegetation.

To enhance the long term aesthetics and habitat characteristics of the structure, consider seeding or transplanting wetland vegetation along shorelines (which should be flatter near the high water line for this purpose, if possible), although many of these will recruit naturally. Do not plant trees in embankments, as their root systems may cause destabilization.

(8) Final Touch

Hold back some materials for the final touch. As construction of the impoundment nears completion, it is nice to have some extra suitable fill, riprap, and equipment time available to add meaningful and functional features to the reservoir basin. These need not be costly or extensive. By adding a small peninsula here, a small island or two there, and some additional shoreline sculpting or rock habitat, (all done under dry conditions) the lake will take on a much more natural appearance with more valuable habitat. And, given it will be there much longer than you, it will be much more likely to look like the natural feature it is intended to be.



The above view of the 26-SR-1 Reservoir at the Black Thunder Mine provides a look at islands placed in the reservoir basin following dam construction (view is from the embankment looking west). The dam, its spillway, and the islands received topsoil to aid revegetation establishment. Additional features such as these islands and the littoral zone around them serve as wildlife habitat enhancement features.

E. HYDROLOGIC CONTROL STRUCTURE TOLERANCES

Section editor: Frank K. Ferris *Subsection author: Frank K. Ferris*

Applicability

Implementing a design for a hydrologic control structure often leaves the question of how closely to adhere to that design. Both carelessness and too-rigid adherence to design criteria can lead to structure failure. This subsection was developed as a guide for acceptable tolerances.

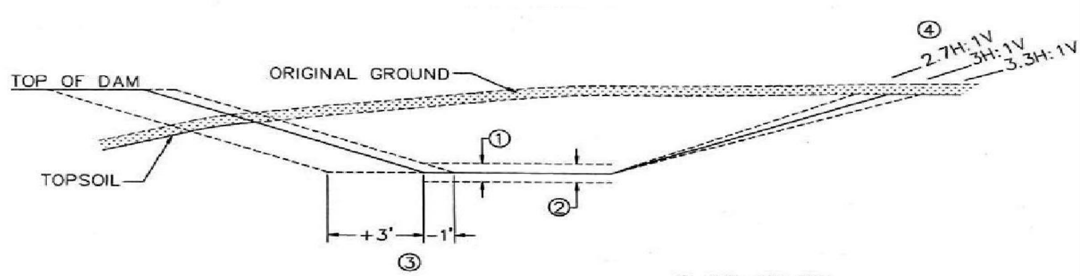
Special Considerations

Lack of experience in a contractor may lead to deficiencies in structure, although excessive supervision could incur significantly more cost than warranted in the building of the structure. Outlining acceptable and unacceptable tolerances solves this problem.

Technique

The tolerances outlined on attached Figures E-1 through 9 were developed from field experience and research of regulations and professional standards. These tolerances were compiled to prevent repeating past mistakes and to clarify construction standards. They also simplify the certification process required by most regulatory authorities. Structure size determines how restrictive these tolerances must be. Tolerances are provided for various structures. The tolerances are illustrated by cross sections and structure component variables for:

Figure E-1 SPILLWAY CROSS SECTION

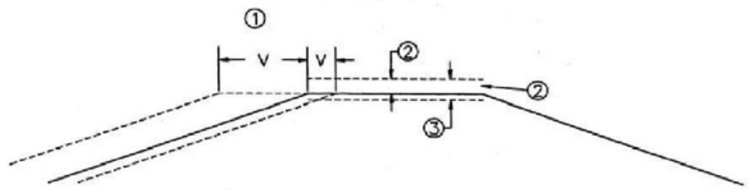


SPILLWAY STRUCTURE COMPONENTS	LESS THAN 2 AC-FT	2 AC-FT OR LARGER, BUT NON-MSHA	MSHA STRUCTURE
① CREST ELEVATION/ CONTROL SECTION	±.3 ft.	±.2 ft.	±.1 ft.
② GRADIENT VARIATION / 100 FEET	±.3 ft.	±.2 ft.	±.2 ft.
③ BOTTOM WIDTH	−1* to +3 ft.	−1* to +3 ft.	−1* to +3 ft.
④ SIDE SLOPES VARIATION	±10%	±10%	±10%

* (−10% max.)

Figure E-2

EMBANKMENT TOP CROSS SECTION

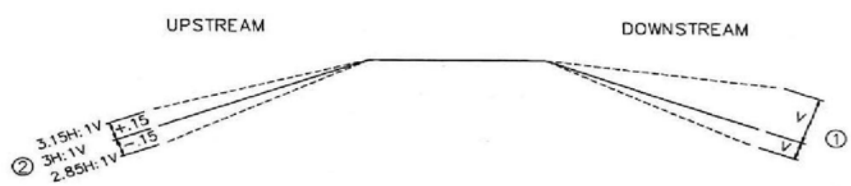


EMBANKMENT TOP STRUCTURE COMPONENTS	LESS THAN 2 AC–FT	2 AC–FT OR LARGER, BUT NON–MSHA	MSHA STRUCTURE
① WIDTH	–1 to +5 ft.	–1 to +3 ft.	–.5 to +2 ft.
② ELEVATION	–.2 to +2 ft.	–.1 to +1.5 ft.	–.05 to +1 ft.
③ UNIFORMITY OF TOP ELEVATION / 100 FEET (TOTAL VARIATION)	1.0 ft.	.8 ft.	.5 ft.

NOTE: MINIMUM TOP WIDTH DESIGN WOULD BE 10 FEET WIDE.

Figure E-3

EMBANKMENT CROSS SECTION

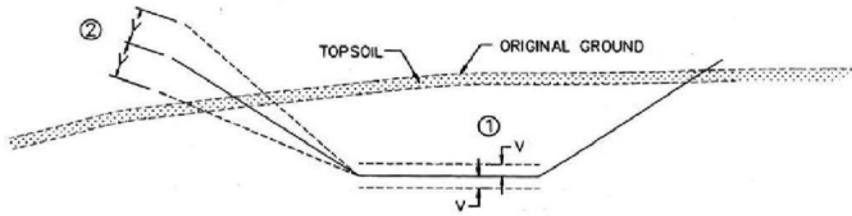


EMBANKMENT SLOPE STRUCTURE COMPONENTS	LESS THAN 2 AC–FT	2 AC–FT OR LARGER, BUT NON–MSHA	MSHA STRUCTURE
① VARIATION (OUTSIDE, DOWNSTREAM)	–10% to +100%	–5% to +10%	±5%
② VARIATION (INSIDE, UPSTREAM)	±5%	±5%	±5%

NOTE: AS BUILT SLOPES MUST MEET THE SLOPE CRITERIA AS DEFINED. EXAMPLE, IF THE DAM HAS AN OVERFILL OF ONE FOOT HIGH AND TWO FEET WIDE, A 3H:1V TOE WOULD BE 5 HORIZONTAL FEET BEYOND THE TOE STAKES. THE TOE STAKES DO NOT GOVERN ON OVER HEIGHT OR WIDTH FILLS, THE AS BUILT TOP DETERMINES THE MINIMUM TOE OF SLOPE.

Figure E-4

KEY WAY



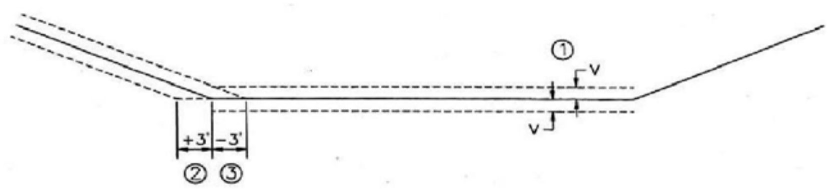
KEY WAY STRUCTURE COMPONENTS	LESS THAN 2 AC-FT	2 AC-FT OR LARGER, BUT NON-MSHA	MSHA STRUCTURE
① DEPTH (FROM DESIGN)	+.5 to -2 ft	+.3 to -2 ft	+.1 to -2 ft
② SLOPES (VERTICAL:HORIZONTAL) (FROM DESIGN)	+50% to -100%	+25% to -100%	+20% to -100%

NOTE: A 15 FEET WIDE KEY IS USUALLY THE MINIMUM NEEDED TO GET COMPACTION WHEN MATERIAL IS REPLACED. 5 FEET WIDE WILL WORK IF APPROPRIATE COMPACTION EQUIPMENT IS USED.

NOTE: SAND LENSES OR OTHER GEOLOGIC FEATURES MAY REQUIRE A DEEPER KEY THAN THE TOLERANCE EXTREME WOULD SEEM TO ALLOW. FIELD CONDITIONS WILL GOVERN WHERE REQUIRED.

Figure E-5

RESERVOIR DIMENSIONS

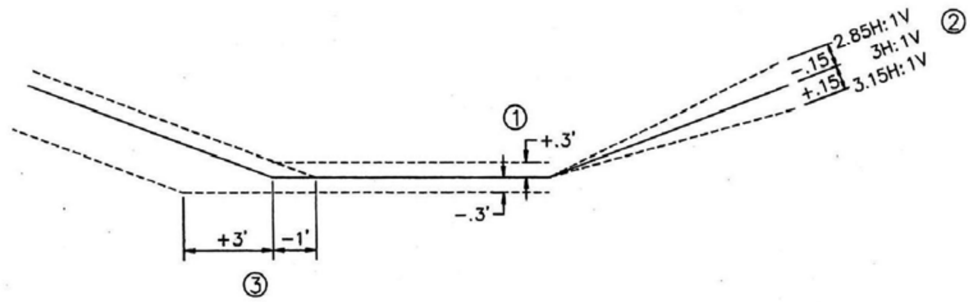


RESERVOIR STRUCTURE COMPONENT	LESS THAN 2 AC-FT	2 AC-FT OR LARGER, BUT NON-MSHA	MSHA STRUCTURE
① DEPTH	± .5 ft	± .3 ft	± .2 ft
② LENGTH	± 3 ft	± 3 ft	± 3 ft
② WIDTH	± 3 ft	± 3 ft	± 3 ft

NOTE: IF THE RESERVOIR DESIGN VOLUME IS NEAR THE TWO ACRE FOOT LIMIT, 20 ACRE FOOT LIMIT, OR SOME OTHER LIMIT FACTOR, USING THE TOLERANCE EXTREMES MAY EXCEED REASONABLE AND CERTIFIABLE CONDITIONS. THUS, THE MOST RESTRICTIVE CRITERIA WILL GOVERN. EXAMPLE: A LONG NARROW RESERVOIR COULD EXCEED THE VOLUME VARIATION EVEN IF THE WIDTH IS WITHIN THE TOLERANCES. THUS, THE VOLUME CRITERIA GOVERNS, THE WIDTH ALLOWANCES MAY HAVE TO BE MORE RESTRICTIVE FOR THE DESCRIBED RESERVOIR.

Figure E-6

DIVERSION CROSS SECTION

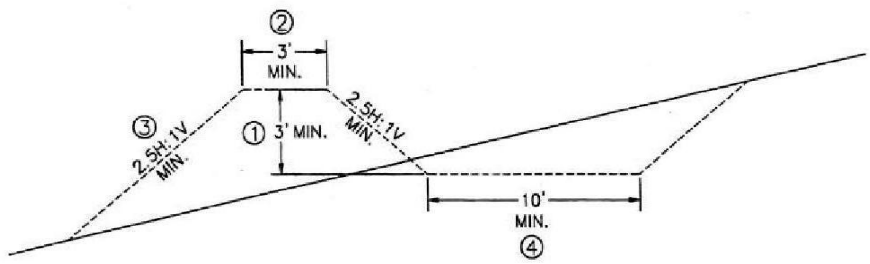


DIVERSION STRUCTURE COMPONENTS

①	GRADIENT VARIATION / 100 FEET	± .3 ft
②	SLOPES	−5% to +25%
③	BOTTOM WIDTH	−1 to +5 ft

Figure E-7

CREST DRAINAGE



CREST DRAINAGE STRUCTURE COMPONENT

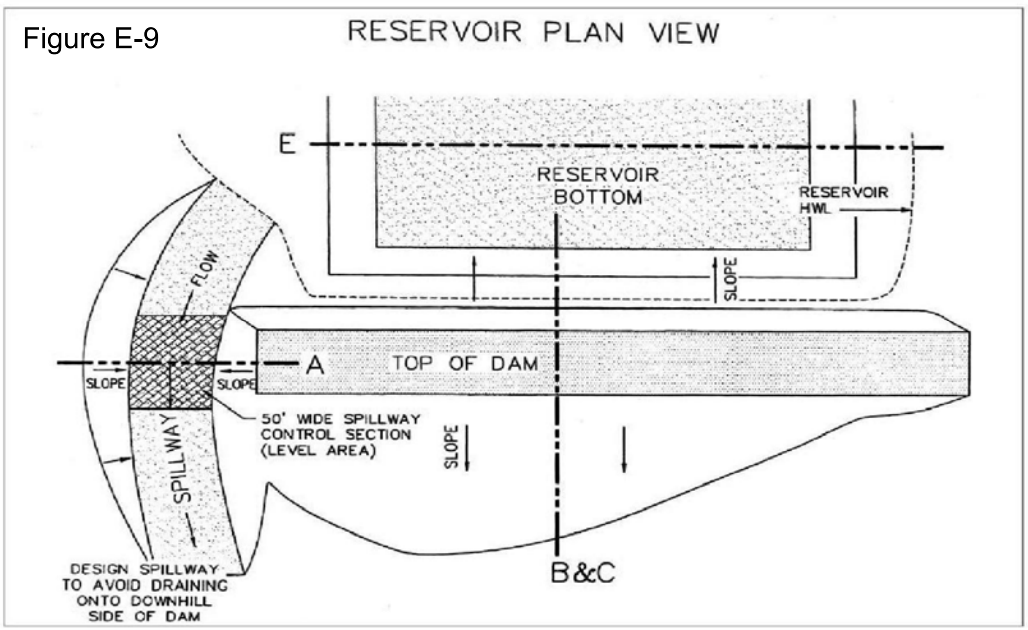
①	BERM HEIGHT	2.5 ft min.
②	BERM TOP WIDTH	2.5 ft min.
③	SLOPES	2.5H:1V min.
④	CHANNEL WIDTH	6 ft min.
	CHANNEL GRADIENT	according to field conditions e.g. large drainage area, shallow slope

Section
Handbo

CREST DRAINAGE

Figure E-8

Figure E-9



F. Surface Water Monitoring Using a Weir

Section editor: Frank K. Ferris *Subsection author: Frank K. Ferris*

Applicability

Surface water monitoring may be required, and can often be difficult to accomplish. A monitoring site should have long duration and quality construction. The equipment to be used should likewise be of high quality for reliability and durability. Stream gaging stations usually include a control section, so that a rating curve can be constructed by hydraulic calculations rather than repeated gaging with a current meter, and a water level recorder. Constructed control sections include weirs, flumes, culverts, and similar structures with regular shapes susceptible to calculation of discharge rates when water depth is known.

Special Considerations

Type and location of control section (weir, flume, etc.) should be carefully selected to reflect the site conditions and the goals of the monitoring program. A long-term monitoring site can be difficult to locate, but will be well worth the effort. The chosen site should remain undisturbed for ten years, or longer if possible, and be located in a narrow channel area. Short duration data are generally of little value. Construction must be of good quality to eliminate frequent repairs, which are usually costly, time consuming, and invalidate data.

During large events, backwater may affect weir hydraulics and require an alternate flow calculation method. This section describes some techniques that may be used for relatively small flow measurement structures. Larger structures require detailed design. Under-designed weirs fail due to over-turning forces caused by the hydrostatic forces from the impounded water, ice forces, or poor foundation conditions or treatment.

Parshall flumes provide accurate flow measurements but can handle a limited range of discharge rates. They are appropriate for measuring flows from a relatively constant water source, such as controlled releases from treatment ponds. Flumes are best used in relatively flat channels since their accuracy is dependent upon approach velocity. Weirs can handle a wider range of flows and can be assembled on site. They create a pond upstream and require enough difference between upstream and downstream water levels that there is no nappe interference. This section describes some considerations to be aware of when designing and installing weirs.

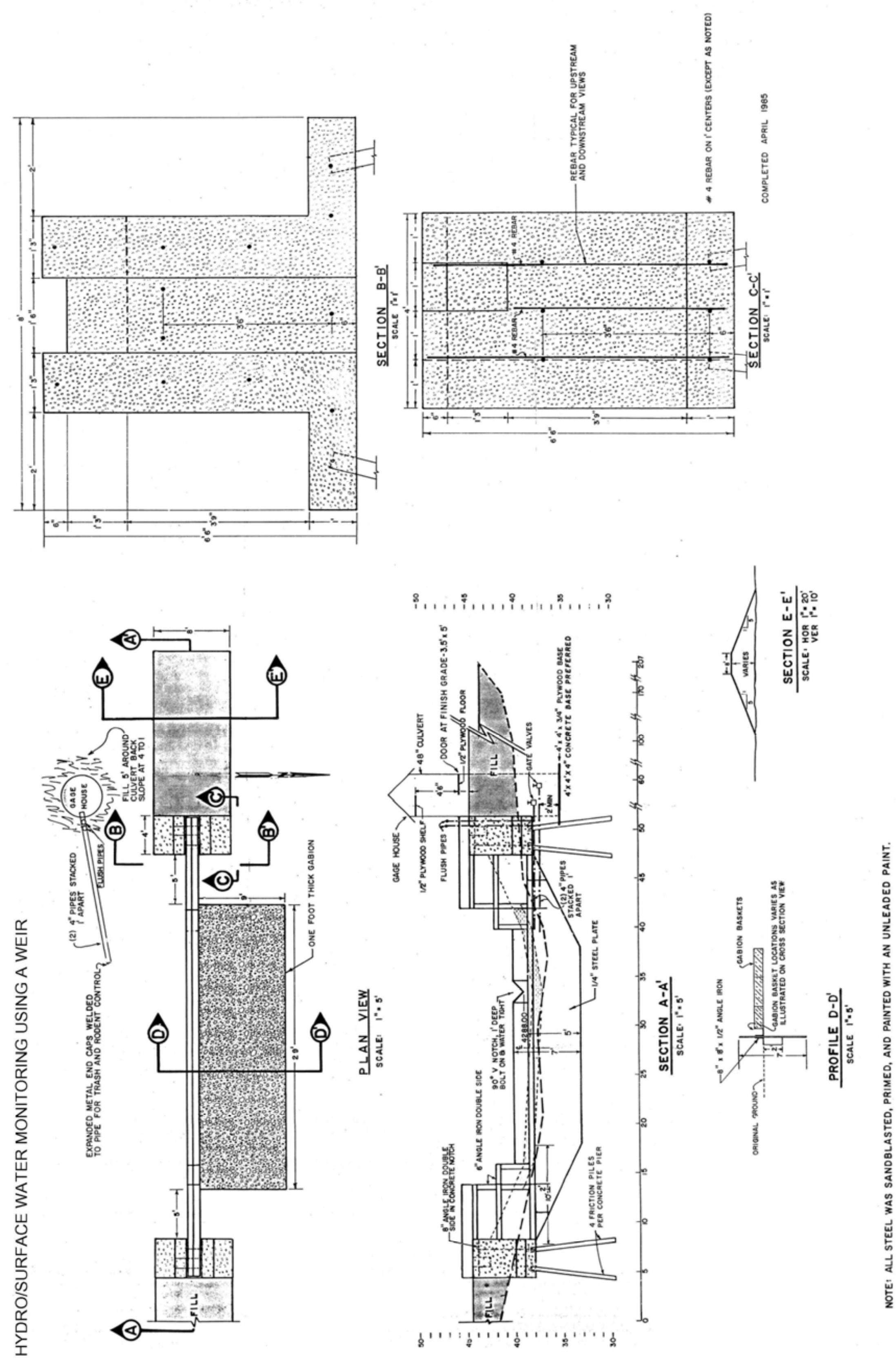
Technique

Construction of control sections for gaging stations generally has been a Cipolleti, compound or vee-notch weir or, Parshall flume. The compound weir can have whatever capacity is desired. The length of the compound section determines the capacity.

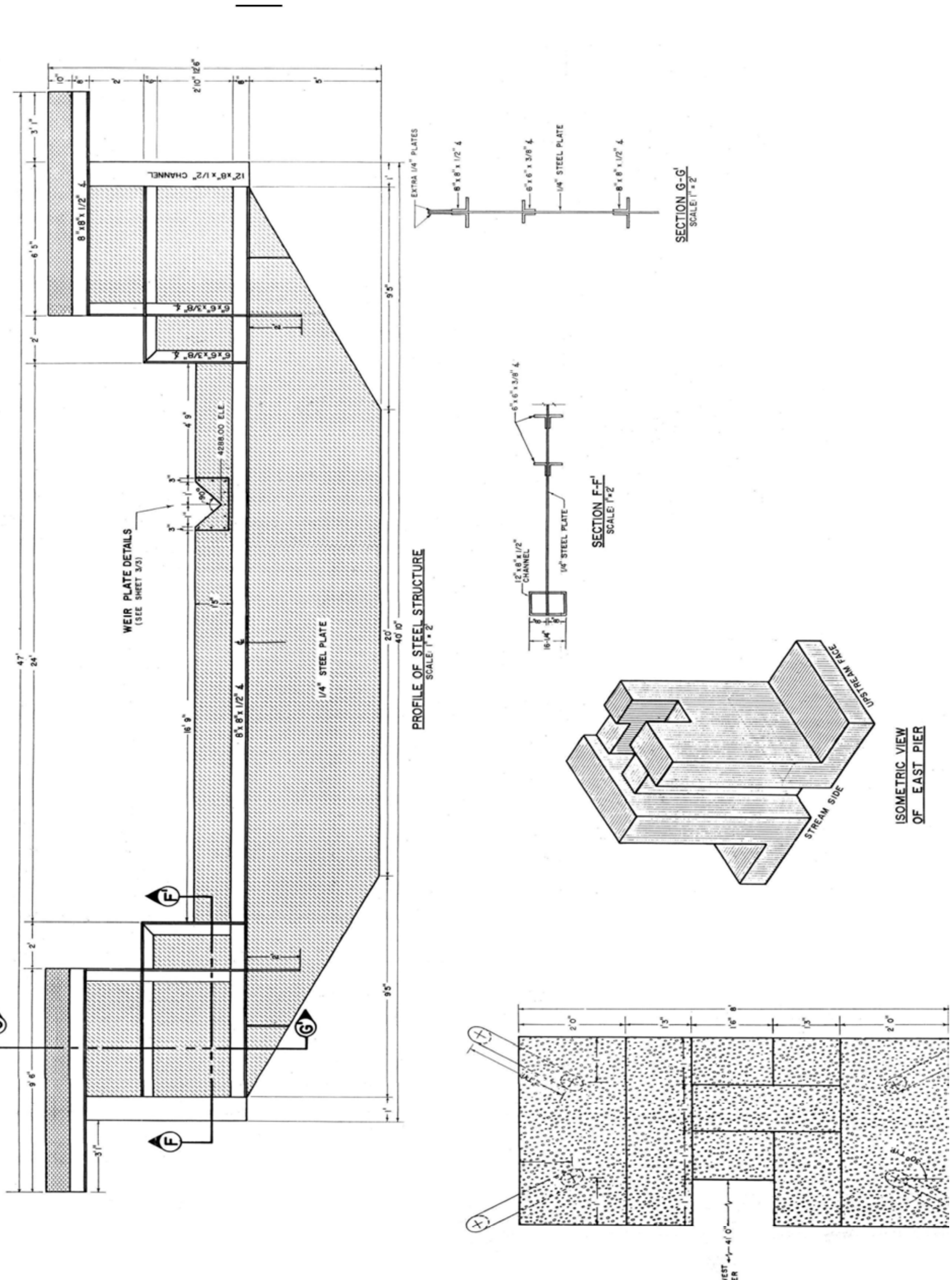
Weirs are usually installed by cutting an open trench perpendicular to the channel, and placing bolted or welded steel plates (4 foot by 8 foot) vertically in the trench. It is often difficult to keep the steel level and straight when installing it in an open ditch. This problem has been solved by using side footings for stabilizing the structure (Figure F-1 and 2). Adjust the footing location and height, and weir size, as channel capacity requires. Bear in mind that the weir functions partly as a retaining wall, and must be designed to withstand over-turning and sliding pressures.

For recording the water levels, high quality recording equipment should be used to assure continuous operation during weather extremes. The gauge house equipment records the water level in the gauge house, which corresponds to the water level at the weir.

Backfill around the weir must be compacted, clayey soil to prevent piping. The weir plate should be at least five feet into the soil at all locations to prevent water from going under the weir.



HYDRO/SURFACE WATER MONITORING USING A WEIR (CONTINUED)



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TOPSOIL

Section Editor: Laurel Vicklund

Handbook of Western Reclamation Techniques

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SECTION 4: TOPSOIL

A. Introduction

Section editor: Laurel E. Vicklund

Topsoil is the most valuable and voluminous environmental resource to be managed in mining and other projects where earthmoving is required. Vegetation establishment and general reclamation success are enhanced by proper salvage and replacement of topsoil.

Microorganisms, seeds, and roots are stored in the upper inches of this skin. The sooner salvaged topsoil can be replaced, the better chance these living features of the soil have to contribute to reclamation success.

Salvage, stockpiling, and replacement activities require large equipment and a dedicated amount of time. Planning and coordination are necessary to ensure that areas are properly salvaged ahead of land disturbing activities, and that timely topsoil replacement and seeding take place as soon as practicable after the land has been reshaped and regraded.

Topsoil salvage and replacement procedures are featured in this section. The methods described for topsoil removal include practices for managing salvage depth to ensure adequate recovery. Non-traditional methods for enhancing native vegetation establishment are presented in the subsection entitled, "Preserving Seedbed Viability Through Direct Haul of Frozen Topsoil."

There is no single best method of handling topsoil salvage and replacement activities. Application of a combination of the techniques presented in this section will aid in adequate topsoil salvage and replacement.

B. Salvage

1. Topsoil Identification and Salvage Control

Section editor: Laurel E. Vicklund *Subsection author: Frank K. Ferris*

Applicability

Topsoil salvage is required by law for mining, and is highly recommended for other forms of surface-altering land disturbances to assure productivity of reclaimed lands. Topsoil identification, stripping control, and experienced equipment operators will assure a high quality topsoil resource for reclamation.

Special Considerations

Topsoil varies in depth atop overburden or subsoil, which are less productive than topsoil for plant growth. Thus, stripping overburden along with topsoil may significantly reduce plant productivity and should be avoided. Accurate identification of topsoil in the field will lead to adequate segregation of topsoil from underlying materials.

Techniques

a. Topsoil Identification

Topsoil identification for equipment operators is most understandable and useful when it is related to location, depth, color, structure, texture, salt depositions, and site ripping. An operator need not have specialized knowledge of topsoil to become expert at stripping.

(1) Location

Deep topsoil is usually located in draws and valley floors; ridge tops generally have very shallow topsoil. Shallow ridge topsoil usually covers subsoil or unweathered overburden that may not be favorable for reclamation.

(2) Color

Brownish earth-tone colors consistent with near surface color indicate topsoil. When bright colored earth tones or distinct color change occurs, it usually means topsoil has ended. Soil moisture darkens the soil so recent rainfall saturation should not be mistaken for an actual change of color.

(3) Structure

Structure is the best indication of topsoil to the trained eye, and well-developed topsoil that lies below the immediate surface can be identified by its blocky hexagonal shape. Deeper-lying overburden has an irregular, blocky look; as does poorly developed near-surface material. Well-developed topsoil has a regular shape due to the presence of organic clays. Tilling destroys soil structure, however, so even well-developed topsoil that has been tilled will not show this structure.

(4) Texture

Because of their limited capacity to support plant growth, soils composed mostly of sand or mostly of clay are best not mixed with other topsoil and should typically be excluded from stripping. Heavy clay soils have limited water infiltration capacity while very sandy soils have poor water retention capacity and are often very low in nutrients.

(5) Salt Deposition

Faint to very white deposits on the surface or within the profile typically indicate the accumulation of salt, usually carbonates and sulfates. Rainfall and surface runoff carry these salts in solution to a certain point and then evapotranspiration causes them to precipitate, which results in salt accumulation over time. In contrast to the whitish appearance of carbonates and sulfates, dark blackish patches on the soil surface where vegetation does not grow usually indicate the accumulation of sodium salts. These areas should be avoided where possible.

In low-lying areas and in drainages, soil with visible salt deposits may be too saline or alkaline for optimum plant growth. Visible salts are a good indication that stripping should cease some feet distant from the accumulation zone. In upland areas, topsoil showing some salt accumulation may be entirely satisfactory. A soil scientist or other skilled professional can make the call when a situation is uncertain.

(6) Roots

Roots can be indicators of topsoil. A dense mass of roots indicates the surface sod. However isolated roots, especially shrub roots, can penetrate well beyond topsoil. Therefore, roots alone should always be used with caution in determining topsoil depths.

b. Topsoil Salvage Control

Topsoil salvage control is best accomplished when several of the following tools are employed for overall control: pedestals, ripping, backhoe pits, site supervision, topsoil classes, augers, and skilled equipment operators.

(1) Pedestals

Pedestals are the most critical references for quality control (see Figure B-1 and 2). They illustrate topsoil horizons and reference the original surface. For example, pedestals eliminate the possibility of draw bottoms being viewed as stripped when in fact no topsoil was stripped (see Figure B-3).

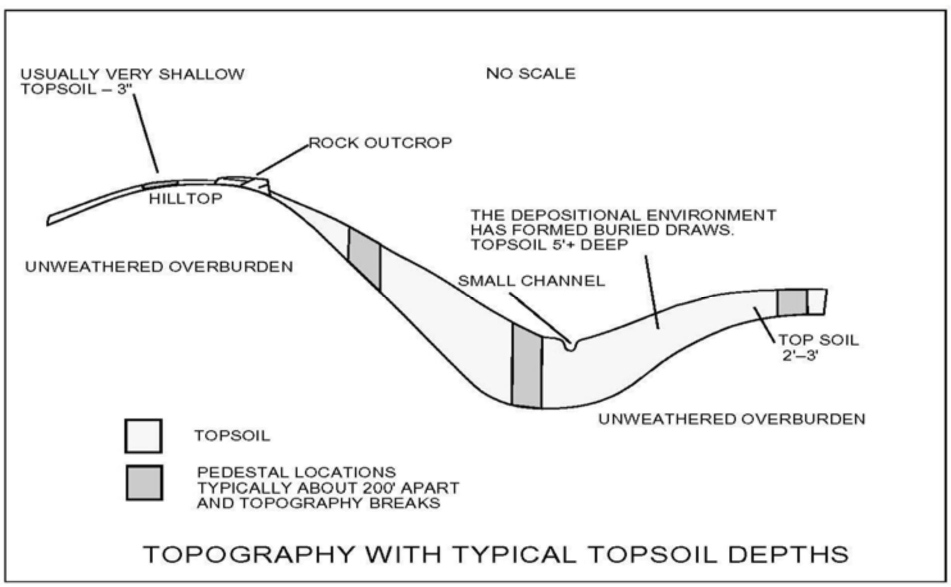


Figure B-1

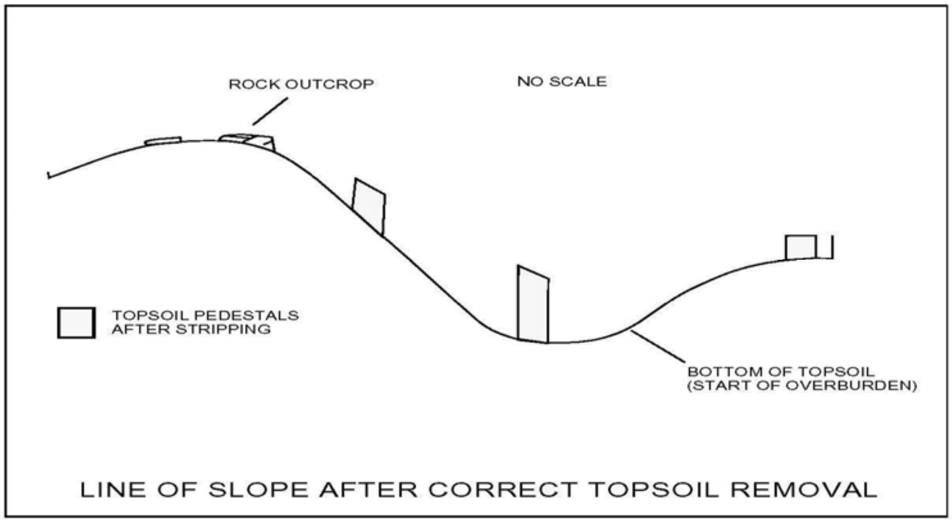


Figure B-2

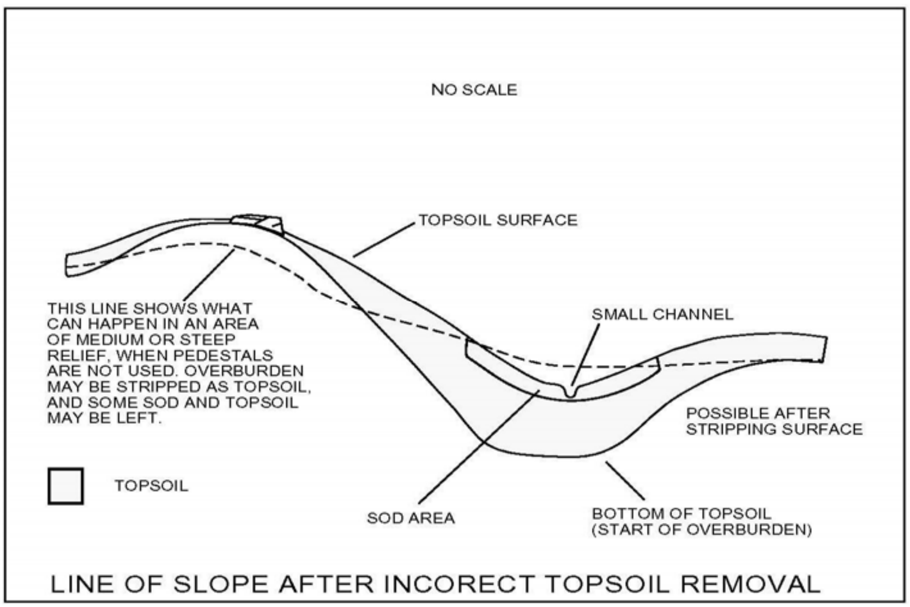


Figure B-3

(2) Ripping

Ripping the area as it is being stripped is the best way to identify topsoil, or the completion of topsoil salvage. Ripped topsoil shows structure while ripped overburden shows a color change from topsoil and a lack of structure.

(3) Backhoe Pits

This is an excellent method of staking topsoil depth. Backhoe pits work very well, because one can enter the sloped pit and observe and dig at the topsoil horizons to determine the color, texture, structure, and moisture limits as well as salt deposition.

(4) Site Supervision

Checking the salvage operations often during the day is important for quality control. Quality control is maintained by halting stripping operations at the bottom of the topsoil, inspecting, and then removing any topsoil remaining in areas the operator may have stopped stripping too soon. During inspections, identify additional cuts or clearly indicate when salvage in an area is complete. When a dependable, quality equipment operator is stripping deep topsoil, multiple visits per day may not be needed.

(5) Instruction

Topsoil identification classes for equipment operators help assure quality topsoil salvage operations. This document can be used as a class study guide.

(6) Quality Contractor

If topsoil handling is contracted, an experienced, reputable contractor is important for a good salvage operation. The foreman and key operators need previous experience, or training to be effective.

(7) Augers

These can be used by a highly trained individual to stake topsoil depths, but should not be used as a primary tool for identifying stripping depths. The auger cuttings are difficult to interpret, as the act of cutting blends soil horizons, masking individual soil features.

2. Topsoil Stripping

Section editor: Laurel E. Vicklund *Subsection author: Frank K. Ferris*

Applicability

General good practice and in some cases regulations, require that all topsoil be removed from areas to be affected within a work area or permit area, and be immediately replaced for reclamation or temporarily stockpiled in the most advantageous manner.

Special Considerations

As with all land disturbing activities, dust emissions resulting from topsoil activities need to be kept to a minimum. Inadequate dust control could result in work stoppage. Access and haul roads associated with topsoil activities should be maintained in safe operating condition. Stripping equipment should be properly maintained and safely operated by qualified operators.

Techniques

a. Topsoil Salvage Control

(1) General

Undisturbed topsoil should be off limits to all equipment and vehicles except when being stripped. This will keep disturbances to a minimum and eliminate topsoil contamination.

The area requiring topsoil removal should be staked or otherwise identified. Prior to starting operations each day, a v-ditch approximately 12” deep and draining back to the stripped area when possible should be cut around the area to be worked. Topsoil should be hauled only on previously stripped areas between the active removal area and the stockpile or replacement area. Whenever possible, all disturbed areas should drain directly to sediment control structures. For optimum quality control, topsoil removal and replacement should occur in daylight.

A clear boundary delineating the native and stripped areas should be established and maintained at all times. The stripped edge should be sloped back to 2H:1V, and a 2H:1V toe-ditch should be bladed into the sub-soil along the final topsoil edge. This ditch provides sediment control for the area and reduces disturbance to the remaining topsoil areas.

(2) Stripping Methods

Topsoil stripping should be completed in one area before moving to another. Stripping should typically progress from areas of thin soils to areas of deeper soils in order to reduce potential contamination. This may result in a down slope progression, which is generally preferred by the dirt contractor for ease of loading. Down-slope loading can lead to difficulties with sediment control, so proper planning needs to be employed to ensure adequate protection is provided.

(3) Pedestals

Topsoil depths, which are generally surveyed at 200-foot intervals prior to initiation of stripping, are indicated on stakes. Pedestals of topsoil are left around these stakes to allow verification of the stripping depths. These pedestals and survey control points are left in place until the project supervisor approves removal. Upon clearance for removal, the pedestals are salvaged as topsoil.

(4) Completion

Upon completion, all topsoil removal areas should be bladed to collect any additional topsoil not salvaged initially by the scrapers or other loading equipment. This topsoil can then be loaded-out and stockpiled or spread. After the final topsoil has been removed, the stripped area can be smooth-bladed for ease in the ensuing operations or left rough to reduce runoff.

(5) Sediment Control

Sediment control needs to be addressed daily. At the end of each work day, all disturbed areas must be contained and controlled. The optimum procedure for sediment control is to strip from the bottom of drainages upward. This helps to prevent contamination of topsoil by disturbed runoff. Up-slope stripping for sediment control can conflict with down-slope stripping for contamination prevention. Thus, it may be necessary to strip drainage corridors to establish proper drainage prior to additional topsoil removal.

b. Contractor Considerations

(1) Environmental Regulations

All levels of contractor supervisory personnel need to be aware of, and required to abide by, all state and federal environmental regulations that govern surface coal mining or other land surface disturbing activities. It is the responsibility of the contractor to train each contractor employee with regard to these requirements.

(2) Security

Access and security policies are site specific, and need to be addressed site-by-site. At surface mining locations, it may be advisable to require the contractor to have a supervisor with State Mine Certification on site during all contractor working hours. The supervisor should have the authority and responsibility to exercise the terms of the contract on behalf of the contractor.

c. Quantities

(1) Daily Work Report

The project supervisor should inspect the working area prior to the beginning of each shift. A daily work report, showing all load counts and hours worked for each piece of equipment, should be completed and signed by the project supervisor.

(2) Payment Calculations

Typically, payment for topsoil removal is based on a per-cubic-yard unit rate of material handled. The unit rate should include payment for all other incidental work, such as haul road construction and upkeep, drainage control, ditch and berm construction, and other ancillary activities needed to complete the job. Mobilization and demobilization costs may be additional to the unit rate(s).

Topsoil quantities and removal areas can also be calculated using aerial photography or standard field survey methods. These methods should be used to confirm the quantities estimated by load count. Retainage of 10% to 20% is usually held until load count volumes are confirmed.

3. Topsoil Stockpiling

Section editor: Laurel E. Vicklund *Subsection author: Marilee G. O'Rourke*

Applicability

Topsoil stripped from an area prior to disturbance can be preserved for later use in a topsoil stockpile. As is always good practice and as may be required by regulation, topsoil that is not to be promptly redistributed should be stockpiled in a manner that minimizes wind and water erosion and unnecessary compaction.

Special Considerations

Procedures should be followed that will prevent the loss of topsoil from the stockpile through erosion. The establishment of a quick-growing cover of vegetation on the topsoil stockpiles is advantageous for this purpose, and may be required by regulation. A more permanent form of vegetation cover may be necessary for long-term stockpiles. Proper construction of stockpile slopes as well as a ditch/berm around the stockpile will also aid in erosion control and topsoil conservation and provide for safe equipment operation.

Techniques

The limits of topsoil stockpiles should be surveyed and field-staked prior to placement of topsoil. Roads to and from stockpiles need to be stripped of topsoil prior to use, unless the duration of their use is short enough to warrant mere blading of the upper several inches Stockpiles should be identified by topsoil stockpile sign before stockpiling is begun; in many instances this is a regulatory requirement.

Construction of a perimeter ditch/berm should precede any activities associated with material placement in the stockpile. The topsoil stockpile should be completely enclosed with this ditch/berm, which should be at least 1.5 feet high, or higher as needed for sediment control and topsoil conservation. If a sediment control structure is required, the ditch/berm will need to be constructed to ensure drainage to the structure.

V-ditches are cost-effective but are usually not sufficient for long-term sediment control and topsoil protection. Flat-bottomed ditches have better capacity and are easier to maintain. If v-ditches are employed, the depth from the bottom of the "v" to the top of the berm should be at least 1.5 feet. On native topsoil, the v-ditch must not penetrate the full depth of the topsoil, which would result in the mixing of topsoil and overburden or subsoil materials. V-ditches should only be used on flat terrain where flowing water in the ditch will not reach erosive velocities.

Berms, while more costly to build, are more durable and can be revegetated. A berm can be constructed with topsoil destined for the stockpile, and then cross-sectioned along with the pile for volume determinations. Significant precipitation events can cause water to build up and ultimately breach a berm, causing severe erosion and loss of the topsoil resource. Proper berm design may include construction of a spillway to eliminate this concern.

Ideally, topsoil stockpile slopes should not exceed 5H:1V, to allow for seeding necessary to prevent erosion. However, slopes as steep as 2.5H:1V can be safely negotiated by four-wheel drive, dual-tired farm machinery and by tracked equipment. When stockpiling is completed, the stockpile may be scarified parallel to the contour to minimize wind and water erosion. Large rocks uncovered during final grading activities should be removed to facilitate revegetation.

4. Topsoil Stripping Equipment

Section editor: Laurel E. Vicklund *Subsection author: Frank K. Ferris*

Applicability

There are three general equipment fleet types used to remove and/or move topsoil. These are scrapers; loaders, trucks, and dozers; and shovels/backhoes and trucks. Each fleet has unique characteristics. Using a fleet of equipment in the wrong application will usually lead to poor quality topsoil recovery, higher costs, and potential compliance problems.

Special Considerations:

Other than removal of topsoil from the upper portion of stockpiles, topsoil should not be stripped at night. Color changes, which are critical in differentiating between topsoil and overburden, are not readily evident after dark.

The stripping of frozen topsoil must be carefully evaluated. Under high moisture conditions and deep frost, shallow topsoil can be cemented to the overburden and it is extremely difficult to strip only the topsoil. Evaluate the site conditions and, if necessary, bypass until later.

Techniques

a. Scrapers

Scrapers are the best stripping method for quality control. Scraper cuts should be no more than 50 percent of the topsoil depth for topsoil six inches or deeper. Trying to single-pass load topsoil that is two feet or less in depth can result in mixing with significant amounts of overburden.

As a general rule, topsoil stripping should proceed from higher to lower topographical areas; generally this is also from shallow to deeper topsoil. In this way the scrapers are always being pushed downhill for their best productivity, and they finish loading in an unstripped area. After the hill slope is stripped to the draws and the width of the topsoil remaining in the draw is not sufficient to obtain a full scraper pan, the direction of topsoil stripping in the draw should be changed to parallel the flow line of the draw.

When completing an area, the topsoil being dragged out of the cut and onto stripped ground will be significant. Loose topsoil inadvertently dragged onto previously stripped areas is difficult to salvage and likely to be lost or contaminated. By reversing scraper traffic periodically, this loss can be minimized.

b. Loaders, Trucks, and Dozers

A bulldozer is not designed to cut six inches of compacted topsoil and a loader operator generally cannot see the digging face. Because of these operational constraints, it is much more difficult to accurately strip topsoil with dozers than with scrapers. However, loaders, trucks, and dozers work well in two feet and thicker topsoils that are on a flat-to-gently rolling topography, especially if the subsoil is suitable as a topsoil substitute. In this case, if topsoil with some suitable subsoil is dozed into piles or rows, and the loader cuts into the undisturbed suitable subsoil under the topsoil while loading, the topsoil quality will not be measurably impacted.

In irregular topography with shallow topsoil on unweathered overburden, the loader and dozer fleet will significantly cut and load overburden and degrade the topsoil resource.

c. Shovels/Backhoes and Trucks

Shovels and trucks are very cost effective in moving large topsoil stockpiles where the shovel is able to stay near its design productivity. If the shovel and truck operation is trying to take all the topsoil stockpile, the economics of the operation will be decreased by 50 percent for the volume that is represented by the stockpile edges and floor. A shovel will spill topsoil, leave stockpile edges and leave topsoil under its tracks if the site is not flat or level. Additional support equipment is needed to push bypassed topsoil into the shovel face. In some cases it is more efficient to complete stripping with scrapers and not use extra support equipment to keep the pile edges and floor pushed in to the loading pile.

A large backhoe loading trucks can be a effective method of salvaging topsoil, especially in deeper soils. The backhoe sits on ground ahead of its cut and pulls the topsoil toward the face of the salvage operation. The backhoe generally has a limited cut depth and the operator can always see the cut.

d. General Notes

Using specific equipment from one equipment fleet to compensate for the weak area of another fleet usually works very well. For example, scrapers could be used to strip the shallow topsoil and place it on the deep topsoil in flat areas for the loader, truck, and bulldozer operation.

C. TOPSOIL REPLACEMENT

1. Replacement Depths

Section editor: Laurel E. Vicklund *Subsection author: Frank K. Ferris*

Applicability

Uniform topsoil depth replacement is often required on reclaimed topography at surface coal mining operations. That notwithstanding, wind and water erosion will ultimately make topsoil depths uneven. In some areas, different topsoil depths will add to species diversity, but extensive erosion may produce very low productivity and an area that is hard to stabilize. Erosion and deposition move topsoil to low-lying areas and where soil-forming processes typically develop topsoil more rapidly than in upland areas. Varying topsoil depth in accordance with topography will help offset these processes, and make more effective use of the topsoil resource.

Special Considerations

In reclamation, sufficient topsoil depth is needed to provide vegetative cover consistent with the surrounding vegetation. The depth of replaced topsoil varies according to how much the area is exposed to erosion. Erosion forces greater than normal for surrounding undisturbed areas can reduce the depth of replaced topsoil to below the minimum needed for suitable vegetation density. The techniques suggested here can help to counteract the effects of excessive erosion, but in some cases approval from the appropriate regulatory agency may be required for their application.

Techniques

Erosion potential is a function of slope steepness, soil texture, and concentration of wind and water movement. By placing deeper topsoil in highly erosional areas and less in depositional areas, the site will be more productive during and after reclamation is complete (Figure C-1-1). The effects of excessive erosion in upland areas, which can lead to areas of low vegetation productivity, can be counteracted by placing deeper topsoil in highly erosional areas.

Additional topsoil should be placed at erosional points, such as heads of draws, shoulderslopes, backslopes, and footslopes where erosion could result in excessive topsoil loss. Less topsoil should be placed in depositional areas, toes of slopes and ridges, and low gradient channels.

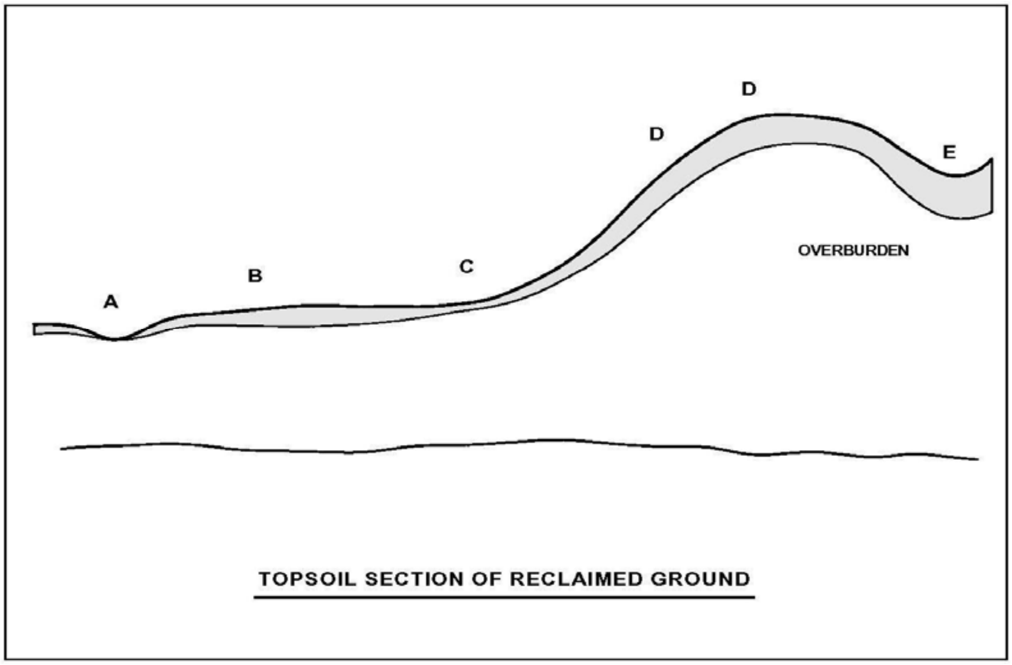


Figure C-1-1

2. Topsoil Replacement

Section editor: Laurel E. Vicklund *Subsection author: Marilee G. O'Rourke*

Applicability

The replacement of topsoil after mining or other activities marks the beginning of reclamation. Careful planning and supervision by the environmental professional, as well as the skill of the equipment operators, will ensure this foundation is properly laid.

Special Considerations

Dust emissions resulting from topsoil replacement activities need to be kept to a minimum. Inadequate dust control could result in work stoppage. Access and haul roads associated with topsoil activities should be maintained in safe operating condition. Equipment should also be maintained in a safe operating condition and should be safely operated.

Techniques

a. General

Prior to topsoil replacement, confirmation of approved final grade and any required sampling of the subsoil should be obtained. The replacement area should then be delineated and scarified parallel to the contour at an approximate depth of one foot on 18-inch intervals.

Special features such as rock piles for wildlife habitat are typically constructed within the redistribution areas prior to topsoil placement, in order to avoid unnecessary compaction and disturbance of the topsoil after replacement. Topsoil is then tapered into the edges of such features during replacement. Rocks unearthed during scarification are either pushed together to form small piles or added to existing rock piles.

AREA (following figure)	DESCRIPTION OF TOPOGRAPHY	SUGGESTED TOPSOIL PLACEMENT RANGE	COMMENTS (see cross section for additional detail)
A	Major channel bottom	Zero	Major channels are usually wet, depositional, have a shallow gradient, and support extensive vegetation.
B	Grain/hay field	85 to 100 percent	Depth may vary according to postmining land use requirements. Deep rooting crops may require deeper soil.
C	Toe of slope	35 to 60 percent	Toe of slope areas need to have a maximum slope of 7H:IV and should be about 300 feet wide. This thinned area may be from 100 to 600 feet wide, depending on the length of transition from slope to field and the size of the slope above the area.
D	Hill slopes and tops	150 percent	Through wind and water erosion, topsoil will be moved from this area, therefore the 150 percent of average topsoil depth. On a more complex hill topography, there could be multiple areas of erosion and deposition.
E	Steep gradient draws	200 percent minimum	Draws and drainage channels coming off of hilly areas usually have a steeper gradient than would be ideal. This steeper gradient will likely cause some erosion in the channel. To be sure the topsoil in the channel is not completely eroded away, additional topsoil is suggested to ensure vegetative establishment. In areas where erosion has broken through the topsoil, it is more difficult to establish adequate vegetation.

Sediment control needs to be addressed daily as discussed above for topsoil removal. At the end of each work day all replacement areas should be contained and controlled.

(1) Equipment Traffic

Equipment operation on topsoil areas should be limited to the extent necessary to remove topsoil from the undisturbed area or stockpile and redistributed it on regraded areas. Equipment traffic routes should not be allowed on topsoiled areas, although roadways may be constructed through topsoil areas by leaving roadways untopsoiled until replacement has been completed elsewhere in the area.

Roadways should have sufficient width to accommodate the expected traffic and maintenance activities. Berms should be constructed near the edges of the roadways to delineate the edge of the active area and protect the topsoil resource. Ideally, topsoil redistribution should only be done during daylight hours.

(2) Replacement Depths

Replacement depths should be determined and marked in the field prior to the initiation of replacement. These depths may be uniform or non-uniform depending on the reclamation objectives. Topsoil thickness can be increased in localized areas to produce micro-contours. Redistributed topsoil should be blended with previously reclaimed areas or native edges where applicable. Guidance stakes on a maximum of 100-foot centers provide verification of the topsoil redistribution depths while maintaining existing contours. In areas of rough topography, stakes should be placed more frequently to indicate topographic break points and other surface elevation changes.

(3) Final Touches

Following topsoil redistribution, the area should be bladed and inspected to ensure that drainage will be adequate and that localized ponding will not occur. The area should then be scarified to a depth of approximately one foot at 18-inch intervals. To minimize erosion problems, scarification should be performed parallel to the contour. The topsoil redistribution edges should be bladed to form 2H:1V slopes in order to protect the resource from erosion while maintaining a clear demarcation of the limit of activity.

A perimeter ditch/berm, constructed of overburden material, ought to be built around the outer edge of the area for sediment control and topsoil conservation. Edges of redistribution areas should be straight and smooth.

(4) Remaining Stockpile

Partially used stockpiles should be recontoured with slopes no steeper than 5H:1V or consistent with existing slopes. The exposed area of the stockpile should be scarified parallel to the contour to minimize erosion. As discussed earlier, a ditch/berm approximately 1.5 feet or higher as needed for sediment control and topsoil conservation, should be reestablished around the remaining stockpile.

b. Contractor Considerations

(1) Environmental Regulations

All levels of contractor supervisory personnel need to be aware of, and required to abide by, all state and federal environmental regulations applicable to the type of operations in which they are working. It is the responsibility of the contractor to train each contractor employee with regard to these requirements.

(2) Security

Access and security policies are site specific and need to be addressed site-by-sites. At surface mining locations it may be advisable to require the contractor to have a supervisor with State Mine Certification on site during all contractor working hours. The supervisor should have the authority and responsibility to exercise the terms of the contract on behalf of the contractor.

(3) Daily Work Report

The project supervisor should inspect the working area prior to the beginning of each shift. A daily work report, showing all load counts and hours worked for each piece of equipment, should be completed and signed by the project supervisor.

(4) Payment Calculations

Typically, payment for topsoil redistribution is based on a per-cubic-yard unit rate of material handled. The unit rate should include payment for all other incidental work, such as haul road construction and upkeep, drainage control, regraded area scarification, topsoil scarification, ditch and berm construction, and other ancillary activities needed to complete the job. Mobilization and demobilization costs are usually additional to the unit rate(s). Topsoil quantities and redistribution areas can also be calculated using aerial photography or standard field survey methods. An average depth of topsoil replaced for a specific area is also calculated.

3. Elevation Control

Section editor: Laurel E. Vicklund *Subsection author: Frank K. Ferris*

Applicability

Depth control is needed to attain the desired topsoil replacement depth for optimum reclamation success.

Special Considerations:

Control of topsoil replacement depth is difficult, because the reference point is continually being covered with topsoil.

Techniques

a. Staking

Staking with four-foot lath seems to be the best method of controlling topsoil replacement depth. Important points for staking are spacing, location, marking, and proofing.

(1) Spacing

Spacing needs to be frequent enough to prevent shallow areas in between the stakes. The rows should be spaced three to four scraper widths apart. Rows can be approximately 35 to 40 feet apart, with stakes at 40 to 80 foot intervals (Figure C-3-1). The interval will be determined by the level of experience of the equipment operator.

(2) Location

Location of stakes should be in a basic grid pattern, with extra stakes at topography breaks. These stakes at topography breaks are the most important.

(3) Marking

Stake marking can be done by painting the portion of the stake to be covered, painting the portion to be left uncovered, or simply marking the final fill line. Any of these methods seem to work well as long as both sides of the stake are marked. About a two-inch overfill is usually needed to account for compaction and settling.

(4) Proofing

Depth proofing is a good quality control check, and an absolute necessity when payment is based on fill depth. Backhoe pits provide the best verification because they clearly illustrate the topsoil/subsoil interface.

4. Preserving Seedbed Viability Through Direct Haul of Frozen Topsoil

Section editor: Laurel E. Vicklund *Subsection author: Kenneth L. Wrede*

Applicability

In the summer of 1987, reclamation personnel at the Wyodak Mine near Gillette, Wyoming, observed that a small parcel of regraded spoil that had received "live" frozen topsoil during a stripping operation the previous winter was producing noticeable stands of native grasses and shrubs. "Live" topsoil is material that is hauled directly from the stripping area to the replacement area. It was also noted that the density of undesirable plant species of an opportunistic nature was lower when compared to adjacent areas conventionally seeded.

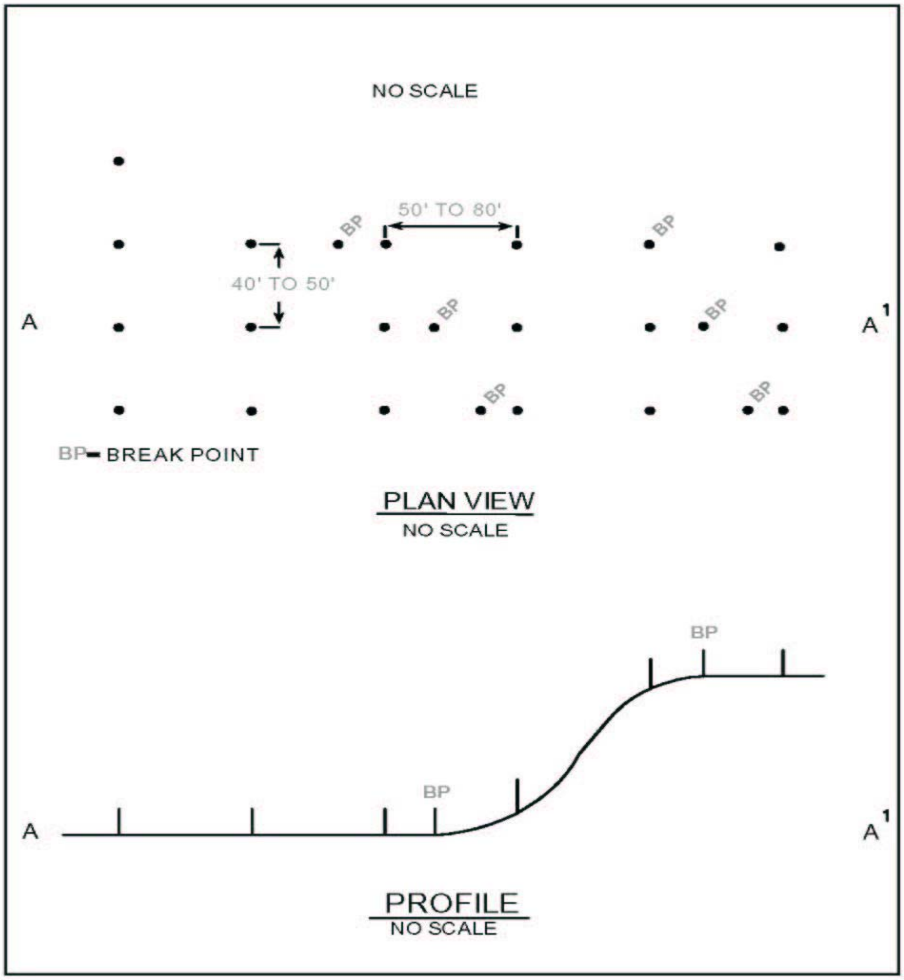


Figure C-3-1

While a formal study was never conducted, it is visibly evident even today that the parcel of land has better diversity and density of native species than do adjacent reclaimed areas. It is also thought, though never so far calculated nor weighed against operational difficulties that hauling "live" frozen topsoil may reduce the cost of final revegetation.

Special Considerations:

While the practice of hauling frozen topsoil might not be considered desirable by operations personnel, on to believe that several long-term benefits could be achieved using this method. Ideally, the direct haul of frozen topsoil would:

1. Propagate heartier stands of native grasses and shrubs.
2. Reduce plant stress by moving them while they are in a dormant state.
3. Reduce the amount of interseeding needed in some reclamation operations.
4. Speed the succession of native species on reclaimed lands.
5. Lower seed costs.

While making a standard practice of moving topsoil in the dead of winter usually is not thought to be an ideal reclamation practice, these results indicate occasional use of the practice might have benefits in special situations. A mosaic of mature native grasses, distributed among areas seeded by conventional means, would provide a seed source for adjoining lands, and mature shrubs would tend to spread to areas outside of the mosaic.

Techniques

During the winter of 1986/1987, an area of approximately 16 acres in and near the floodplain of the restored Donkey Creek channel received "live" frozen topsoil during a direct haul stripping operation. A dozer/scraper fleet was used for this operation. Replacement depth was approximately 1.88 feet. Efforts were made to selectively handle the top six inches of frozen topsoil, and "cap" topsoil previously laid. It was hoped that this "seed bank" approach might encourage quicker reestablishment of native species and cover. (Wyodak Mine Annual Report, 1987)

Spring and fall plantings were not conducted in the area during 1987, but were delayed until the following year. In spite of this, substantial stands of intermediate, western and bluebunch wheatgrass appeared during the spring and summer of 1987, along with two predominant shrub species, rubber rabbitbrush and silver sagebrush. It is also theorized that native plant species in this area benefited from the infiltration of additional moisture during the spring runoff, as the area was not bladed following topsoil placement.

Operational difficulties were encountered as could be expected with any wintertime stripping operation involving scrapers. Rough conditions, common in the cut and fill areas, reduced cycle times. "Live" topsoil was many times placed beneath "B" and "C" horizon material in the reclaimed area due to logistical difficulties. Although it turned out to have a positive effect as was previously mentioned, final grading could not be done effectively because the massive blocks of frozen topsoil were nearly impossible to fine blade.

Another fear was that seeds of undesirable weed species would be caught in the void spaces left in the ungraded topsoil, germinate, and compete with native plant species. The opposite has in fact proven true, as the area was nearly free of kochia weed during the first growing season and has not experienced the encroachment of undesirable weed species.

D. References

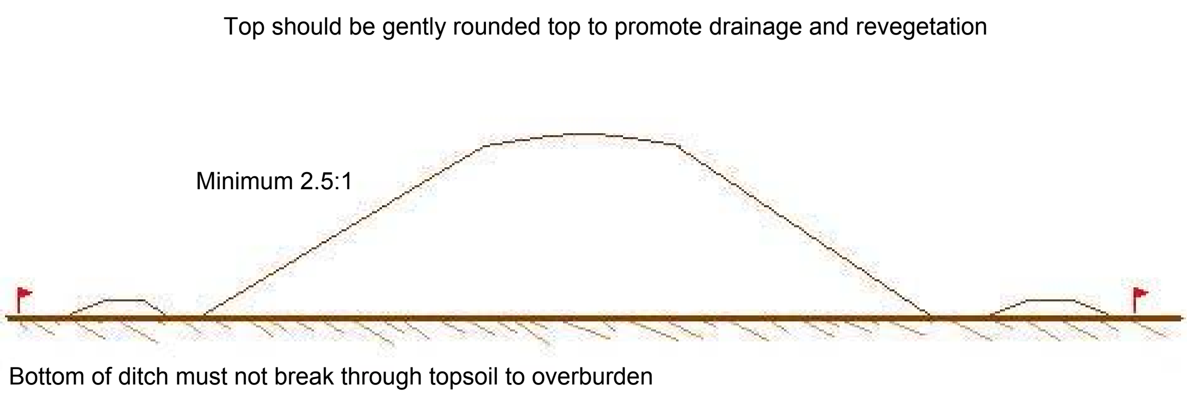
Wyodak Mine. November 30, 1987. Annual Report, submitted to the Wyoming Department of Environmental Quality - Land Quality Division. p. 10.

Topsoil Handling Quick Guide

PURPOSE

This quick reference guide will help earthwork contractors keep topsoil handling activities in compliance. The topsoil resource must be preserved and protected by preventing contamination of topsoil with overburden while at the same time salvaging all possible topsoil. Water resources must also be protected by limiting sedimentation through adequate revegetation and the construction of control structures such as berms and ditches around the stockpiles. Preservation and protection methods and requirements will vary by agency and company.

TOPSOIL PILE CROSS SECTION ON TOPSOIL



1. Place stakes at the limits of expected disturbance including any ditch or berm.
2. Pile slope: To get a slope that is stable to preserve the topsoil resource. At angle of repose ~1.5H:1V, any inspecting agency will likely require grading to a flatter slope. Flatter slopes provide a safer working surface for final grading, seeding, and surveying. The steeper they are, the smaller the pile foot print, greater erosion potential, and harder to survey and grade. Most piles vary between 4h:1V and 3H:1V. A slope of 2.5:1 can be revegetated with dual-wheel four-wheel drive farm equipment.

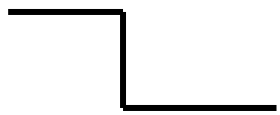
TOPSOIL PILE CROSS SECTION ON OVERBURDEN

1. When placing topsoil on overburden, fill/cover the overburden between the pile and the berm/containment ditch. This prevents the mixing of overburden and topsoil during runoff events when the flowing water would mix the topsoil pile and berm sides with the ditch bottom of overburden if it were not covered.

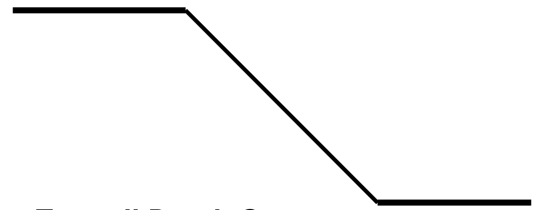
TOPSOIL PILE CONTAINMENT STRUCTURES

1. A containment structure of some kind is required for all topsoil piles to prevent contamination of the resource and to control sedimentation. The containment structure can be a berm or a ditch. If the pile is constructed on topsoil, the berm must be constructed of topsoil. If the pile is constructed on overburden, the berm may be of topsoil or overburden, but care must be exercised to prevent topsoil contamination.
2. In most cases a berm is the best structure because it can be vegetated, is stable during major runoff events, and it prevents the mixing of topsoil and overburden in steep topography. Sufficient capacity must be provided by the berm to prevent overtopping during precipitation events.
3. To keep a berm competitive with a ditch, build it with the topsoil placed in the pile and cross section it as part of the pile.
4. At the low spot around the pile, where water collects, build the berm stouter and higher. When the pile is constructed on topsoil, build an overflow spillway on undisturbed topsoil at a foot below high water line. Next to the spillway, undercut the ditch side 6 inches to 9 inches so the flows will first go to the low area to infiltrate and then just the backwater would flow out the spillway and not breach a deep section of berm or ditch.
5. When a ditch is constructed, care must be exercised to prevent mixing of topsoil and overburden. A flat-bottomed ditch is preferred for long-term piles as the flat-bottomed ditch has a greater capacity than a v-ditch and can be more readily revegetated. When quick removal of the pile is anticipated, a substantial v-ditch can be installed with a blade or dozer.
6. V-ditches work well in dry years. However, they are generally a blade cut that is thrown up to look effective. Since they are not compacted during placement, they will fail more readily if saturated by water. Since v-cut ditches are not usually graded for re-vegetation, they are a weed source for many years. In steep topography and areas of shallow topsoil, a v-ditch will cut into the under lying overburden. The bladed-up berm is then a mixture of overburden and topsoil. In addition, the v-ditch will blend topsoil and overburden during runoff events and the runoff will go at a greater velocity in a narrow cut v-ditch compared to a native grassed surface.

TOPSOIL EDGE CONSTRUCTION



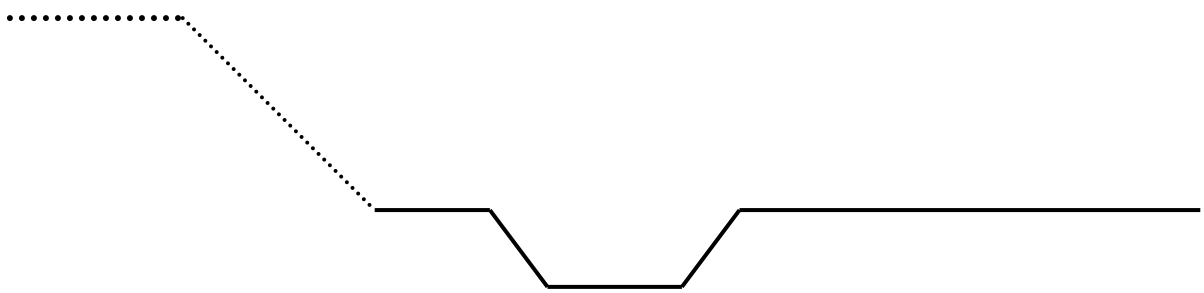
Topsoil Depth of 2-ft or less



Topsoil Depth Greater Than 2-ft

The idea is to maintain a very visual topsoil edge to show limits of activity and the start of future work. At about 2 vertical feet, topsoil edges become a safety hazard. So where topsoil depth is above 2 feet, the edge should be sloped to ~3H:1V.

TOPSOIL EDGE DITCHES

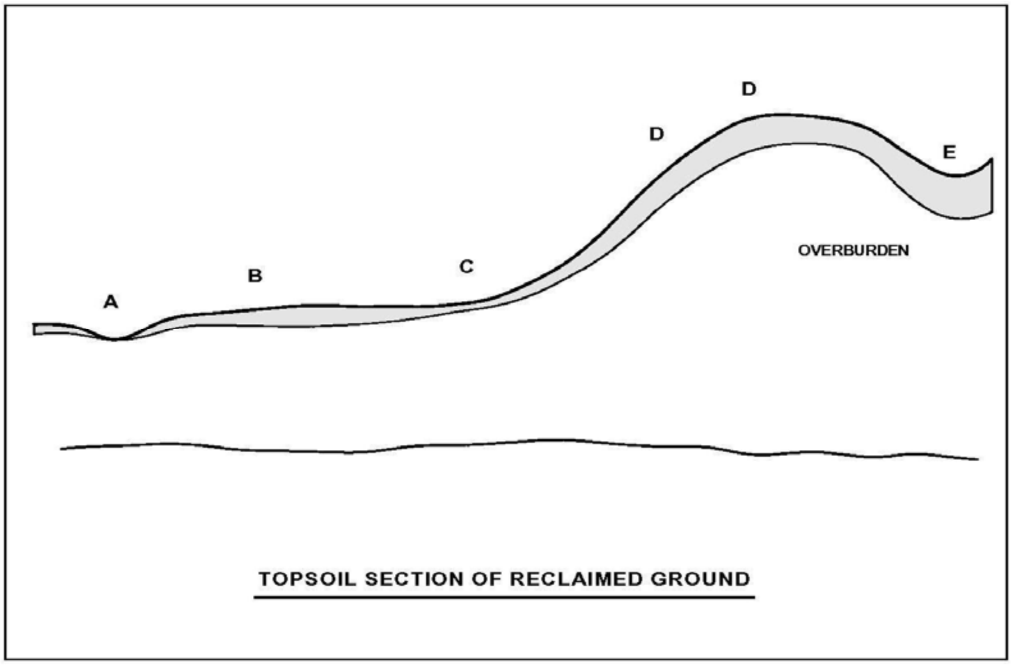


Purpose: To protect the topsoil resource. Where the overburden slopes away from the topsoil edge, no ditch should be needed.

When the stripped surface slopes to the topsoil edge, a ditch is needed to route runoff away from the topsoil. A cut flat bottom ditch is the most stable and protects the topsoil edge the best. In some cases a vee ditch may be an economical choice when gradients are not too extreme and erosion is not expected to block the vee ditch.

If topography is too irregular, ASCMs, sediment fence, or dug outs should be considered.

TOPSOIL SPREADING



Where non-uniform depths are desired, the supervisor must direct the operators on exact placement locations and amount. This requires a constant presence in the field and a good mental picture of the desired result. It also requires careful surveying to ensure placement amounts are accurate.

Too shallow topsoil replacement will cause poor to no vegetative cover. This is illustrated on many highway borrow areas and road cuts where less than of foot of topsoil was replaced over a sterile subsoil. Significant wind erosion can rapidly occur on unvegetated re-spread topsoil.

Staking frequency is critical to controlling topsoil spread depth. Serious errors in placement can result if staking and compliance with staking are lax.

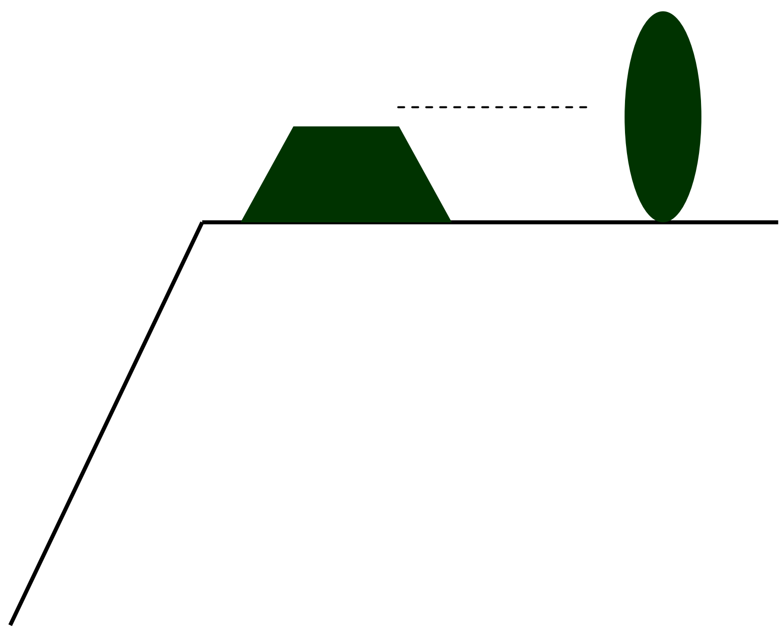
1. Set a stake pattern of ~ 60 feet wide rows with in line stakes a bit more frequent ~45 to 50 feet. Mark the fill depth on the stakes and fill the area in between the stakes leaving the stakes standing. Upon reaching the correct depth on both sides of the stake, for the length of the fill area, then fill in the stake line to the previously established depth. Very irregular topography may require additional staking.

SCRAPER HAULAGE ROAD CROSS SECTION THROUGH TOPSOIL AREA

Key: Prevent the blending of topsoil into the road material by the road maintenance equipment. Strip the road running width plus enough for road maintenance materials. If the road maintenance berms are not maintained, the blade will likely pull topsoil onto the road for leveling.

ROAD CROWNED FOR DRAINAGE
(vertical scale exaggerated)

HIGHWALL OR SIGNIFICANTLY ELEVATED ROAD BERM



The berm shall be ½ the height of the largest tire that uses the road. The berm shall not be undercut.

REVEGETATION

Section Editor: Mickey Steward

Handbook of Western Reclamation Techniques, Second Edition

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SECTION 5: VEGETATION

A. INTRODUCTION

Section editor: Larry H. Kleinman revised by Mickey Steward

Successful revegetation is essential to successful postmining land use, a fundamental requirement of the Surface Mining Control and Reclamation Act. Revegetation is the basis for most mined land reclamation programs. The revegetated mined area must meet two basic objectives: forage and habitat must be provided and erosion must be controlled. Forage and habitat resources are most commonly used for grazing and wildlife. Erosion control must result in an erosion regime that is similar to that found on adjacent undisturbed native lands. The variety of postmining land uses and undisturbed landscapes associated with surface coal mining ensures that no single "best" method can fit all circumstances. However, the procedures and techniques described in this section have been found to be successful and are broadly applicable.

Subsection B deals with establishing and implementing a revegetation program. The objective of the revegetation program is to establish the desired vegetation. The procedures described are seed-bed preparation, farming practices, seed handling, planting, mulching, shrub establishment, and reforestation.

Subsection C addresses seed ordering. Seed quality is vitally important to successful revegetation. Topics such as seed ordering, preparing a seed purchase request, origins and quality of seed, seed tags (certified and common seed), seed testing, and determining "Pure Live Seed" are discussed.

Surface stabilization is discussed in Subsection D. A stable surface will control erosion. Vegetative and non-vegetative methods for stabilizing the land surface or controlling erosion are described.

After vegetation is established, husbandry (management) becomes critical for its survival and longevity (Subsection E). Revegetation may deteriorate to less than desirable cover and production and to a less desired species composition without some type of management to sustain it. Native plant species evolved under some type of foraging pressure. Non-use is not natural for the species used in the revegetation programs. Therefore, some type of management that at least simulates "use" is vital for the maintenance of revegetated areas. The husbandry practices described in this fourth set of subsections include mowing for weed control, grazing, and burning.

Vegetation monitoring practices are described in Subsection F. Monitoring is essential for optimization of the revegetation program and for demonstrating progress toward conditions suitable for release of the Final Reclamation Liability Bond. All state regulatory agencies require that specific monitoring methods be approved and form part of the Mining Permit Application. To a large extent, State regulatory agencies specify vegetation monitoring practices. This section addresses non-regulated concerns such as specifics of vegetation sampling, recordkeeping of the total operation, and Electronic Document Management in Mining.

Many authors contributed to this section, each with a particular expertise and experience. The methods recommended here are not intended to be prescriptive or all-inclusive, but do represent tested and usable methods for addressing the topic at hand. In this revision, changes and additions have been made to the original document, but these changes and additions are designed to reflect new information and advances in technology, not to change the fundamental method or practice originally recommended by the author.

B. Establishing and Implementing a Revegetation Program

1. Preparing a Revegetation Package

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Adequate preparation and planning are vital to the success of any revegetation program. A revegetation package prepared for each planting season is a useful tool that will ensure sufficient planning as well as provide clear, concise instructions to those performing the actual revegetation work. It will also provide documentation for work accomplished, and serve as a record of revegetation activities.

Special Considerations

Inadequate preparation can lead to inefficient utilization of optimum weather conditions, as well as improper fertilization, soil preparation, planting, or mulching methods. Proper planning by outlining exact instructions or tolerances for each variable listed in the revegetation package ensures suitable implementation of revegetation practices.

Requirements of seed per acre for each area in the revegetation package provide a base for preparing a seed bid request. Husbandry practices, such as mowing, haying, interseeding, and burning should also be included in the revegetation package.

Techniques

a. Field Tour

The first step in the preparation of a revegetation package is to decide which areas (or revegetation units) need work. A field tour is always necessary to ascertain the status of these units. The field technicians who will be performing the planting can often be helpful at this stage in providing input regarding possible methods.

b. Decisions and Planning

First, the units to be included in the current revegetation season must be selected. Then, each unit must be categorized as permanent or temporary. Planning for permanent units must be done with forethought about **postmining land use requirements**. Decisions must be made regarding each of the variables that make up the revegetation package. Table 1 provides an example of the variables that are typically included in the revegetation package.

c. Revegetation Package

Revegetation packages are composed of maps, revegetation unit requirements, and information on seed mixes and revegetation practices to be used.

(1) Maps

Each revegetation unit is identified on a map of the mine area (optimum is an ortho-photo overlain with topographic information) and given a number (see "Unit Number" below). Each unit is digitized to determine its acreage. The map is included in the revegetation package.

(2) Revegetation Unit Requirements

Table B-1-1 is an example page from a revegetation package with the information required for the reclamation of each unit. A database is the best environment to use in assembling this information. Units can then be sorted by category, seed mix, etc., and requirements for mulch, fertilizer, and seed can be easily totaled. The package also provides a base for recordkeeping and reporting of exact work accomplished. If retained, the revegetation packages can serve as a history of unit-by-unit revegetation practices. The following variables may be included for each revegetation unit:

(a) Unit Number One method of numbering that works well combines year (96), <u>S</u>pring or <u>F</u>all (S), and number (01); 96S01. These numbers coincide with numbers placed on the corresponding map.

(b) General Area Each unit can be given a name or a description.

(c) Category Permanent Grazingland, Topsoil Temporary, Long-term Temporary, Husbandry, etc., are examples of categories that may be used.

(d) Acres Acreages are determined by digitizing each unit on the map.

(e) Date work may begin The earliest date work may commence for reclamation of that unit.

(f) Task List in order exact reclamation practices to be used for each unit. Task and equipment requirements are best listed in a multi-records table embedded in the master table.

(g) Suggested Equipment

(i) A <u>dual-wheel tractor</u> is needed for safe operation on slopes steeper than 4:1.

ii) A <u>hydroseeder</u> may be required to ensure successful seeding of small and trashy seed, and seed whose germination is enhanced by light. It is also required on slopes too steep for drill seeding, and for application of wood, paper, or synthetic fiber mulch.

TABLE B-1-1. Example of Unit Activities from a Revegetation Package

2003 SPRING REVEGETATION PACKAGE	
UNIT NUMBER	2003S01
GENERAL AREA	Jack's Flat
CATEGORY*	Permanent Grazingland
ACRES	91.1
ACCEPTABLE WORK WINDOW	15 March – 15 June 2003
Task	**Suggested Equipment**
Disc	Offset Disc, 6-inch
Cultipack	Cultipacker
Roll before Seeding	48-inch Roller
Seed	Multi-box Drill w/Depth Bands
Hydroseed	Hydroseeder
Roll after Seeding	Tubgrinder
Mulch	Crimper
Seed Mix: Permanent Grazingland	
Nitrogen	10 # per acre
Phosphorus	20 # per acre
Potassium	10 # per acre
Mulch Type	Straw
Mulch Rate	1 ton per acre
Remarks: Rockpick where necessary	

iii) A multi-box drill may be required to ensure proper seeding and coverage for a variety of seeds.

iv) A grain drill may be needed where grains are planted as a cover crop.

v) A 48-inch roller can be used to ensure a firm and evenly compacted seed-bed, and optimum seed/soil contact. The roller can be used before and after seeding. Rolling is particularly useful in dry conditions where soil moisture is limited.

vi) A tubgrinder is used for the even application of grass and straw mulch.

vii) A crimper is used for the adequate anchoring of grass and straw mulch.

viii) A rotary mower may be required for certain husbandry practices.

ix) One or more of the following cultivation implements may be required for seed-bed preparation. More detail on these implements, is provided in the subsection "Cultivation Practices".

a) Plow
b) Chisel plow
c) Disk
d) Rotary hoe
e) Subsoiler
f) Harrow
g) Cultipacker
h) Seed Mix
The named seed mix to be used for specific areas. Exact specifications for each seed mix to be used are inserted separately in the package.
i) Mulch Type
The type of mulch to be used on that unit.
(j) Mulch Rate
Tons per acre of mulch to be applied.
(k) Nitrogen
Any requirements for fertilizer are determined from soil samples taken after topsoil is laid.
(l) Phosphorus
Fertilizer requirement
(m) Potassium
Fertilizer requirement
(n) Remarks
Any specific requirements for the unit (may include safety specifications).

(3) Seed Mixes

Specific requirements for each seed mix to be used in reclamation are included in each package. Table 2 shows an example page used in this portion of the package. This spreadsheet shows pure live seed (PLS) per acre of each seed in the mix, lists and totals acreages of the units requiring this seed mix, and multiplies the two to show the total PLS required for each seed. This information is used in ordering the seed required for revegetation during that season.

TABLE B-1-2. EXAMPLE OF SEED MIX DESIGNATION: PERMANENT GRAZINGLAND

COMMON NAME	SEEDER BOX*	PLS RATE	TOTAL PLS #
ALFALFA	L	2	186.20
BIG SAGEBRUSH	H	0.3	27.93
BLUE GRAMA	L	2	186.20
BUFFALO GRASS	M	2	186.20
FOUR WING	M	0.5	46.55
FRINGED SAGE	L	0.5	46.55
GREEN NEEDLE	B	4	372.40
PRAIRIE	H	.5	46.55
SLENDER	B	2.5	232.75
SUNFLOWER	L	0.5	46.55
THICKSPIKE	B	3.5	325.85
WESTERN	B	4	372.40
WINTERFAT	M	1	93.10
YARROW	L	0.5	46.55

UNIT	ACRES
96S01	91.1
96S02	2

TOTAL ACRES 93.1

====================================

*B - Back Box
L - Legume Box
M - Middle Box
H – Hydroseed

----

2. Cultivation Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Cultivation practices break and loosen the soil surface to prepare a proper seed-bed. Cultivation is necessary to provide a suitable environment for seed germination and root growth, as well as for weed and moisture control.

Special Considerations

Because initial surface conditions vary, as does the response of different seed species to soil conditions, there are many methods of cultivation. The equipment used for cultivation will depend on the method and magnitude of the cultivation practice.

Technique

a. Methods of Cultivation

Fields should be cultivated parallel to the contour on slopes, and perpendicular to prevailing winds on flat areas. This reduces the likelihood of erosion. The methods of cultivation that may be used on the reclaimed surface include:

(1) Plowing

Plowing is used to initiate preparation of extremely hard or previously untilled ground. The plow cuts, lifts, and turns ground, burying crop residue or vegetation, and aerating the soil. Plowing can also be used to control weeds or incorporate fertilizer.

Variations in design of the plow bottom can allow for plowing in heavy clay or sticky soil. Safety devices available include a safety trip release mechanism and a hydraulic auto-reset, both of which prevent damage to the plow in rocky soils.

(2) Chisel Plowing

A chisel plow cuts through the soil without turning over the surface. This encourages water infiltration and retention, and limits surface evaporation.

The chisel plow can be operated just deep enough to cut off weeds with a minimum of surface disturbance. The cutting depth is dependent on soil conditions and desired results. A wide variety of soil-engaging tools are available for varied depths and tillage results.

(3) Disking

Disking cuts, lifts, and rolls the soil. Disking can be used for primary tillage of heavy soils, for mulching crop residue, or to pulverize lumps and close air spaces after plowing.

Disk scrapers can be added when necessary for use in sticky soil. Disking can also be done in rocky soil, as disk blades will roll over obstructions. A tandem disk tills the soil twice, leaving a more level surface. An offset disk moves soil in opposing directions while also tilling the soil twice and leaving a level surface.

(4) Rotary Hoeing

A rotary hoe tills the surface of the ground with an implement that mimics the action of a hoe. The resulting disturbance is only one to three inches in depth. Rotary hoeing is good for shredding and mixing stubble, and for removing undesired vegetation.

(5) Subsoiling

Subsoiling breaks up compacted soil layers beneath the surface without turning the soil over. This improves water infiltration and drainage, and aerates subsoil layers to encourage root penetration. Subsoiling can range in depth from 6 to 24 inches, and at shallow depths can be used to control undesirable vegetation. Subsoiling works best in dry soil.

(6) Harrowing

A harrow scratches the surface of the ground to loosen a thin surface layer. Three types are the spike-tooth, tine-tooth, and spring-tooth harrows. Harrows kill undesirable vegetation by ripping out the plants roots. Harrowing also prepares the surface of the soil for seeding by breaking up the top crust, shattering dirt clods, and closing air pockets. Harrows prepare an excellent seed-bed for small seeds that require fine, loose soil for good seed/soil contact and moisture absorption.

(7) Cultipacking

A cultipacker breaks clods and firms the soil surface better than most other machines. It leaves a well pulverized, firmly packed soil for excellent seed/soil contact.

The front rollers of a cultipacker crush clods and level the surface. Spring-teeth then close air pockets and bring up buried clods for the rear roller to crush, leaving a firm, level surface.

(8) Rolling

Rolling applies even pressure to a surface that has been previously cultivated. The purpose of rolling is to create a firm planting bed for maximum seed/soil contact without excessive compaction. Flexible frames will allow the roller to follow ground contours for the best possible performance.

b. Husbandry

Seed-bed preparation often includes methods other than cultivation to prepare the surface for planting. Rock removal, controlled burning, and biomass removal, such as is accomplished by haying or combining, are seed-bed techniques that may be used on a reclaimed surface. Other subsections within this section provide more information on husbandry methods.

c. Safety

Safety should always be a consideration in decisions of revegetation practices for a given area. As a general rule, loose slopes steeper than 4:1, and firm slopes steeper than 3:1, will require dual four wheel drive tractors for cultivation, drill seeding, and mulching. Loose slopes steeper than 3:1, and firm slopes steeper than 2.5:1, will generally require hydroseeding and hydromulching.

d. Tolerances

The primary purpose of the tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for work performance. The application of tolerance criteria is expected to be the exception rather than the rule.

(1) Disking

(a) Ridges and Valleys

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the height of ridges and depth of valleys left as a result of disking shall not exceed two inches, for a maximum total difference from top to bottom of four inches. Measurement is made by both the contractor and the mine supervisor in randomly selected locations. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soil scientist or agricultural engineer.

(b) Depth of Cultivation

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the depth of disk harrowing shall be six inches plus or minus two inches. Depth will be assessed by excavation of a test hole and subsequent measuring. Measurement shall be made by both the contractor and the mine supervisor in randomly selected locations. If contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soils scientist or agricultural engineer.

(2) Cultipacking

(a) Ridges and Valleys

Based on the average of one sample per acre per unit (minimum two samples per unit), the height of ridges and depth of valleys left as a result of cultipacking shall not exceed one inch, for a maximum total difference from top to bottom of two inches. Measurement shall be made by both the contractor and the mine supervisor in randomly selected locations. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soil scientist or agricultural engineer.

(b) Size of Clods

Based on the average of one sample per acre per unit (minimum two samples per unit), the size of clods that remain after harrowing shall not exceed three inches in the greatest dimension. Clod size will be assessed by measurement of the largest clod within three feet of randomly located points within the unit. Measurement shall be made by both the contractor and the mine supervisor in randomly selected locations. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soils scientist or agricultural engineer.

(3) Rolling

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average depth of three footsteps (made by an approximately 170 pound person) closest to randomly located points in the unit may not exceed 3/4 inch. Measurement shall be made by both the contractor and the mine supervisor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soils scientist or agricultural engineer.

3. Drill Seeding Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Drill seeding is generally the most effective method of planting most seed types for both permanent and temporary reclamation. However, a combination of drill seeding and hydroseeding is one preferred method of seeding permanent reclamation. While most seed is best drill seeded, hydroseeding may be preferred for certain species such as shrub seed, which, because of low purity and germination, must be seeded in large amounts. For safety purposes, most slopes steeper than 2.5:1 will require hydroseeding rather than drill seeding.

Weather and soil conditions permitting, permanent seeding should be accomplished as soon as practicable after topsoil is laid on reclaimed ground. A season or more of annual grains cropping may enhance seeding success by improving soil tilth and soil moisture. Temporary seeding, which should not be performed when the probability of adequate moisture for seedling establishment is low, is necessary for erosion control on areas such as topsoil stockpiles. All revegetation must be conducted in the manner most efficient for moisture retention and erosion control.

Special Considerations

Antecedent soil moisture has a large impact on seeding success. It is undesirable to seed into powder-dry earth, unless there is a high probability of a significant period of post-seeding precipitation. Soil with moisture as close as possible to field capacity, but which can also be seeded without undue compaction, is most likely to support successful germination.

In Wyoming, seeding early in the spring, even in January or February, has consistently resulted in successful establishment, particularly of cool season grasses and shrubs.

Technique

a. Three common types of drill seeders are:

(1) Grain Drill

The grain drill is for flowable seeds such as oats and wheat. It should have a legume box and a drill range that adjusts from six to fifty pounds per acre.

(2) Grass Drill

The grass drill will efficiently seed the majority of seed varieties. This drill should have: chain drags, press wheels, one-half to one inch depth bands, and a drill range that adjust from six to sixty pounds per acre. This will ensure even seeding and proper depth and coverage of seeds. It should also have three seed boxes with agitators to keep seed mixed:

(a) A legume box for small seed

(b) A box with picker wheels for trashy seed

(c) A standard box for flowable seeds such as grains

(3) No-till Drill

The no-till drill has characteristics similar to the grass drill. In addition, it has coulter wheels to cut through surface vegetation and open a narrow path for seeding. The no-till drill may be used where it is desired to minimize surface disturbance.

b. Method

All drill seeding should be done parallel to the contour on slopes, or perpendicular to the prevailing wind on flat areas. Calibration of the drill must be accurate to ensure the correct PLS of each seed is planted. Table 1 gives step-by-step instructions for drill calibration.

c. Tolerances

The primary purpose of the tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for work performance.

(1) Seed Mixing

(a) Computation Tolerance

Acceptable tolerances for mixing seed to be used in drill seeding will be based on the proper computation of bulk pounds of the mix for each box. The record of seed mixing for any individual revegetation unit, including the computation of the proper bulk mix, should indicate a deviation of not greater than ten percent from the properly calculated bulk mix. This tolerance criterion applies to each species seeded by the box being evaluated.

For example, if the proper computation of bulk pounds requires ten bulk pounds of species A in the back box of a three-box drill for each acre seeded, and the computation made by the contractor shows eight pounds, the deviation from the tolerance is greater than ten percent.

(b) Application Tolerance

The tolerance is based on the average of three samples per box per unit, taken before the drill is loaded. The proportion of bulk pounds for each species for the box, compared to total bulk pounds for the box, will be within 50 percent (as estimated visually) of the properly computed ratio described above.

For example, if the bulk pounds of species A is two pounds per acre for the back box of a three-box drill, and the total bulk pounds of the mixed seed for the back box is twenty pounds per acre, the proportion of species A must be between 1/20 (five percent) and 3/20 (fifteen percent), as estimated visually. Species comprising less than five percent of the bulk mix by computation need only be visually present to meet the seed mixing tolerance.

Assessment of seed mixing is made prior to hydroseeding. If the contractor and the mine supervisor cannot agree on the average visual estimate of mixing, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

(c) Seed Density

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average unit density of seeds in a 12 inch wide by 24 inch long block shall be equivalent to plus or minus 30 percent of the pounds of PLS per acre required by the seed mix being applied. The location of the sample squares should be made by the mine supervisor. Computation of pounds of PLS per acre is made for each mix prior to drill seeding.

Seed count can be made by the mine supervisor and confirmed by the contractor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

(2) Seed Depth

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average depth of seeds in a 12 inch wide by 24 inch long block shall be between 1/4 and 1 inch. The sample squares will be randomly located. Seed depth can be measured by the mine supervisor and the contractor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

TABLE B-3-1. SAMPLE DRILL CALIBRATION

- *1 revolution of the drive tire is 7.667 feet. (This depends on tire size, so the circumference of the tire must be calculated.)*
- *The drill seeds 10 feet wide. (This depends on the drill, so it should be measured.)*
- *There are 43,560 square feet per acre.*

Therefore, 568.15 revolutions would equal 1 acre covered:

$$\frac{43{,}560 \text{ sq.ft./acre}}{7.667 \text{ ft/rev} \times 10 \text{ ft wide}} = \frac{568.15}{\text{rev/acre}}$$

There are 16 furrow openers. (This depends on the drill, so it should be counted.)

2.2 pounds equals 1 kilogram.

1 kilogram = 1,000 grams

BOX	BULK LBS.	PLS LBS.	SPECIES
Middle	1.34	1.0	Little bluestem
Middle	3.78	2.0	Fourwing saltbush
Legume	5.10	2.0	Blue grama
Back	3.36	3.0	Green needle
Middle	1.18	1.0	Side oats grama
Legume	1.05	1.0	Alfalfa
Middle	2.24	2.0	Buffalo grass
Back	3.83	3.0	Slender wheatgrass
Back	2.22	2.0	Thickspike wheatgrass
Back	3.44	3.0	Western wheatgrass
Middle	0.55	0.5	Sanfoin

Note: Bulk needed for the specified PLS will change slightly when using different lots, vendors, etc.

MIDDLE BOX		LEGUME BOX		BACK BOX	
Little bluestem	1.34	Blue grama	5.10	Western	3.44
Fourwing	3.78	Alfalfa	1.05	Thickspike	2.22
Side oats	1.18		**6.15 lbs. bulk**	Slender	3.83
Buffalo grass	2.24			Green needle	3.36
Sanfoin	0.55				**12.85 lbs. bulk**
	9.09 lbs. bulk				

$$\frac{9.09 \text{ lbs.}}{2.2 \text{ KG/lb.}} = 4.132 \text{ KG} \qquad \frac{6.15 \text{ lbs.}}{2.2 \text{ KG/lb.}} = 2.795 \text{ KG} \qquad \frac{12.85 \text{ lbs.}}{2.2 \text{ KG/lb.}} = 5.841 \text{ KG}$$

To change kilograms to grams multiply by 1,000.

4,132 grams of bulk needed for the middle box per acre.
2,795 grams of bulk needed for the legume box per acre.
5,841 grams of bulk needed for the back box per acre.

TABLE B-3-1 (continued)

Now we want to find out how many grams we need for 1 revolution for 1 seed cup (opener):

$$\frac{4.132 \text{ grams/acre}}{16 \text{ openers X } 568.15 \text{ revolution/acre}} = 0.4545 \text{ grams/revolution for 1 opener}$$

OR

$$\frac{4.132 \text{ grams}}{9090.4} = 0.4545 \text{ grams}$$

0.4545 grams is too small to weigh on most scales accurately. So we spin the drive tire 10 times when testing, which is more accurate.

<u>4.545</u> grams is what the middle box seed should weigh for 10 revolutions.

The back box bulk grams required (cutting out the extra numbers) would be:

$$\frac{5{,}841 \text{ grams X 10 revolutions}}{9090.4} = 6.425 \text{ grams}$$

$$\frac{2.795 \text{ grams X 10 revolutions}}{9090.4} = 3.075 \text{ grams}$$

The bulk pounds needed must be calculated from the seed tags*****. Add the bulk pounds up for each box, convert to kilograms, then to grams.

$$\frac{\text{bulk grams X 10 revolutions}}{9090.4} = \text{grams}$$

*In order to figure PLS you will need to MULTIPLY:

Purity from the seed tag X Germination from the seed tag = PLS
PLS pounds / PLS percent will give needed bulk pounds

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4. Hydroseeding Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

A combination of drill seeding and hydroseeding is useful for seeding permanent reclamation. A hydroseeder is also required on slopes too steep for drill seeding, and for application of mulch. It may also be used to ensure successful seeding of small seed, trashy seed, and seed whose germination is enhanced by light.

Special Considerations

A successful seeding program includes both drill seeding and hydroseeding. Several factors must be considered in deciding which method will be most efficient and successful. When hydroseeding is the best choice, it must be done properly to avoid damaging seed.

Technique

a. When to Hydroseed

(1) Trashy Seed

Hydroseeding is an option for trashy seed, such as little bluestem, blue grama, and prairie sandreed. It is often preferred, however, that seed be cleaned and drill seeded when possible.

(2) Seed Enhanced by Light

Hydroseeding may be the best choice for seed such as sand dropseed and sagebrush, which grow best near the surface where light enhances germination.

(3) Seed with Low PLS

Shrub seed, such as sagebrush, rubber rabbitbrush, and winterfat, often has a very low PLS, and must be applied in large quantities. Hydroseeding is the most efficient choice, as one pass with a hydroseeder will seed the required amount, which may take two or more passes with a seed drill.

(4) Mulch Application

Mulch should be applied in a separate step, after hydroseeding. This enhances the seed/soil contact and optimizes seed protection. Wood, paper, and synthetic fiber mulch are applied in a water slurry at recommended rates. Synthetic fiber may also require a hydroseeder, and should be applied according to the manufacturer's instructions.

(5) Safety

On steep slopes, safety considerations make it necessary to apply all seed and mulch with a hydroseeder. Generally, loose slopes steeper than 3H:1V, and firm slopes steeper than 2.5H:1V will require a hydroseeder.

b. Methods

(1) Avoid Seed Damage

Agitation of seed and water in the hydroseeder should be at the lowest possible rate, in order to avoid damage to the seed. Using very high water pressure may also damage seed.

(2) Attain Complete Seed Coverage

Hydroseeding on slopes should be done from both the bottom and top of the hill to ensure complete coverage.

(3) Mulch

Applying the average requirements for mulch with the seed can hinder seed/soil contact. The bulk of the mulch should be applied after all seeding is complete. A small amount of wood or paper mulch, however, works as a good de-foaming agent, especially with shrub seed. An organic hydrocolloid tackifier and dye can be used with paper and wood fiber mulch. Tackifier should not be used with seed, however, as damage may result.

c. Tolerances

The primary purpose of tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for the work performance of the contractor. The application of tolerance criteria is expected to be the exception rather than the rule.

(1) Seed Mixing

Acceptable tolerance for mixing seed to be used for hydroseeding is based on the proper computation of bulk pounds for the hydroseed mix and the record of pounds of seed placed in each hydroseeder load. The record of hydroseeding for any individual unit, including the computation of the proper bulk mix, should not deviate more than ten percent from the properly calculated bulk mix. This criterion applies to each species seeded by the hydroseeder.

For example, if the proper computation of bulk pounds requires ten bulk pounds of species A in the hydroseeder for each acre seeded, and the computation made by the contractor shows eight pounds, the deviation from the tolerance is greater than ten percent.

(2) Seed Density

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average unit density of seeds on a cardboard square 12 inches by 12 inches shall be equivalent to plus or minus 30 percent of the number of bulk seed per acre required by the seed mix being applied. For example, if proper computation of the bulk mix calls for 4,356,000 seeds per acre to be applied, the square should contain between 70 and 130 seeds.

The placement of the cardboard square will be made by the contractor or employee in the field as approved by the contractor or the mine supervisor. Computation of pounds of bulk seed per acre will be made for each mix prior to hydroseeding.

Seed count of the cardboard square can be made by the contractor and confirmed by the mine supervisor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

5. Mulching Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Mulch, made of plant residue or other suitable materials, is placed upon a recently seeded soil surface to aid in soil stabilization and soil moisture conservation.

Special Considerations

Mulch should be applied immediately after seeding, and never with seed; this maximizes contact of soil and seed. Mulch need not be used if seed has been planted into a cover crop or standing stubble.

Technique

a. Application Rates and Methods

Recommended application rates proposed for various conditions of slope and soil are presented in Table 1 (tables are at end of text). One or more of the methods specified for each of the conditions shown in the table should be applied to a seeded surface. Mulch rates will vary, dependent upon the type of mulch used and manufacturer's recommendations. Where mulch is used to control erosion, the amount used will depend upon steepness of the slope. The types of mulch that may be used include:

(1) Nurse Crop

Oats, at no less than six pounds and no more than fifteen pounds per acre, are included in the approved perennial seed mix at the time of planting.

(2) Cover Crop

Oats, at no less than fifteen pounds and no more than sixty pounds per acre, are planted the season prior to the approved perennial mix. The cover crop may be hayed or combined, and the perennial is then planted into the standing stubble.

(3) Native Hay

Hay is applied with a tub grinder or similar blower, at a rate of between 1/2 and two tons per acre, and then crimped into the ground with a flat blade disc crimper. Crimping should be done 1/2 to 2 inches deep, on eight to twelve inch centers.

(4) Straw

Certified weed-free straw is applied and crimped in a fashion similar to native hay mulch.

(5) Wood Fiber

Wood fiber is applied as a hydromulch at a rate of between 1/2 and 1 ton per acre. An organic hydrocolloid tackifier and dye should be used with wood fiber.

(6) Paper Fiber

Paper fiber is applied similar to wood fiber, with tackifier and dye.

(7) Wood/Paper Fiber

A mixture of fiber is applied similar to wood fiber, with tackifier and dye.

(8) Synthetic Fiber

Synthetic mulch is applied in accordance with manufacturer's instructions.

b. Equipment

(1) A hydroseeder is used for application of wood, paper, or synthetic fiber mulch.

(2) A tubgrinder is required for even application of grass and straw mulch.

(3) A crimper is needed for the adequate anchoring of grass and straw mulch.

(4) A smooth-fronted roller is used in place of, or in conjunction with, other methods of mulching to meet desired performance standards.

c. Tolerances

The primary purpose of the tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for work performance. The application of tolerance criteria is normally the exception rather than the rule.

Evaluation of mulching is made from the records of the contractor, who must report the bags or tons of mulch applied per unit. The amount of mulch applied must be within plus or minus 20 percent of the prescribed amount for the unit. For example, if hydromulching of the unit calls for the application of 0.5 ton of mulch per acre and the records show less than 0.4 or more than 0.6 ton per acre was applied, the contractor will have failed to meet the tolerance for that unit.

In the case of insufficient mulch, additional mulch should be applied at the discretion of the supervisor. If too much mulch has been applied, the area may require re-seeding, depending on seeding success. In no case should payment be made for more than the specified amount of mulch.

TABLE B-5-1. Mulch Application Rates

MULCH	SOIL TYPE: Primarily Sandy - "Light"	Primarily Silty or "Medium"	Primarily Clayey or "Heavy"
Mulch Application - Slope less than 2.5H:1V			
Nurse crop rate	12 lbs	12 lbs	12 lbs
Cover crop rate	40 lbs	40 lbs	40 lbs
Native hay rate	1 ton	1 ton	1 ton
Straw rate	1 ton	1 ton	1 ton
Fiber rate	2 tons	2 tons	2 tons
Synthetic rate	Manufacturer's specifications	Manufacturer's specifications	Manufacturer's specifications
Mulch Application - Slope 2.5H:1V to 5H:1V			
Nurse crop rate	12 lbs	12 lbs	12 lbs
Cover crop rate	30 lbs	40 lbs	40 lbs
Native hay rate	1 ton	1 ton	1 ton
Straw rate	1 ton	1 ton	1 ton
Fiber rate	2 tons	2 tons	2 tons
Synthetic rate	Manufacturer's specifications	Manufacturer's specifications	Manufacturers specifications
Mulch Application - Slope greater than 5H:1V			
Nurse crop rate	12 lbs	12 lbs	12 lbs
Cover crop rate	40 lbs	40 lbs	40 lbs
Native hay rate	1 ton	1 ton	1 ton
Straw rate	1 ton	1 ton	1 ton
Fiber rate	2 tons	2 tons	2 tons
Synthetic rate	Manufacturer's specifications	Manufacturer's specifications	Manufacturer's specifications

6. Seed Handling

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Before seed is received by reclamation personnel, careful handling, ordering, and testing ensures the best possible quality. Proper care must continue after seed is received to maintain this high quality.

Special Considerations

Seed storage facilities must be adequate to maintain seed quality. Expertise is necessary in the preparation of seed mixes to ensure the proper PLS of each seed is included in the mix, and to prevent damage to seed.

Technique

Seed must be stored in a temperature-controlled, moisture-free environment. This will prevent mold, heat damage, and premature germination of seed. The use of a rat poison is usually necessary to control vermin.

Once seed has been delivered to the storage area, additional testing may be required for verification of purity, germination, and weed content. Employing a state seed inspector for obtaining samples will assure both the vendor and the buyer that this is done properly. Samples should be sent to a certified seed laboratory for testing. More details on seed testing are presented in the subsection entitled "Understanding Seed Tests".

Familiarity with the physical characteristics of different species is necessary in determining the best method of seeding. Visual assessment is possible with the use of a seed library. To make a seed library, fill small, clear bottles (like spice jars) with seed samples. Label each with seed name, number of seeds per bulk pound, or other data desired. The seed library can be very helpful in seed mixing and drill calibration.

Table 6-1 lists some common species used in reclamation, with the drill box or method preferred for best results in planting. Species to be used in each seed box must be mixed according to PLS requirements per acre and total acreage to be seeded. Seed to be mixed in the hydroseeder should be agitated gently to avoid damage. Care must also be exercised when using a hopper wagon for mixing seed, as mixing too long and hard can easily cause damage to seed. With extremely dusty seed such as saltbush, it may be preferred to mix by hand in the seed box.

TABLE 6-1. SEED PLANTING METHODS

SCIENTIFIC NAME	*COMMON NAME*	*DRILL BOX or METHOD**
Achillea lanulosa	*WESTERN YARROW*	*L*
Agropyron dasystachyum	*THICKSPIKE WHEATGRASS*	*R*
Agropyron elongatum	*TALL WHEATGRASS*	*R*
Agropyron intermedium	*INTERMEDIATE WHEATGRASS*	*R*
Agropyron riparium	*STREAMBANK WHEATGRASS*	*R*
Agropyron smithii	*WESTERN WHEATGRASS*	*R*
Agropyron trachycaulum	*SLENDER WHEATGRASS*	*R*
Agropyron trichophorum	*PUBESCENT WHEATGRASS*	*R*
Artemisia cana	*SILVER SAGEBRUSH*	*H/P*
Artemisia frigida	*FRINGED SAGEWORT*	*L*
Artemisia tridentata	*BIG SAGEBRUSH*	*H/P*
Astragalus cicer	*CICER MILKVETCH*	*R*
Atriplex canescens	*FOUR WING SALTBUSH*	*P*
Atriplex gardneri	*GARDNER'S SALTBUSH*	*P*
Avena fatua	*OATS*	*G*
Bouteloua curtipendula	*SIDE OATS GRAMA*	*P*
Bouteloua gracilis	*BLUE GRAMA*	*L*
Bromus enermis	*SMOOTH BROME*	*R*
Buchloe dactyloides	*BUFFALO GRASS*	*P*
Calamovilfa longifolia	*PRAIRIE SANDREED*	*R*
Ceratoides lanata	*WINTERFAT*	*H/P*
Chrysothamnus nauseosus	*RUBBER RABBITBRUSH*	*H/P*
Distichlis stricta	*INLAND SALTGRASS*	*R*
Helianthus annuus	*SUNFLOWER*	*P*
Lupinus caudatus	*LUPINE*	*P*
Medicago sativa	*ALFALFA*	*L*
Melilotus officinale	*YELLOW SWEET CLOVER*	*L*
Onobrychis viciaefolia	*SAINFOIN*	*P*
Oryzopsis hymenoides	*INDIAN RICEGRASS*	*R*
Petalostemum purpureum	*PURPLE PRAIRIE CLOVER*	*L*
Phalaris arundinacea	*REED CANARYGRASS*	*R*
Poa canbyi	*CANBY BLUEGRASS*	*R*
Poa pratensis	*BLUEGRASS*	*L*
Ratibida columnifera (columnaris)	*PRAIRIE CONEFLOWER*	*L*
Schizachyrium scoparium	*LITTLE BLUESTEM*	*P*
Secale cereale	*RYE*	*G*
Spartina pectinata	*PRAIRIE CORDGRASS*	*R*
Sporobolus airoides	*ALKALI SACATON*	*L*
Stipa viridula	*GREEN NEEDLE*	*R*
Triticum aestivum - Spring	*SPRING WHEAT*	*G*
Triticum aestivum - Winter	*WINTER WHEAT*	*G*

* G - Grain drill
H - Hydroseeder
L - Legume box - grass drill
P - Seed box with picker wheels - grass drill
R - Regular box

7. Planting Methods for Permanent Reclamation

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Choosing the proper methods for cultivation and planting of reclaimed ground is vital to revegetation success. The order of these methods is also important in producing a properly prepared seed-bed for the best possible germination of seed.

Special Considerations

Reclaimed ground must receive adequate tillage, but excess tillage should be avoided. The final seed-bed should be finely pulverized, but firmly packed. The different seeds should be planted at depths appropriate to the seed type, with the best possible contact between seed and soil.

Technique

The following steps have proven successful in permanent revegetation in the Powder River Basin, and should be completed in the order given. For detail on methods, refer to the individual subsections that cover each of these steps.

(1) Disk

Plowing freshly laid topsoil is usually unnecessary. Disking is typically the best initial measure for soil preparation.

(2) Cultipack

Using a cultipacker is the next step in seed-bed preparation. Cultipacking will ensure that the soil is finely pulverized, firmly packed, and ready to receive seed.

(3) Hydroseed

Hydroseeding (without mulch!) is the most efficient choice for shrub seed, which, because of low PLS, must be applied in large quantities. Hydroseeding is also efficient for fluffy or trashy seeds. Hydroseeding is especially good for seeds such as sagebrush, whose germination is enhanced by light. Hydroseeding should follow cultipacking.

(4) Roll

Rolling is done after hydroseeding to firm the soil and ensure maximum seed/soil contact. This is an essential practice. A typical smooth front roller is three feet in diameter and can be filled with water for weight.

(5) Drill

A multi-box grass drill is required for seeding the species not seeded with the hydroseeder. For details on determining the best seed box to use for each species, refer to the subsection entitled "Seed Handling". The drill should have a chain-drag attached to ensure even coverage of seed.

(6) Roll

Rolling should be done once again after all seed has been planted. This will firm the soil adequately and ensure the best possible seed/soil contact.

(7) Mulch

Mulching, where necessary, should be done after all seed is in the ground. It is desirable to avoid the use of mulch over species that require light to germinate, such as shrub seed, and species that have a shallow planting depth, as mulching may destroy seed/soil contact and/or increase surface drying.

8. Broadcast Seeding

Section editor: Larry H. Kleinman *Subsection author: Laurel E. Vicklund*

Applicability

There are occasionally areas requiring seeding that are not accessible with a pull-type seed drill. Not all of the areas that require seeding will be final reclamation; special-use areas may be small, rocky, have a steep slope, have peculiar seeding requirements, or be inaccessible to a tractor and drill. Using various methods to broadcast the seed ensures that the area is planted to stabilize the surface.

Special Considerations

Areas with excessive slopes should be evaluated for safe access before using tractors and other equipment. Establishment of vegetative cover in "fringe" areas reduces erosion, sediment runoff, and the potential for noxious weed invasion as well as improving air quality by reducing wind erosion. When hydroseeding is not essential, broadcast seeding is more economical.

Technique

a. Mechanical Broadcast Seeding

A seed broadcaster that fits on a three-point tractor hitch and runs off the power-take-off is very convenient for seeding small areas. Vegetation establishment may be required on areas not scheduled for final reclamation, such as overburden areas, sediment ditches or ponds, around rockpiles, or other open areas of disturbance.

Some areas may be too rough to pull an expensive seed drill over. This may be especially true of backfill requiring interim stabilization, which is often too rocky. Using a broadcaster to seed these areas reduces excessive wear on a pull-type drill. Other areas may be inaccessible to a pull-type drill, such as scraper-built sediment control ditches or other small "fringe" areas around the pit.

(1) Seeding Rate

Generally, regular reclamation seed mixtures can be used for broadcast seeding by doubling the rate. The rate is increased to compensate for seed not placed at the proper depth, that may be washed away, or that will not germinate.

A harrow or a chain drag is pulled behind the seed broadcaster to aid in covering seed. Calibration varies with the brand of seed broadcaster, and the type of seed used. Follow the instructions for calibration that comes with the seed broadcaster.

(2) Shrub Seeding

A seed broadcaster can be used in conjunction with a pull-type seed drill. This procedure has been used when the seeding rate of a shrub species could not be applied through a conventional drill. The grass component of the seed mixture is drilled into a standing stubble mulch. The shrub portion of the mixture is then broadcast into the same area, however a harrow or chain drag is not used behind the broadcaster in this instance.

b. Hand Broadcasting

Hand broadcasting is useful in small areas where access is limited, or in areas where a small amount of a specific seed is to be planted. A hand type seed broadcaster may be used, or seed may simply be scattered by hand. Hand seeding works well around rockpiles, wetland areas, and other small areas inaccessible to pull-type drills or mechanical seed broadcasters.

Calibration is less accurate with these methods of seeding. Calculate the acreage of the area to be seeded and the volume of seed required for the area, and distribute the seed as evenly as possible. As with the mechanical broadcaster, the amount of seed applied should be doubled.

9. Transplanting Live Plants and Planting Plant Parts

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

Planting and transplanting are sometimes necessary to establish a seed source of shrubs and trees for further enrichment of a revegetated stand. Certain shrub and tree seeds germinate only sporadically in the wild and those species should be included in the revegetation as transplants.

Special Considerations

Planting and transplanting may take place prior to seeding of the normal seed mixtures, after seeding, or even with no seeding whatsoever. Several of the methods described are labor intensive, expensive, and may require specialized equipment; others are relatively inexpensive, easily performed, and require no specialized equipment. The methods that are described in this subsection are: containerized stock, bareroot stock, shrub/tree pads, and sprigs or cuttings.

Moisture competition by grasses and weedy plants may be the most probable cause of shrub and tree transplant failure. When planting or transplanting into an already established stand or a newly seeded area, the existing living plant material should be removed from the soil immediately around the transplants. This can be done by scalping to just below bare ground or by herbicidal control. Normal seed mixtures may be inter-seeded into the plantings; preferably after the new plants are well established.

Methods that can be utilized for the seeding include no-till drills, grass seeders such as the "Brillion" (raise the roller packers so that they do not disturb the transplants), hydroseeders, or broadcast seeders such as the "Cyclone" seeder. It is recommended to reduce the normal interseeding mixture by as much as one-half to reduce competition. If directly placed topsoil is used for the top dressing before transplanting, no additional seeding may be necessary. Match the directly-placed topsoil with the type of plantings. For example, chances of success would be improved if ponderosa pine transplants were planted into directly placed pine soils.

The planting and transplanting of live plants may be undertaken in the spring or fall, provided certain precautions are taken. The plants should be hardened (dormant), and there should be adequate soil moisture, or at least the chance for adequate soil moisture.

Technique

a. Containerized Stock

Containerized transplants of shrubs or trees may be obtained in almost any size desired, from six cubic-inch cones to five gallon buckets. Many nurserymen and planters prefer a ten cubic inch cone container, as they are easily handled and planted with small chance of root disturbance. They produce vigorous and straight root growth. The above-ground portion of the plant is vigorous, well formed, and generally one year old stock.

Containerized plants are quite expensive to get into the ground. Each individual plant may cost up to approximately $2.00 per plant to buy and have planted by professional planters. If mine laborers do the planting, the cost may be several times the $2.00 per individual plant. Care must be taken to plant the transplant correctly without bending the roots, without leaving too much airspace around the roots, and to put the plant in the most appropriate niche.

There are mechanical rotary tree planters available that are pulled behind a tractor. These reduce the final cost considerably if several thousand trees or shrubs are to be planted per day. A professional planter is able to plant 400 to 600 trees per day in a precise location, whereas a mechanical planter is able to plant up to 2,000 or more trees per day.

b. Bareroot Stock

The same considerations and techniques given for containerized plants are appropriate for bareroot transplants. In general, bareroot stock is less expensive to buy but more care must be taken to keep the roots from drying out before planting. There are fewer fine root hairs to immediately begin growth than with containerized plants. Thus the plants must utilize more stored carbohydrates to initiate growth of root hairs for water and nutrient uptake. More care must be taken to keep from bending the roots than for containerized plants, and in some cases the roots and the crown should be pruned before planting.

c. Shrub/Tree Pads - Front-End Loader Bucket

This technique is a simple, inexpensive, and rapid method of transplanting a whole pad or clone of certain trees and shrubs. Plant species that spread by rhizomes, adventitious stems, or root sprouting are the most successful in establishing by this technique. Species that may be successfully established using this technique include willow, cottonwood, snowberry, and skunkbush sumac.

Specialized front-end loader buckets with flat bottoms that protrude out in front of the bucket may be purchased or built on site. However, a normal bucket such as on a Cat 966 Front-End Loader has proven very successful without modification.

A small, accessible patch of the desired plants (seedlings one to three years old, preferably) must be located. It would be best if the plants were in an area where the topsoil was to be stripped or an area of already disturbed ground. The bucket is lowered and tipped forward so as to dig with the front edge of the bucket. Dig with the front edge approximately six to ten inches deep, slide the edge of the bucket under the plants, and lift the bucket when full. Transport in the bucket to the desired location on reclaimed ground.

Tilt the bucket edge until the plant/soil pad starts to slide out and slowly back the loader, continuing to tilt the bucket until the pad is out. If desired, a little topsoil can be banked around the pad so that the roots are not exposed; however, just leaving the pad with no extra topsoil around it has been successful. The pad may be deposited on top of respread topsoil or on top of regraded spoil with topsoil banked around it. If desired, the pad may be deposited inside a pre-gouged depression the depth of the pad. This technique is most successful while the plants are dormant, but has also proven successful in the late spring or early fall while the plants were actively growing.

d. Plant Parts - Cuttings and Sprigs

Sprigs and cuttings are labor intensive. An undisturbed area is rototilled and the sprigs and roots are removed and relocated to reclaimed ground. The equipment used is a modified potato harvester with an undercutting blade that loosens and cuts the roots. The disturbed soil, which includes the cuttings and sprigs of root/plant material, is conveyed to a truck bed or trailer and transported to the reclamation site. The plant material is re-spread by means of a manure spreader.

It is desirable that the plant material be re-spread onto topsoil because there will be very little topsoil adhering to the sprigs and roots. After the sprigs and cuttings are in place, a light covering of sand or topsoil should be spread on top and lightly compacted with a roller packer to assure soil contact by the roots and cuttings. Reception of moisture soon after planting is very important to initiate growth of new roots and stems. Scrapers have been utilized to pick up the cuttings and sprigs and respread them on the reclamation site with only limited success.

10. Reforestation

Section editor: Larry H. Kleinman *Subsection author: Roy L. Garrison*

Applicability

Centralia Mining Company operates a surface coal mine located seven miles east of Centralia, Washington. It is an uncommon example of a mine where reforestation is a standard revegetation practice. Conifer and hardwood species dominate cover on the hills and the poorly drained valleys accommodate grasses and various riparian species: Red alder is the most prevalent hardwood species found in pure stands and mixed throughout conifer stands. Mine disturbed lands will be returned to their primary land use, in most cases tree farming on the uplands and pasture/riparian areas in the valley bottoms.

Special Considerations

Centralia is located 50 miles east of the Pacific Northwest coastline, which receives significant precipitation in the range of 30 to 56 inches annually with 24-hour events ranging between a trace to 4.5 inches. Generally rains begin in October and continue intermittently through April, accompanied by mild temperatures ranging from 0^0 F to 95^0 F (-18^0 C to 35^0 C).

Technique

a. Soils Handling

Proper reclamation and soils handling play a very important role in the success of establishing a forestry land use. Slopes are backfilled, graded, and shaped to adequately drain. Four feet of suitable soil is then placed over final graded slopes to ensure a productive rooting medium. Overburden suitability programs ensure the quality of the rooting medium.

All reclamation field operations are carried out during the drier months, June through September. Soil moisture conditions prohibit any surface travel or soil handling on reclaimed areas during the remainder of the year.

(1) Drainage Design

Temporary and permanent drainage structures are designed in the final topography to control and transfer surface runoff. Terraces are placed on the contour of the slope at a 1% gradient to intercept surface runoff and direct flow to waterways designed to carry the water off the slope. Drainage control is critical in providing for a stable slope and minimizing soil erosion in this high rainfall region.

(2) Cultivation

Prior to reforestation, the rooting medium is ripped on the contour to an average depth of three feet. Ripping promotes internal drainage, root penetration, and mixing of topsoil with underlying subsoil. Ripping appears to provide these benefits initially but does not demonstrate long term effectiveness.

b. Reforestation

Conifer and hardwood species are planted on prescribed slopes to achieve stocking levels of 400 and 435 trees per acre respectively. Typically Douglas-fir (*Pseudotsuga menzesii*) is planted on ridge tops, and southerly or westerly reclaimed slopes. Red alder (*Alnus ruba*) is typically planted on northerly and easterly slopes. These species are best suited for the climatic conditions of the prescribed slopes. Riparian species are planted along waterway channels for stabilization and diverse habitat for wildlife. Small open spaces are encouraged in pure stands of conifer or hardwoods to enhance species diversity and wildlife feeding areas.

c. Challenges to Reforestation Success

One of the major challenges to reforesting reclaimed lands in the Pacific Northwest is controlling the invading grass species after topsoil distribution. The grass itself is not the main threat to young tree seedlings, but heavy stands of grass provide an environment for large populations of rodents. The Townsend vole (*Microtus townsendii*) is the primary deterrent to the survival of young tree seedlings. The voles feed on the bark at the base of the young tree, which, in most cases, kills or severely damages the tree.

Trees are most susceptible to rodent damage during the first five years after planting. Foil and netting are placed around the base of young seedlings to prevent rodent damage during this period. In addition, an herbicide program is initiated the spring following planting to control the grass cover. Where high rodent populations persist, rodenticide may be used to control the pests.

High soil moisture conditions can also be threatening to the survival of young tree seedlings. This condition is prevalent where slope gradients are less than five percent. To eliminate this problem, Centralia Mining Company has developed a tool that creates a mound of soil for every tree planting site. The mound is approximately two feet in diameter and provides eight to twelve inches of relief in the surface topography. This allows the tree seedling to establish its roots in a suitable moisture regime during its initial growing years.

d. Monitoring

Continual monitoring of reforested lands ensures that the requirements of OSM regulations are met, and identifies any remedial work necessary. New practices are monitored very closely and assessed for their effectiveness. Revegetation surveys are taken periodically throughout the bonding period to document stocking levels and ground cover percentage.

11. Seeding Shrub Seed

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

Small, trashy shrub seed is difficult to seed by normal drill seeding. The seed is generally collected from native stands and therefore rather expensive. Most of the "compositae" seed such as sagebrush and rabbitbrush are very low in viability and purity and have a very poor storage life. The seeds are so small that when cleaned the seed may be lost and the hulls kept. Please refer to the subsection entitled "Selecting Good Shrub Seed", by Richard Dunne.

Most mine operations are regulated by State agencies which require that a certain amount of revegetation be dominated by large shrubs. Therefore, the successful seeding of shrubs is a serious concern for reclamation specialists and government agency personnel.

Special Considerations

Artemisia and *Chrysothamnus* seed (sagebrush and rabbitbrush) are very sensitive to being planted too deep. They are also sensitive to inadequate moisture. The seed should be planted onto the surface of a very compacted seed-bed, or at most less than 1/4 inch deep. The seed will over-winter on the ground and in the soil and germinate early the next spring (March). Not all of the seed will germinate at the first opportunity, but may germinate the second or even the third year.

The seed seems to hold viability while in the soil but not when in storage in a bag. The seeding of these species has been especially successful when seeded into green or non-stockpiled topsoil because of the mycorhizal fungi in the soil. These species are somewhat sensitive to grass competition, especially cool season grasses which also germinate in the spring. Because of this, these shrubs should be planted without accompanying grass seed, with a reduced cool season grass mixture, or with only warm season grasses which germinate in the early summer.

A drill seeding technique used in the past by Chet Skillbred at Glenrock Coal Company and a hand broadcast technique used by the author at Big Horn Coal Company are described in the following subsection.

Technique

a. Drill Seeding of Sagebrush Seed

Sagebrush is generally seeded with no other species in the mixture. However, light rates of blue grama and sandberg bluegrass have been added with successful results.

Areas that have been excessively compacted by scraper tires are areas where shrub seed can be seeded with good success. The grass species in the usual seed mixture generally have a difficult time establishing because of the compaction of the soil.

(1) Brillion Grass Seeder

The Brillion grass seeder is essentially a broadcast seeder with an attached rear roller packer. In this case the rear roller packer can either be removed or the tension set at the minimum.

The seed boxes should be enlarged to accommodate the lighter, bulkier seed. Holes, which are 7/8 inch diameter, are drilled in the bottom of the boxes, which bypass the normal wire agitator, and are open at all times. Therefore, the seed should be poured into the seed boxes only when at the actual location to be seeded. Only the correct amount of seed needed for the acreage to be revegetated should be put into the seed boxes at any one time.

Every possible advantage should be provided for the shrub seeding. Four feet of shrub-suitable soil material, with a top dressing of green or directly placed shrub soil, is laid down. The green shrub soil contains mychorrizal fungi which will inoculate the newly germinated shrub seed and provide for better seedling survival. The seed-bed is made very firm after disking by the use of a roller packer.

Sagebrush should be seeded at a rate of 10 PLS pounds per acre when seeding in November or December. Snowfall is assured after seeding, and the seed will break dormancy by over-wintering and germinate in the spring. Seeding in March at a rate of 6 PLS pounds per acre has also been successful.

(2) Truax Grass Seeder

The Truax grass seeder has been used to seed sagebrush during December and January when the soil surface is frozen. This assures a very firm seed-bed and snowfall after seeding. The Truax drill has disk furrow openers with press wheels behind. The furrow openers are set at minimum pressure.

The center seed box on the drill is used and the seed metering is set wide open. The sagebrush is seeded at a rate of 5 PLS pounds per acre during December or January when the soil is frozen. However, choose a nice sunny day to seed so that the very top surface film of soil is friable. The disk openers will not cut too deep and the press wheel will cover the seed with a very thin layer of soil.

b. Hand Broadcast Seeding Sagebrush

Hand broadcast seeding of sagebrush is simple and inexpensive, especially when small shrub patches less than one acre in size are the desired result. The only equipment needed is a five gallon plastic bucket to carry the seed. The correct amount of seed for the desired acreage of sagebrush seeding must be determined and that amount of seed is spread over the desired area by throwing handfuls of seed onto the ground.

A person may follow behind the equipment used to seed the other species of the seed mixture. The seed may be broadcast onto specific locations where more shrubs may be desired, such as swales for extra moisture, ridge tops where there will be less grass competition, or in and around rock piles.

While this method has been successful, it must be realized that much of the shrub seed may not germinate for one to three years after seeding, or there may be staggered germination and establishment over a three year period.

The best results have been by hand broadcasting in similar areas and situations as described in the drill seeding subsection.

(1) Accompanying Species

The seed may be broadcast into an area that has not been seeded with other species, especially if the topsoil is directly placed, or green. There usually is sufficient residual grass seed in the topsoil to fill in between the established shrub seedlings without crowding the shrub seedlings for available moisture.

(2) Topsoil

If the topsoil has been stockpiled for more than one year, a choice must be made to either seed only shrubs and hope that the other species invade and fill in, or drill a very light rate of the other species before hand broadcasting the shrub seed. A seeding rate of 1/4 to 1/2 PLS pounds per acre has been successful in establishing shrub stands.

(3) Compaction

Excessively compacted areas are ideal for shrub patches because of the ability of the shrub seed to germinate and establish without being covered by soil.

(4) **Timing of Seeding**

The timing of seeding is similar to drill seeding. The best results have been from seeding in November and December. Big Horn Coal has not seeded shrubs in January, though there may be no reason not to try it.

(5) **Shrub Seed Used**

Shrub seed purchased from the previous years' collection may be used, or if desired, seed may be collected from adjacent shrub stands and seeded even the same day. The seed should be collected after seed hardening and ripening (see the subsection entitled "Selecting Good Shrub Seed"), usually in November or December. The seed may be stripped from the seed plant into a plastic five gallon bucket.

c. General Considerations

There are several critical points to be considered in both of these techniques. The seed-bed must be very firm. The seed must be placed on the soil surface, or with only a very thin covering of soil at the most. The seed should be seeded soon before the prolonged winter snowfall for adequate moisture. Quality seed that has been cleaned properly and has not been stored for more than one year should be used. Finally, grass competition should be reduced by seeding a lesser grass rate than normal or by not seeding any grasses in the shrub areas at all.

C. SEED ORDERING METHODS

1. Ordering Seed

Section editor: Larry H. Kleinman *Subsection author: Richard Dunne*

Applicability

Timing a seed order to coincide with cash-flow or collection cycles of seed vendors can improve the price, availability and quality of seed offered.

Special Considerations

When ordering seed, ample time must be allowed for vendor response and delivery. Seed may be ordered pre-mixed; the advantages of ordering pre-mixed versus mixing your own are discussed in this subsection.

Technique

a. When to Order

To purchase the best seed at the lowest prices, order during slow seasons and time the order to coincide with the entry of new seed lots onto the market. Most grass seed is harvested and tested by January 1, and most shrub seed is available by February 1 of each year. January-February is a slow cash-flow period for most seed vendors, which increases the chances of purchasing superior quality seed at lower prices. June, July, and August are also slow months for seed dealers and a good time to buy, except in a year of shortages when quality and availability decrease.

Some native seeds are chronically scarce and may be available only for a short time following harvest. Seeds such as winterfat, northern-origin fourwing saltbush, silver sage, globemallow, black samson, thermopsis, prairie cordgrass, northern sweetvetch, prairie rose, prairie sage, dotted gayfeather, and western snowberry are often sold out by fall.

b. Lead Time

For large, complicated bids, allow vendors two weeks to bid and at least two weeks to deliver. Compressing this time frame will increase the chances of errors or delays.

c. Mix Your Own Versus Pre-mixed

A seed company can mix seed cheaper than it can be mixed at the reclamation site. Mixing costs are usually included in a bid when a mix is specified, and often a seed company will absorb mixing costs to win the bid. The ease of ordering pre-mixed seed makes this a practical buying strategy, but there are hidden risks the buyer should be aware of:

(1) When ordering blue-tagged, Certified seed to be blended in a mix, there is no assurance that Certified seed will be used in the mix. The buyer should request receipt of the blue tags from the Certified Seed bags emptied into the mix.

(2) Scarce or expensive items may be omitted from the mix.

(3) Weedy lots can be blended into a mix without the buyer's knowledge.

(4) Cheaper varieties may be substituted for more expensive varieties.

These are not common practices in the seed trade, but are common practices among unscrupulous vendors. Keep in mind that testing a mix involves greater margins of error than testing species individually. These problems can be compounded when a contractor is employed for revegetation, as his practices may exacerbate bad seed mixing practices. If a seeding contractor is used, it may be best to let choices regarding mixing be made by the contractor, with the client concentrating on setting and evaluating tolerance criteria.

The advantages of mixing your own seed include the ability to verify receipt of expensive or scarce seeds, and to isolate and replace individual seed lots which contain unacceptable weeds or have germination problems. Some seed lots may be used in different mixes at different times; so, buying seed in individual lots gives more flexibility in planting. This is especially important when readiness of individual sites cannot be pre-planned.

2. Preparing a Seed Purchase Request

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

A seed buyer can experience difficulty in evaluating competitive seed bids, unless enough information is requested to determine the relative quality of the seed lots offered.

Special Considerations

This subsection outlines the information that must be requested in order to properly evaluate seed bids, and includes a sample bid request sheet.

Technique

The attached sample bid sheet (Figure C-2-1) shows one way to prepare a seed bid request. The following variables should be considered when purchasing seed (numbers correspond with figure):

--- Select a named variety or a native collection. (2)

--- Is it Blue-tag Certified or Yellow-tag Source Identified? (2)

--- Is it offered on a Pure Live Seed (PLS) basis? (5)

--- Is the purity high enough to reduce problems with stems, and fluffy or non-debearded seed? (7)

--- Is the germination high enough to indicate vigorous seed? (8)

--- What kinds of other crop seed? e.g., 4% yellow sweet clover could pose a problem. (10)

--- How many and what kinds of weed seeds? Even if the weed is not legally listed as noxious, certain "common" weeds, such as the weedy bromes, cheat grass, and chess could affect revegetation. (11)

--- Origin is important with warm-season grasses such as sand dropseed, blue grama, sideoats grama, alkali sacaton; and some shrubs such as fourwing saltbush, sagebrush, and winterfat. (13)

--- Date tested. Although most seed stores well, sagebrush, winterfat, rabbitbrush, and greasewood often start to drop in viability after 9 months. If the seed is not the previous year's crop, request a new germination test completed within 3 months. (14)

--- All germinations may be based on Tetrazolium (TZ) tests for shrub seed.

--- All grasses to be sold on the basis of germination test, except Indian ricegrass.

--- Indicate year collected for shrubs.

--- Buyer may request an official seed laboratory analysis, signed by a certified seed analyst, for each lot of seed offered.

If the buyer notifies the vendor that he intends to purchase all the seed from a single vendor, rather than pick-and-choose, he will usually get a better package price. If a certain species is in short supply, such as *Atriplex gardneri*, *Ceratoides lanata*, or *Sphaeralcea coccinea*, it will often be high priced or not offered at all on a pick-and-choose bid.

The following schedule provides for submitting offers for either certified or non-certified seed or both. The buyer reserves the right to award on any item offered. All awards will be based upon the lowest pure live seed (PLS) price offered on each item. Award may be made on a higher PLS priced certified seed versus a non-certified PLS priced seed of the same species and variety; or may be made on the basis of weed content, other crop content, or origin.

TABLE BID SCHEDULE - Bidder must complete Column (4) through (14) So

Item No.	SEED. Agricultural (type)	QUANTITY IN PLS POUNDS		PLS PRICE PER POUND	TOTAL AMOUNT	BIDDER'S SPECIFICATION						SEED ORIGIN (STATE)	DATE TESTED
		NEEDED	OFFERED			PUR	GERM	PLS RATING	% CROP	% WEED	WEED & OTHER CROP NUMBER SEEDS/LB.		
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**
1A	Certified *Agropyron dasystachyum* Thickspike wheatgrass Critana	2,000											
1B	Non-Certified *Agropyron dasystachyum* Thickspike wheatgrass Critana	2,000											
2A	Source Identified *Artemesia tridentata* Wyoming Big Sagebrush Wyomingensis	1,000											
2B	Non-Source Identified *Artemesia tridentata* Wyoming Big Sagebrush Wyomingensis	1,000											

3. Warm Season Grasses -- The Importance of Origin of Named Varieties and Native Harvests

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

Grasses can be categorized as either warm- or cool-season, depending upon their germination and growth temperature requirements. Warm-season grasses germinate in the late spring when soil temperatures are warmer, and grow during the heat of the summer. Cool-season grasses, on the other hand, germinate early in cool soils and grow in the spring and the fall. In general, cool-season varieties can be moved farther from their origin (the location from which the breeder originally collected seed) than can warm-season varieties.

Special Considerations

Current named varieties of native plants are selected ecotypes that exhibit superior performance for defined areas of adaptation. The experience of the Soil Conservation Service indicates that a warm-season ecotype can be moved about 300 miles north or 200 miles south of its origin without having serious problems of winter hardiness, longevity, and disease. Movement east or west can cause problems due to changes in precipitation and elevation. Generally, an increase of 1,000 feet in elevation is equivalent to a move of 175 miles north. However, the rule is not universally applicable as photoperiod changes with changes in latitude, while it remains the same despite elevation changes.

Varieties developed from northern ecotypes mature earlier, are shorter, are lower in total forage production, and are more susceptible to leaf and stem diseases when moved southeastward from their point of origin. Varieties developed from southern ecotypes generally mature later, are taller, and produce higher yields of forage. These differences become more visible when moved north from the original area of collection. However, varieties moved too far north may not be winter hardy and stands may be reduced or completely lost during the year of establishment or under stress conditions applied by climate or management factors.

Technique

When seeding native species, use certified, blue-tagged seed of selected varieties known to be adapted to your site (Figure C-3-1). Certified seed assures proper identity and genetic purity of the selected variety. An alternative is to use seed harvested from range or native haylands within your zone of adaptation. Care must be exercised, however, as range-collected seed may be contaminated with noxious weeds. The guidelines for native species do not apply to introduced species; however, each introduced species and/or variety has a definite, though greater, range of adaptation.

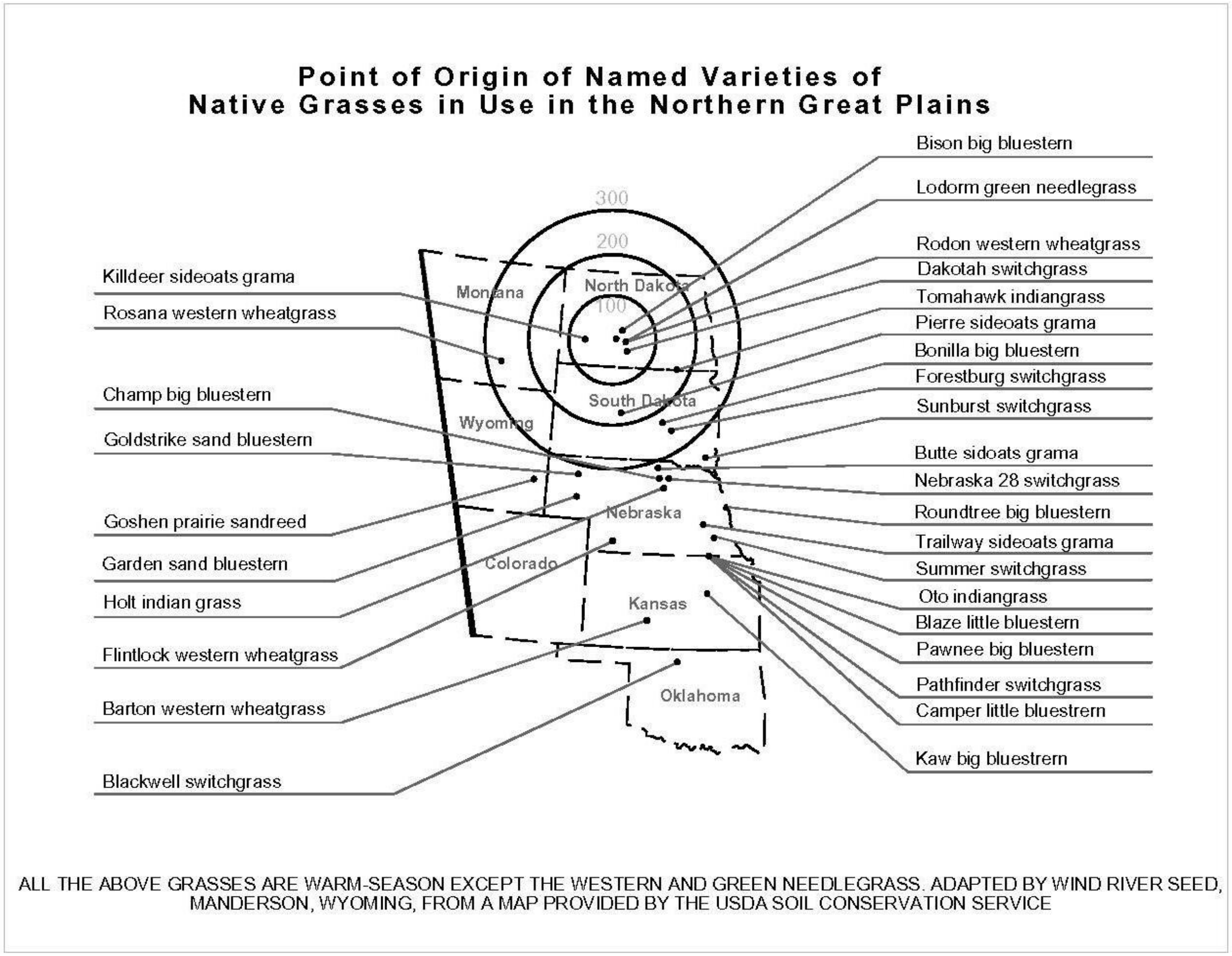

Point of Origin of Named Varieties of
Native Grasses in Use in the Northern Great Plains
300
200
100
Montana
North Dakota
South Dakota
Wyoming
Nebraska
Colorado
Kansas
Oklahoma
Killdeer sideoats grama
Rosana western wheatgrass
Champ big bluestern
Goldstrike sand bluestern
Goshen prairie sandreed
Garden sand bluestern
Holt indian grass
Flintlock western wheatgrass
Barton western wheatgrass
Blackwell switchgrass
Bison big bluestern
Lodorm green needlegrass
Rodon western wheatgrass
Dakotah switchgrass
Tomahawk indiangrass
Pierre sideoats grama
Bonilla big bluestern
Forestburg switchgrass
Sunburst switchgrass
Butte sidoats grama
Nebraska 28 switchgrass
Roundtree big bluestern
Trailway sideoats grama
Summer switchgrass
Oto indiangrass
Blaze little bluestern
Pawnee big bluestern
Pathfinder switchgrass
Camper little bluestrern
Kaw big bluestrern
ALL THE ABOVE GRASSES ARE WARM-SEASON EXCEPT THE WESTERN AND GREEN NEEDLEGRASS. ADAPTED BY WIND RIVER SEED, MANDERSON, WYOMING, FROM A MAP PROVIDED BY THE USDA SOIL CONSERVATION SERVICE

Figure C-3-1

4. Certified Blue-tag Versus Non-certified (Common) Seed

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

In the seed industry, Seed Certification is the means of maintaining the pedigree of a specific variety of seed (such as the named variety “Goldar,” which is a variety of blue bunch wheatgrass). Each variety is released for propagation because it is deemed superior in one or more characteristics, such as seedling vigor, low dormancy, broad range of adaptability, seed production, form and color, or palatability. Each state has a Seed Certifying Agency (or Crop Improvement Association) which writes the rules for seed produced in its state. Some seed growers voluntarily use certification to assure their customers that extra care has been taken to provide them with:

1. Correctly identified, genetically pure seed
2. High mechanical purity and germination
3. Freedom from the worry of noxious weeds

Special Considerations

Even though a bag may not have a blue tag, it may still contain the variety claimed. A seed lot may fail certification merely because the mechanical purity was proven to be slightly lower than the standard for that variety; or, since certified seed often does not command a much higher price than common seed, a grower may not go to the trouble and expense of having his field and cleaning plant inspected by the seed certifying agency. Since varieties cannot be determined by observing the seed in the laboratory, the integrity of the grower and the seed dealer determine whether the seed is truly the variety claimed on the label.

The blue tag assures the buyer that the seed in the bag meets high purity and germination standards, as well as low levels of other crop seed and weed seed (usually less than 0.25%). There are no standards for non-certified seed other than state limitations on weed seed (often as high as 2.00%).

Freedom from worry over noxious weeds is another benefit of field inspection. Common or native fields are not walked by the inspector, and a "clear tag" laboratory test will be based on only 25,000 seeds (about 60 grams). A noxious weed missed in the sample may show up in subsequent samples (if they are taken), or after the seed is in the ground, when a costly spray control program is the only course remaining. Eradication is difficult to achieve once noxious weeds become established.

Technique

Many seeders have already found that quality seed pays in better establishment, permanence, and absence of noxious weeds. The trend toward blue-tagged seed supports reputable seed companies and encourages growers to produce enough high quality seed to meet the demand.

To ensure receipt of certified seed, specify on seed orders:

> "Certified blue-tagged seed shall be supplied where a named variety is specified. Vendor shall indicate on the bid whether certified or common seed is being offered, as well as the origin of the seed. The blue tags removed when the seed is mixed

shall be given to the revegetation engineer; in addition, mix tags showing the weighted averages of the ingredients shall be attached to each bag."

5. Source-identified Yellow-tagged Seed

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

Until the advent of the "Source-Identified" class of certified seed, a buyer had no way to verify the actual collection site of native harvest seed. For example, cheaper southern origin seed would be relabeled and sold as northern origin to garner higher prices. At the request of buyers and reputable seed collectors, national standards have been set by the Tree, Shrub, and Native Grass Committee of the Association of Official Seed Certifying Agencies (AOSCA). The Source-Identified system is in place in Wyoming, Utah, Colorado, Montana, and New Mexico.

Special Considerations

On-site inspection is done by the seed certifying agency to verify the county and elevation of the collection site, and the identity of the species. There is no guaranteed freedom from noxious weeds; the buyer should refer to the supplier's label for analysis and weed content. The certifying agency will issue the collector enough yellow tags (Figure C-5-1) to tag the number of bags of cleaned seed collected.

Technique

When asking for prices of native shrubs, have vendors indicate on their bids whether the seed is Yellow-tag Source-Identified, and the state, county, and elevation of the collection site. If the seed is to be mixed, have the vendor provide the yellow tags.

FIGURE C-5-1

SOURCE-IDENTIFIED CLASS

WYOMING CERTIFIED SEED

Species *Artemisia tridentata Wyomingensis*

Common Name WYOMING BIG SAGEBRUSH

Geographic Source LINCOLN COUNTY, WYOMING

Elevation **6800 FT.** ***Lot # 1029***

MEMBER OF ASSOCIATION OF OFFICIAL SEED CERTIFYING AGENCIES, INC.

LIMITATIONS OF LIABILITY APPLICABLE: CALL FOR COPIES

6. Understanding Seed Tests

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

The use of seed tests is often helpful in evaluating seed quality and vendor claims; however, the limitations of seed testing are also important to understand.

Special Considerations

Seed is tested to monitor the veracity of claims made by vendors on the bag label, to monitor storage conditions, or to check for weeds. There are vendors who are sloppy, who cheat, or who are unable to meet the rigors imposed by demanding buyers. A savvy buyer needs to test for purity, germination, and weed content to verify the quality of the seed. Using blue-tagged Certified seed reduces the need to test, since a paper trail of independent verification exists for each blue-tagged lot.

Certified seed older than one year should be retested for germination by the vendor. Seed with a very short shelf life, such as sage, rabbitbrush, winterfat, or greasewood, should be tested for germination frequently. Chaffy native harvests, such as blue grama, should be tested for noxious weeds and undesirable common weeds. Reclamation specialists should be extremely wary of introducing noxious weeds and excessive numbers of weedy annual brome species. Unwanted infestations interfere with the establishment of desirable revegetation species, can be expensive and sometimes impossible to eradicate, and could create litigation exposure if the noxious weed spreads to adjacent landowners.

Technique

a. How to Test

Most state agriculture departments employ inspectors who will sample seed and send it to the state seed lab. With advance notice, seed inspectors will come to a warehouse free of charge. Make sure the inspector has a probe long enough to reach lengthwise through a bag. The probe may be critical for sampling mixes in which small seed may migrate through larger seed during shipping and concentrate on the margins. The seed inspector should randomly sample bags in the following way:

(1) Sample at least five bags, plus 10% of the bags in a given lot.

(2) With very chaffy, non-flowing seed such as winterfat or blue grama, sample by hand, rather than probe, from various parts of the bags. Use the same sampling formula as above.

(3) Sample should weigh 100 grams, or contain at least 25,000 seeds.

(4) Indicate which tests to perform; usually purity and tetrazolium (TZ).

(5) Box samples to avoid crushing in the mail.

(6) Do not subject samples to temperature or humidity extremes. Do not place samples in auto trunks or on dashboards on hot days.

If time is a consideration, a buyer can draw their own samples with a probe and send them to the chosen seed lab; however, the results are less open to dispute if a

Department of Agriculture employee is called. If questions arise over a lab result, the vendor should be allowed to suggest labs or tests to verify his claims.

b. *What Tests to Order*

Often, when the buyer wants to get the seed in the ground immediately, or when the vendor needs to be paid, time dictates what tests to order. Germination tests are the most accurate tests for most grass species, but may take up to 25 days to complete. The TZ test is a 48-hour test which estimates germination through a process in which live seeds are chemically stained. Purity (which includes the weed test) can be done as soon as an analyst gets to it, sometimes becoming available the same day a sample is received.

Fees for tests vary by lab and by species tested. For an extra charge a sample may be "Rushed". A full seed test of purity and germination may cost anywhere from $30 to $70 per sample for a single species. Shrub seed and TZ tests cost somewhat more than grass seed and germination tests.

It is strongly recommend that if seed is to be tested, it be done before being mixed with other lots. Some grass seed and most native shrub seed should be sent for a TZ test rather than for germination. Not all species react favorably to standard germination techniques, and standardized rules for germination don't exist for unusual wildland species. For instance, some species exhibit a high degree of dormancy, which may not respond to germination techniques, or may be susceptible to fungal attack under laboratory germination settings. The following is a list of species which should be tested for TZ rather than germination:

> Indian ricegrass, green needlegrass, fourwing saltbush, gardner saltbush, mat saltbush, skunkbush sumac, woods rose, Rocky Mountain juniper, bitterbrush, chokecherry, northern sweetvetch, lupine, Rocky Mountain bee plant, thermopsis, and sagebrush.

During a time of seed shortage, or when dealing with unusual species, seed may be sold on the basis of a cut test, or utricle fill. No claim is being made about germinative potential or dormancy, only that the seed is filled; in fact, the seed may not even be alive. Any vendor selling seed by fill should make this clear to the buyer.

c. *Interpreting Test Results*

Germination results are statements of statistical probability, and can be influenced by many factors. As an example, the sample may not be representative of the entire lot of seed. Especially with trashy seed such as sagebrush, samples tend to be far from homogeneous; two samples from the same bag can vary widely in both purity and germination. Tables of variance used by seed labs to assess seed quality (Table 1), are based on the degree of homogeneity found in flowable seeds such as corn and wheat. From the standpoint of homogeneity, western wheatgrass would be considered trashy; sagebrush approaches statistical anarchy.

Tolerance tables (Tables C-6-1 and C-6-2) are used to compare different analyses of purity and germination. The analysis stated on a seed bag label can be compared with additional analyses to decide whether there is a real deficiency. Obviously, incorrect analyses are discarded and remaining tests averaged. If the difference between the averaged tests and the analysis stated on the label exceed tolerances established for that level of purity and germination, then the original sample is considered deficient. The tolerances have a probability of error of 5% and are meant to compare testing averages. The use of tolerances to determine the variation between only two tests should be done with great caution, recognizing that the probability of error is higher than if several tests are averaged.

Uncertainty in sampling and testing increases as purity and germination decrease, with the greatest uncertainty between 40% and 60% purity and germination below 60%. Tests of trashy seed usually have a larger margin of error than do those for non-trashy seed. However, as PLS approaches zero, sample homogeneity once again increases, as does statistical certainty. Samples of non-chaffy seed averaging 99.00% pure with a 99% germination actually reflect a 95% probability that test samples will show a purity of between 98.41% and 99.59% (Table 1), and 95% probability that the test samples will show a germination between 94% and 100% (Table 2). Reading from those same tables, a test series with an average 25% purity and 60% germination could be interpreted in this manner: A 95% probability that a test result will fall within the tolerance range of 21.96% to 28.04% purity and a germination range of 51% to 69%.

Due to several factors, variations within native-collected trashy seed lots may exceed the tolerances on Tables 1 and 2. Seed quality may vary substantially depending on the time of day collected, soil properties, competition among plants collected within the same patch, and access to moisture by individual plants. Variation may become more pronounced within a stand of shrubs when a limiting factor such as rainfall influences seed set. Given the high variation of seed within a native stand during collection, and given the difficulty of mixing trashy seed lots to achieve homogeneity, expect variations in shrub tests beyond tolerances.

Although seed testing requires expertise and time, and sometimes yields ambiguous results, it is an important tool in helping to guarantee the desired outcome.

TABLE C-6-1. Regular tolerances for any component of a purity analysis.
SOURCE: ASSOCIATION OF OFFICIAL ANALYSTS

Average Analysis Purity		Nonchaffy Seeds	Chaffy Seeds
A	B	C	D
99.95 - 100.00	0.00 - 0.04	0.13	0.16
99.90 - 99.94	.05 - .09	.20	.23
99.85 - 99.89	.10 - .14	.24	.29
99.80 - 99.84	.15 - .19	.28	.34
99.75 - 99.79	.20 - .24	.32	.37
99.70 - 99.74	.25 - .29	.35	.41
99.65 - 99.69	.30 - .34	.37	.45
99.60 - 99.64	.35 - .39	.40	.48
99.55 - 99.59	.40 - .44	.42	.50
99.50 - 99.54	.45 - .49	.44	.53
99.40 - 99.49	.50 - .59	.47	.57
99.30 - 99.39	.60 - .69	.51	.60
99.20 - 99.29	.70 - .79	.54	.64
99.10 - 99.19	.80 - .89	.57	.66
99.00 - 99.09	.90 - .99	.59	.70
98.75 - 98.99	1.00 - 1.24	.64	.75
98.50 - 98.74	1.25 - 1.49	.71	.82
98.25 - 98.49	1.50 - 1.74	.76	.89
98.00 - 98.24	1.75 - 1.99	.82	.95
97.75 - 97.99	2.00 - 2.24	.87	1.01
97.50 - 97.74	2.25 - 2.49	.92	1.07
97.25 - 97.49	2.50 - 2.74	.96	1.12
97.00 - 97.24	2.75 - 2.99	1.00	1.17
96.50 - 96.99	3.00 - 3.49	1.06	1.24
96.00 - 96.49	3.50 - 3.99	1.14	1.34
95.50 - 95.99	4.00 - 4.49	1.21	1.41
95.00 - 95.49	4.50 - 4.99	1.27	1.49
94.00 - 94.99	5.00 - 5.99	1.36	1.60
93.00 - 93.99	6.00 - 6.99	1.47	1.73
92.00 - 92.99	7.00 - 7.99	1.58	1.85
91.00 - 91.99	8.00 - 8.99	1.67	1.96
90.00 - 90.99	9.00 - 9.99	1.75	2.06
88.00 - 89.99	10.00 - 11.99	1.87	2.19
86.00 - 87.99	12.00 - 13.99	2.01	2.36
84.00 - 85.99	14.00 - 15.99	2.14	2.51
82.00 - 83.99	16.00 - 17.99	2.24	2.64
80.00 - 81.99	18.00 - 19.99	2.35	2.76
78.00 - 79.99	20.00 - 21.99	2.44	2.86
76.00 - 77.99	22.00 - 23.99	2.52	2.96
74.00 - 75.99	24.00 - 25.99	2.59	3.04
72.00 - 73.99	26.00 - 27.99	2.65	3.12
70.00 - 71.99	28.00 - 29.99	2.71	3.19
65.00 - 69.99	30.00 - 34.99	2.80	3.29
60.00 - 64.99	35.00 - 39.99	2.89	3.40
50.00 - 59.99	40.00 - 49.99	2.96	3.48

EXAMPLE: A lot is of unmixed non-chaffy seed. The tolerance for non-chaffy seed is in column C. The percentage of pure seed in the first and second analyses, respectively, are 89.65 and 87.55; the average is 88.60; and the apparent deficiency is 2.10 (89.65-87.55). The average is between 88.00 and 89.99, which are on a line in column A. Therefore, the tolerance is 2.19. Since the apparent deficiency does not exceed the tolerance, the deficiency is not considered real and the percentage of pure seed given on the label may be considered satisfactory.

TABLE C-6-2. Germination tolerances

The following tolerances are applicable to the percentages of germination, and also to the sum of the germination plus the hard seed, when 400 or more seeds are tested:

Mean	Tolerance
96 or over	5
90 or over but less than 96	6
80 or over but less than 90	7
70 or over but less than 80	8
60 or over but less than 70	9
Less than 60	10

When only 200 seeds of a mixture are tested, 2% shall be added to the above germination tolerances.

7. Determining Pure Live Seed

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

When purchasing seed by bulk pounds, a buyer is paying for not only Pure Live Seed (PLS), but also inert materials such as dust and chaff, and other crop seed or weed seed. Buyers can obtain a much better dollar value through purchasing seed by the PLS pound.

Special Considerations

Since every seed lot has a different analysis, a system has been devised that allows customers to buy only the pure, live seed in a bag.

Technique

To figure the Pure Live Seed percentage, multiply the purity percentage by the germination percentage of the seed lot. By then multiplying the Pure Live Seed percentage by the weight of the bag, one can determine the amount of pure live seed in the bag. Let us compare two lots of seed to determine the best value:

Lot A is labeled 98% pure with a 95% germination and costs $5.00 per bulk pound.
Lot B is labeled 89% pure with a 92% germination and costs $4.75 per bulk pound.

Lot A: .98 x .95 = .931 PLS
Lot B: .89 x .92 = .819 PLS

Now divide the seed cost by the PLS percentage to determine the Pure Live Seed cost:

Lot A: $5.00 ÷ .931 = $5.37 per PLS pound
Lot B: $4.75 ÷ .819 = $5.80 per PLS pound

As you can see, the seed lot that was less expensive on a bulk seed basis actually represents an inferior value on a PLS basis. Seed with a higher PLS rate tends to have more vigorous, healthy seed than seed with a lower PLS rate. Also, higher quality seed costs less to ship. Let's see how many pounds of seed would be shipped if one ordered 1000 PLS pounds from these seed lots:

Lot A: 1000 ÷ .931 = 1074 bulk pounds
Lot B: 1000 ÷ .819 = 1221 bulk pounds

In order for a purchaser to adequately evaluate seed value, Pure Live Seed prices must be determined before seed is purchased.

8. Selecting Good Shrub Seed

Section editor: Larry H. Kleinman *Subsection author: Richard Dunne*

Applicability

Purchasing and evaluating seed requires an understanding of species peculiarities and pitfalls. This subsection is a general guide for shrub seed evaluation.

Special Considerations

Each species has different characteristics for adaptability, shelf life, purity, germination, and planting. Seed tests are important in evaluating a seed lot, and ocular inspection may detect irregularities requiring further attention.

Technique

a. Sagebrush

(1) Origin

Whenever possible, select seed of northern, locally adapted ecotypes. Yellow-tagged, Source-Identified seed is becoming available and is the best guarantee that the origin is correctly stated. Although some species are not site specific, the best choice is within your geographic area and elevation.

(2) PLS

Ask the vendor what year the seed was harvested; the older the seed, the more frequently the seed should be retested for germination. Seed collected in November and germinated in December or January will have a test that will carry it through the following fall. Beyond that time, the buyer should insist on seed tests no older than three months to assure that it is still viable. Sage is usually tested by tetrazolium (TZ). A good purity is 12% or better; a good TZ is 65% or better. As with all range-collected shrub seed, purity and TZ may be much lower in drought-year crops. Poor test results during good crop years may be a sign of a "troubled" seed lot.

(3) Seeding

Seed should be sown on the soil surface. As with most surface shrub seedings, late fall or early spring seeding capitalizes on snow melt to create conditions favorable for germination.

(4) When purchasing sagebrush seed, look for the following warnings signs:

(a) A stale, musty smell may indicate the seed is not from a new crop.

(b) Seed rubbed out of its pericarp or inert material, or ground very fine may indicate over-processing and heat or mechanical damage.

(c) Less expensive Basin big sage is sometimes passed off as silver sage, which has a much larger seed and a different smell. There should be no trident leaves in a bag of silver sage, which has smooth-tipped leaves.

b. Fourwing Saltbush

(1) Origin

Northern adapted ecotypes are now coming onto the market as yellow-tagged, Source-Identified seed, which generally has more resistance to winterkill and a greater ability to regenerate. Avoid New Mexico or Arizona ecotypes, whenever possible. Utah, Colorado, and Wyoming ecotypes are often more expensive and frequently unavailable.

(2) PLS

This seed stores well, so testing every 12-months is adequate. Fourwing is usually tested by Tetrazolium, which is more indicative of viability than mere utricle fill. A good purity is 95%; a good TZ is 40%.

(3) Seeding

Fourwing should be drill seeded 1/2-inch deep.

(4) When purchasing fourwing seed, look for the following warning signs:

(a) Some seed from New Mexico and southern Utah has been known to be infested with field bindweed or wild morning glory (*Convolvulus arvensis*).

(b) Watch for broken utricles as a sign of over-processing.

(c) Watch for greyed or discolored seed. This may indicate a post-harvest drying problem.

(d) Native fourwing rarely tests over 70% viable by TZ; question a high TZ.

c. Winterfat

(1) Origin

Northern adapted ecotypes are not likely to be available for several years. Most seed originates in New Mexico or Arizona as Sonoran Desert transition ecotypes. Expect chronic shortages as greater demand chases available seed. "Hatch" is a selected cultivar from a Utah ecotype.

(2) PLS

Seed storage life is one to two years. Beyond September of the year following collection, the buyer should insist on tests no older than three months. Winterfat is usually tested by Tetrazolium. A good purity is 70%; a good TZ is 55%.

(3) Seeding

Seed should be sown on the soil surface.

(4) When purchasing winterfat seed, look for the following warning signs:

(a) Yellowing fluff on the seed may indicate age, improper drying, or premature collection.

(b) Utricle breakage reduces viability and storage life significantly. There will be some breakage in all lots, but more than 10% should be cause for further scrutiny.

d. Rabbitbrush

(1) Origin

Rabbitbrush seems to be more amenable to being moved than other shrub species. Any source from a neighboring state is probably adequate, and is usually readily available.

(2) PLS

Rabbitbrush often has a very poor storage life, with significant loss of viability possible at any time, and with a high likelihood of serious viability loss within one year of collection. Purity can be as high as 50%, but is usually about 20%. A good TZ would be 65% or better.

(3) Seeding

Seed should be broadcast on the soil surface.

(4) When purchasing rabbitbrush seed, look for the following warning signs:

(a) Broken seed indicates over-processing. The remaining seed may be microscopically cracked.

(b) Yellowing of inert material (fuzz) may indicate aging.

(c) Good seed should snap when bent; unfilled seed bends without snapping.

e. Greasewood

(1) Origin

The ecotype sensitivity of greasewood is poorly understood. Select the nearest origin possible.

(2) PLS

Seed has a shelf-life of one to two years. A purity of 40% to 60% can be expected, and a TZ above 40% is acceptable.

(3) Seeding

Greasewood should be drill seeded to a shallow depth.

(4) When purchasing greasewood seed, look for the following warning signs:

(a) Broken utricles or excessively rubbed wings may indicated processing damage.

(b) Holes in utricle sides are signs of insect damage. If seed is labeled as 60% TZ, but 50% of the utricles have holes, the seed may be mislabeled.

D. SURFACE STABILIZATION

1. Vegetative Surface Stabilization

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

One of the greatest threats to the physical integrity and ability of re-topsoiled spoil to support plant growth is surface erosion. Steep, smooth, and unrevegetated spoils are subject to high rates of water and wind erosion. The stability of the site is lessened, valuable topsoil is lost, and the cost of repair is very high. In addition, State and Federal regulations govern the amount of acceptable erosion.

There are several factors that increase the amount of erosion or lessen the stability of a reclaimed site. The more important factors are probably: slope steepness, slope length, type of drainage provided, lack of and/or type of control structures, lack of vegetation, and the physical properties of the spoil and soils material.

Special Considerations

Soils and slopes are stabilized and erosion reduced by intercepting and reducing raindrop impact, and by slowing down, redirecting, and allowing infiltration of surface runoff. There are many successful methods for stabilizing soil. Only the methods that have been tried and proven successful on surface mined lands will be presented. Surface manipulation (non-vegetative) methods are mentioned in a separate subsection. Vegetative techniques for soil stabilization will be discussed here.

Technique

a. Establishment of a Vegetative Cover

The establishment of a vegetative cover is basic to successful soil stabilization. The raindrop impact energy is expended on vegetation rather than soil. Surface flow velocity is decreased by the vegetation and infiltration is increased. The root system binds soil particles together, which reduces particle movement and transport. Therefore, the goal is to provide a vegetal cover as quickly as possible.

The timing of vegetation establishment is vital for success. The optimum planting season is just before the longest period of favorable growing conditions. This period is the longest period of sufficient soil moisture and when the soil temperature is high enough to initiate seed germination but not so high as to retard growth.

Techniques for stabilizing slopes and soils include immediate vegetation establishment, and mulching. There is no need for a detailed description of these methods in this subsection. The goal and concern is to revegetate the soil surface as quickly as possible. The methods listed here and described in other subsections have been tried and proven successful in stabilizing soils and slopes with the very least amount of erosion and soil loss.

(1) Immediate Vegetation Establishment

(a) Drill Seeding
Drill seeding places the seed in the soil surface at a prescribed depth. Exact methods are described in the subsection entitled "Drill Seeding Practices".

(b) Hydroseeding
Hydroseeding is a method of placing the seed on the soil surface in a water slurry mixture. More exact methods are described in the subsection entitled "Hydroseeding Practices".

(c) Broadcast Seeding
Broadcast seeding places the seed on the soil surface by means of a whirly bird type of seeder (cyclone seeder), by hand, by seed dribblers, or even by airplane. Needless to say, there not many mines that reseed by airplanes. The other methods are used extensively for light fluffy seed, such as sagebrush and rabbitbrush. More exact methods are described in the subsection entitled "Broadcast Seeding".

(d) Transplanting Live Plants and Planting Plant Parts
These methods include containerized stock, bareroot stock, shrub/tree pads, and sprigs or cuttings. These methods are described elsewhere in this section.

(2) Mulching

Mulching places a layer of inorganic or (most preferred) organic material on the soil surface and on top of the seed to increase soil moisture, prevent erosion, moderate the soil temperature, and increase the potential for seedling establishment. These methods of mulching are described in detail in a previous subsection and are only listed here:

(a) Nurse Crop
(b) Cover Crop
(c) Native Hay Mulch
(d) Straw Mulch
(e) Wood Fiber Mulch
(f) Paper Fiber
(g) Wood/Paper Fiber
(h) Synthetic Fiber

2. Non-vegetative Surface Stabilization

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

One of the greatest threats to the physical integrity and ability of retopsoiled spoil to support plant growth is surface erosion. Steep, smooth, and unrevegetated spoils are subject to high rates of water and wind erosion. The stability of the site is lessened, valuable topsoil is lost, and the cost of repair is very high. In addition, State and Federal regulations govern the amount of acceptable erosion.

There are several factors which increase the amount of erosion or lessen the stability of a reclaimed site. The more important factors are probably: slope steepness, slope length, type of drainage provided, lack of and/or type of control structures, lack of vegetation, and the physical properties of the spoil and soils material.

Special Considerations

Soils and slopes are stabilized (erosion reduced) by intercepting and reducing raindrop impact, and by slowing down, redirecting, and allowing infiltration of surface runoff. There are many successful methods for stabilizing soil. Only the techniques that have been tried and proven successful on surface mined lands will be mentioned here. Surface manipulation (non-vegetative) techniques are also discussed in the Hydrology section of this handbook. Those techniques include most types of control structures except for contour furrowing.

Technique

a. Contour Furrowing

Contour furrowing across the slope has been used to intercept surface runoff and redirect it back into the uphill side of the slope. The contour furrows are generally cut into slopes that have gradients from 5H:1V to 3H:1V. The furrows (ditches) are generally cut with a small track dozer such as a D-6, because a motor grader with a 14 or 16-foot blade cannot safely traverse the steep slope.

b. Sequence of Operations

The furrow may be cut into the slope before farming, seeding, and mulching; however, these operations are more easily and safely accomplished without the furrows in place. Some seed and mulch will be lost in the bottom of the furrow, but will be placed on the berm or outside edge of the furrow. The extra mulch and vegetation on the berm better stabilize the structure with less cutting through. The vegetation will soon spread into the bottom of the furrow because of increased moisture supply.

(1) Before Furrowing

(a) The spoils are regraded to the desired gradient and topography.

(b) The regraded spoils are retopsoiled to the desired depth.

(c) The area is farmed and reseeded with the desired species.

(d) The area is then mulched with native hay and crimped. Other types of mulches may be used if desired. It is easier to mulch before furrows are cut, thus eliminating running equipment across the furrows.

(2) Steps of Operations in Building the Contour Furrows

(a) The contour furrows are cut into the slope with the D-6 dozer at a gradient of two to three percent. The furrows should not be "0" gradient as the runoff needs to gradually drain back into the slope of the hill. If it does not drain back, runoff will pond and cut through the furrow causing rilling and gullying downslope.

(b) The furrow should be cut to a depth of one to two feet and a width of five to six feet.

(c) A contour furrow should be cut into the slope approximately every 50 to 100 foot run of the slope. Therefore, a slope with a length of 400 feet should have four or five contour furrows cut into it.

E. HUSBANDRY

1. Mowing for Weed Control

Section editor: Larry H. Kleinman *Subsection author: Laurel E. Vicklund*

Applicability

Annual weeds can present problems in newly seeded areas. Chemical control is costly and sometimes not feasible. Mowing offers an economical option for weed control.

Special Considerations

Areas seeded to permanent grass should be evaluated periodically during the first few growing seasons. Noxious weeds and other problems need to be identified and dealt with as soon as they develop.

Once permanent vegetation is seeded, treatment options for the area are limited so as not to affect the bonding clock. Mowing to control annual weeds provides good results with low environmental impact on the area, and does not restart the bonding clock. Mowing maintains a stubble cover, but prevents seed set for the year and knocks back the weeds that take available moisture from the developing grasses.

Technique

Annual weeds are a prevalent feature of reclaimed areas. They serve the function of shading small grass seedlings, collecting snow, reducing wind erosion, and aid in the stabilization of the ground against water erosion until the permanent grass seedlings are established. However, abundant annual weed growth utilizes soil moisture and chokes out new seedlings.

During the first summer after permanent grass mixtures have been seeded, a rotary deck type mower can be used to cut the annual weeds. This should be done prior to weed flowering and seed production. The weeds usually have enough height to be cut by May or early June. If the year is moist enough, the area may need additional mowing later in the summer. Multiple mowing reduces the size of the windrow created.

2. Burning to Enhance Vegetation

Section editor: Larry H. Kleinman *Subsection author: Laurel E. Vicklund*

Applicability

Successful reclamation depends on moisture received during the year in the form of rain and snow. Without adequate moisture, even with the best tillage and seeding techniques, reclamation will fail. Often the failure is not immediately identified. By the time a seeding failure is noticed, the area can be covered with too much vegetative matter to make drill seeding or hydroseeding possible.

A firm seed-bed already exists beneath the vegetative rubble; therefore, it is not advantageous to re-till the area. Burning the vegetative matter removes the surface trash for reseeding to take place with a minimum of seed-bed preparation.

Special Considerations

State Air Quality officials may require a burning permit prior to burning activities. Burn days usually must coincide with air sampling run days. Local county officials will also usually require notification prior to burning an area.

Site specific safety regulations should be followed for a planned burn, and safety equipment and pertinent safety personnel should be advised and on hand. Areas that have steep slopes may need additional protection from erosion after the burn.

Techniques successful for burning to enhance vegetation are very site-specific. The Cordero Mine has had good results from using these techniques. The size of the area will vary from site to site. Do not start a fire larger than you feel you have the personnel and equipment necessary to extinguish.

Weed seeds will not necessarily be destroyed by the fire, so additional weed control methods may be needed. Mowing as weed control is economical, and does not have the environmental concerns associated with chemical weed control. However, perennial noxious weeds cannot be controlled by mowing and need aggressive treatment when found in reclamation.

Technique

Areas to be excluded from the planned burn should be identified. A plan should be developed to ensure the burn will be contained in the identified area. Natural barriers work the best for a planned burn. For example, roads, ditches, rock areas, or other areas devoid of vegetation work well as natural barriers.

When possible, the burn should be planned around a planting season. Most burning is done in the fall or spring, so this fits right in. The less time that elapses between the burn and reseeding, the less chance for erosion to develop before the grass cover is adequately established.

Check the wind direction and velocity prior to starting the fire. Pick a time when vegetative cover in the area is dried but regional burning is not banned. Start the fire in the corner of the area that the wind is coming from, opposite from the corner of the barrier and perimeter of the area. In this way, the wind will carry and spread the fire towards the barrier of the burn. An area seems to burn best with a slight wind, however an excessive wind can spread the fire past the barriers and out of control.

Once the fire has consumed the area, check to ensure that it is completely out. Extinguish any areas that have not burned out. Some areas that had excessive trash cover may need extra attention to ensure a complete burn and reduce the danger of fire spreading after the burn.

Interseed the area at the first available seeding window. Drilling should be done on the contour to reduce erosion.

3. Husbandry Grazing

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

There are certain circumstances under which livestock grazing can be used to effect changes in the species composition of a revegetated stand once the vegetation has become established. For example, annual bromegrasses are very difficult to control without plowing and refarming the field or utilizing complete herbicidal control. Judicial use of late fall and early spring grazing by livestock has been shown to decrease the amount of annual bromegrasses.

There may be older seeded stands that have a preponderance of introduced species that are suppressing more desirable native species. Smooth bromegrass and crested wheatgrass often begin spring growth several weeks before other cool season grasses and certainly before warm season grasses. Heavy grazing in the early spring can cause a decrease in the early growing cool season grasses and an increase in the later growing grasses.

Litter buildup can occur on revegetated areas that have not been grazed, burned, or hayed. This buildup of litter will continue until the seeded species are suppressed, if no action is taken.

Special Considerations

The livestock owner must be flexible in cooperating with the reclamationist. The reclamationist must be able to bring the cattle onto the revegetation at just the right time and take the cattle off the revegetation with only a day or two notice. The reclamationist must be on hand to determine when the grasses desired for control are ready to be grazed and when the grasses desired for increase begin active growth. The desired species should be dormant at the time of grazing.

Technique

Livestock grazing for the following three described purposes, annual bromegrass control, introduced cool season grass suppression, and litter reduction, may and probably should take place in concert with each other. It must be emphasized that the timing of grazing be flexible and that the reclamationist be cognizant of the timing of plant growth. For additional information on grazing practices, refer to the Postmining Land Use section of this handbook.

a. Annual Bromegrass Control

Annual bromes are considered to be winter germinators. If conditions are favorable during early November, they will germinate and grow to a height of two to four inches before cessation of growth for the winter. If they are grazed at this time, those individuals will not continue growth to seed set the next spring. Cattle will readily graze the available green forage and thus reduce the number of plants that will set new seed the next spring. The dormant perennial grasses will not be damaged even by heavy grazing.

The annual bromegrasses will germinate earlier in the spring than any of the introduced or native cool season grasses. If the annuals are grazed in the spring after growth has begun and before the desired perennials begin growth, the weed crop for that year will be lost. If the annuals are inhibited, the perennials will increase. A decrease has been noted in the amount of annual bromes within two years by grazing in the early spring or late fall. The cattle must be taken off the revegetation just as the desired perennial species begin substantial growth (leaf height of one to two inches).

b. Introduced Cool Season Perennial Grass Control

Livestock grazing has been used to reduce the amount of introduced cool season grass species in the revegetated stand, including crested wheatgrass and smooth bromegrass. These two species generally initiate growth several weeks earlier in the spring than do the native perennials. The livestock grazing should take place after the introduced grasses have begun growth and before the native species have attained substantial growth (leaf height of one to two inches).

c. Litter Reduction

Livestock grazing can reduce the amount of standing litter and break up the fallen litter in a revegetated stand. The desirable species should be dormant at the time of grazing. Grazing may take place at any time during dormancy from late summer to early spring. The desired species will not be damaged by the heavy grazing necessary to reduce the amount of litter. The grasses can be grazed to a stubble height of one to three inches with no damage to the dormant plant. Enhanced growth will be noted the next growing season.

F. MONITORING

1. Vegetation Sampling

Section editor: Larry H. Kleinman *Subsection author: Greg E. Jones*

Applicability

Vegetation assessments of permanently reclaimed areas should be conducted at specified intervals to document vegetation development, assess readiness for and effects of grazing on reclaimed areas, and to document land uses.

Special Considerations

Sampling methodology should be developed and agreed upon by the operator and regulatory agency prior to initiation of data collection. Consistent methods should be used for baseline and postmining sampling.

Technique

a. Delineation of Reclaimed and Study Areas

Each reclaimed area should be identified with a specific designation, so all activities relating to its development and assessment can be recorded and documented. These designations can correspond to mine site, year of topsoiling, area number (postmining vegetation type) and sub-area linkage (non-contiguous/same treatment areas). If a permanently reclaimed area is redisturbed (topsoil removed) or drastically altered (tilled under or completely reworked), that portion (acreage) can be removed from the previous designation and/or redesignated to reflect the alterations performed.

Since reclamation activities (acreages) vary from year to year, several similar, although not contiguous, reclaimed areas can be combined to constitute one monitoring area. These monitoring areas would preferably range from 50 to 100 acres in combined size.

During the bond release period, study areas may consist of combined reclaimed areas of similar vegetation types, which may be at differing stages of development. These studies can be summarized as a whole although individual sample locations should be tracked to allow analysis of individual reclaimed areas.

b. Monitoring Plan Parameters

Each reclaimed area should be sampled for the following parameters at specified intervals using those methods described below:

-% vegetation cover by species*
-% total vegetation cover (sum of all species)*
-% total ground cover (vegetation + litter + rock)*
-% bare ground*
-herbaceous production
-shrub density
-list of species observed during sampling

* % values are reported as absolute % cover

c. Sampling Methods

Sampling methods should comply with those accepted by the appropriate regulatory agency of your area. The methods discussed below are provided as examples and can be altered to meet the desired sampling needs.

(1) Cover Data Collection

Cover data can be collected using the line transect/point intercept method. Sample locations for cover are chosen by randomly selecting points within a grid of the revegetated area. Grid intervals should not exceed 100 feet on the ground. Randomly generated sample location coordinates should be plotted on a map and located in the field by pacing from known features or land marks. Random numbers between 1 and 360 should be generated to orient each transect.

Sample locations that encompass non-contiguous reclamation areas or varying vegetation types should be consecutively numbered through each area or vegetation type to allow individual or grouped analysis and comparison of the data collected. Sample hits are taken at 1 meter intervals along the entire length of a 50 meter transect. These first hit (50) data points will constitute the absolute cover values for one full sample set. Additional hits at each meter mark may be recorded separately but not included in absolute cover values for that particular transect. Multiple hit information can be used to compile the overall plant list for the area and to qualitatively describe the stratified vegetation cover within each respective revegetation area.

Cover by individual species should be collected for the 50 hits within each transect and later combined into total vegetation cover. In addition, litter, rock, and bare ground hits should be recorded and later combined into total ground cover. Transects that exceed designated vegetation boundaries should be randomly reoriented to be within the sampled vegetation area.

(2) Production Data Collection

Production data can be collected using one meter square plots. Sample locations should be chosen by randomly selecting points within a grid of the revegetated areas or by randomly locating plots along a cover transect in those areas monitored for cover. Another method is to locate plots three feet perpendicular and three feet to the right from the 50 meter end of a cover transect. Sample locations should again be consecutively numbered for grouped or individual analysis as described in the paragraph above on cover data.

Should the study areas include lands that will be grazed during the sampling period, the use of grazing exclosures will be required. The number and type of exclosures should be sufficient to provide an adequate sampling area (one meter square) and sample size (maximum samples within the grazed area). When grazing is anticipated, both cover and production can be sampled with the one-meter square plots.

Annual above-ground herbaceous biomass should be clipped by dominant species and remaining minor species by lifeform. Full shrubs, succulents, noxious weeds, and cushion plants should not be clipped. If annual grasses and/or annual forbs are major community components, these life forms should be included in the sampling.

Clipped biomass should be placed in paper bags and dried in a forced air oven (105ºC for 24 hours). Samples should be weighted on an appropriate scale to the nearest 0.10 gram and reported in grams per meter squared and pounds per acre. Clipped samples less than 0.10 gram can be reported as trace samples. Average bag weight must be calculated and subtracted from weighed samples.

(3) Shrub Density Data Collection

Shrub density data can be collected at random locations in conjunction with cover transects on selected revegetation areas. All shrubs (full, half, or sub) should be counted within 50 centimeters either side of the 50 meter cover transect (1 meter by 50 meter belt transect). Shrub counts should be recorded by species and reported as shrubs per meter squared and shrubs per acre.

In those reclaimed areas designated as a shrub mosaic or patch, the plot configuration may vary in order to define the establishment and/or development of the shrub component. When developed and productive stands of shrubs are defined through periodic sampling, permanent transects and/or plots may be established to document trends in shrub development and longevity.

(4) Plant Species List

A list of all plant species observed during cover and production sampling should be recorded by life form and described by scientific and common names. The listing can also include those species observed during the course of sampling although not encountered within a specific cover transect or production plot.

Any federally designated threatened and endangered species, state plants of concern, noxious weeds, and primary selenium indicator species observed should be identified.

(5) Species Diversity

Relative cover percentages calculated from revegetation area cover data can be used to evaluate the species diversity and richness of the area.

(6) Sample Intensity

The intensity or amount of samples collected within each revegetation area should follow those requirements outlined by applicable regulatory requirements. Interim monitoring of revegetated areas may require a set amount of samples per area, dependent upon the size (acres) of the area. An example of sample size could be ten random samples for each study/reclaimed area up to 100 acres in size, with one additional sample for each ten acres of increased acreage within the area.

Should the study area require sampling to statistical adequacy, statistical testing formulas outlined by the applicable regulatory agency should be used. At a minimum, all sampling results should include the computed Z value and confidence level achieved with the number of samples collected.

(7) Sample Frequency

Sampling of individual revegetation areas usually will not begin until the third growing season following the year of permanent seeding. A schedule should be developed which includes three sampling periods during the ten year minimum bonding period. This schedule would serve as a minimum sampling frequency, additional samples may be taken or substituted for determination of grazing readiness and stocking rates or to document special treatments on specific areas.

d. Sample Data Analysis

All data collected should be analyzed and presented in a tabular format acceptable to the applicable regulatory agency. Tables F-1-1, F-1-2, and F-1-3 illustrate the results of cover, production, and shrub density vegetation studies conducted on reclamation areas.

TABLE F-1-1

Report: Cover Summary

Site Identification: R9101				Sample Method: Point Intercept			
Name: Reclamation Area R9101				Sample Size: 50 Meter Transect			
Comm. Type/Form: Reclamation/Grassland				Number of Samples: 10			
Sample Date: 03-Jul-1995				Report Date: 08-Sept-1995			
() Represents Second Hit Data							
	Cover (%)		Std. Dev.	Frequency (%)			
	Mean Absolute	Relative	(n-1)	Absolute	Relative	I.V.	Rank
Annual Grass							
Bromus japonicus	9.0 (0.2)	12.8	4.3	100.0	9.8	22.7	3
Bromus tectorum	0.6	0.8	1.3	20.0	2.0	2.8	15
Festuca octoflora	0.2	0.3	0.6	10.0	1.0	1.3	22
Total Life Form	9.8 (0.2)	14.0	5.0	100.0			
Cool Season Perennial Grass							
Agropyron cristatum	0.2	0.3	0.6	10.0	1.0	1.3	20
Agropyron dasystachyum	2.2	3.1	1.8	70.0	6.9	9.9	7
Agropyron smithii	15.6 (0.2)	22.1	6.4	100.0	9.8	31.9	1
Agropyron spicatum inerme	9.2	12.8	5.9	100.0	9.8	22.7	4
Agropyron trachycaulum	1.0	1.4	1.9	30.0	2.9	4.3	14
Koeleria macrantha	3.0	4.2	3.2	70.0	6.9	11.1	6
Stipa comata	1.4	2.0	3.1	30.0	2.9	4.9	10
Stipa viridula	12.6	17.6	5.3	100.0	9.8	27.4	2
Total Life Form	45.2 (0.2)	63.4	8.5	100.0			
Warm Season Perennial Grass							
Bouteloua gracilis	1.6	2.2	2.3	40.0	3.9	6.2	12
Total Life Form	1.6	2.2	2.3	40.0			
Annual Forb							
Alyssum alyssoides	0.4	0.6	0.8	20.0	2.0	2.5	16
Alyssum desertorum	6.6 (0.2)	9.5	3.7	90.0	8.8	18.3	5
Camelina microcarpa	1.2	1.7	1.9	40.0	3.9	5.6	11
Descurainia pinnata	0.2	0.3	0.6	10.0	1.0	1.3	19
Descurainia sophia	0.2	0.3	0.6	10.0	1.0	1.3	21
Helianthus annuus	0.2	0.3	0.6	10.0	1.0	1.3	24
Plantago patagonica	0.8 (0.2)	1.4	1.7	30.0	2.9	4.3	13
Sisymbrium altissimum	1.2	1.7	2.1	30.0	2.9	4.6	9
Total Life Form	10.8 (0.4)	15.6	6.3	100.0			

Site Identification: R9101 Name: Reclamation Area R9101 Comm. Type/Form: Reclamation/Grassland Sample Date: 03-Jul-1995 () Represents Second Hit Data			Sample Method: Point Intercept Sample Size: 50 Meter Transect Number of Samples: 10 Report Date: 08-Sept-1995				
	Cover (%)		Std. Dev.	Frequency (%)			
	Mean Absolute	Relative	(n-1)	Absolute	Relative	I.V.	Rank
Perennial Forb							
Sphaeralcea coccinea	0.8	1.1	1.9	20.0	2.0	3.1	17
Sphaeralcea munroana	1.8	2.5	2.4	50.0	4.9	7.4	8
Vicia americana	0.2 (0.2)	0.6	1.3	10.0	1.0	1.5	23
Total Life Form	2.8 (0.2)	4.2	4.0	50.0			
Perennial Shrub							
Artemisia tridentata	0.4	0.6	0.8	20.0	2.0	2.5	18
Total Life Form	0.4	0.6	0.8	20.0			
Total Stratified Vegetation Cover	71.6	100.0	6.8	100.0			
Total Non-stratified Vegetation Cover	70.6		7.1				
Litter	17.4		6.2	100.0			
Rock	0.4		0.8	20.0			
Total Ground Cover	88.4		5.1				
Bare Ground	11.6		5.1	100.0			
Total Cover	100.0		0.0				
Species Abundance (# species/sample)	10.2		1.9				

TABLE F-1-2
Report: Production Summary

Site Identification: N8701ALL			Sample Method: Random Plots	
Name: Reclamation Area N8701ALL			Sample Size: 1.0 sq m.	
Comm. Type/Form: Reclamation/Grassland			Number of Samples: 10	
Sample Date: 27-Jun-1995			Report Date: 08-July-1995	
	Mean Production (gm/sq.m)	Mean Production (lbs/ac)	Relative Production (%)	Std. Dev. (n-1) (gm/sq.m)
Annual Grass				
Bromus japonicus	0.953	8.502	0.605	2.410
Bromus tectorum	0.650	5.799	0.412	1.598
Total For Life Form	1.603	14.302	1.017	4.008
Cool Season Perennial Grass				
Agropyron cristatum	0.266	2.373	0.169	0.841
Agropyron dasystachyum	58.438	521.372	37.079	46.374
Agropyron riparium	0.341	3.042	0.216	0.782
Agropyron smithii	26.508	236.499	16.820	25.408
Agropyron spicatum	1.647	14.694	1.045	5.208
Bromus inermus	28.544	254.664	18.111	60.805
Stipa viridula	3.496	31.191	2.218	10.372
Total For Life Form	119.240	1063.834	75.659	38.081
Annual Forb				
Alyssum alyssoides	0.721	6.433	0.457	2.280
Alyssum desertorum	3.848	34.331	2.442	4.195
Camelina microcarpa	4.591	40.960	2.913	8.777
Descurainia pinnata	0.053	0.473	0.034	0.168
Thlaspi arvense	0.615	5.487	0.390	1.502
Total For Life Form	9.828	87.683	6.236	14.228
Perennial Forb				
Lithospermum incisum	0.077	0.687	0.049	0.243
Medicago sativa	17.094	152.509	10.846	33.778
Onobrychis viciaefolia	0.307	2.739	0.195	0.971
Ratibida columnifera	0.922	8.226	0.585	2.916
Sphaeralcea munroana	0.077	0.687	0.049	0.243
Vicia americana	0.154	1.374	0.098	0.487
Total For Life Form	18.631	166.222	11.822	33.259
Perennial Sub-shrub				
Artemisia frigida	0.200	1.784	0.127	0.632

Site Identification: N8701ALL				Sample Method: Random Plots	
Name: Reclamation Area N8701ALL				Sample Size: 1.0 sq m.	
Comm. Type/Form: Reclamation/Grassland				Number of Samples: 10	
Sample Date: 27-Jun-1995				Report Date: 08-July-1995	
		Mean Production (gm/sq.m)	Mean Production (lbs/ac)	Relative Production (%)	Std. Dev. (n-1) (gm/sq.m)
Ceratoides lanata		8.100	72.267	5.140	9.480
	Total For Life Form	8.300	74.051	5.266	9.310
TOTALS		157.602	1406.092	100.000	62.542

Site Identification: R9103
Name: Reclamation Area R9103
Comm. Type/Form: Reclamation/Sagebrush Grassland
Sample Date: 27-Jun-1995

Sample Method: Transect Plots
Sample Size: 50.0 sq m.
Number of Samples: 5
Report Date: 08-Sept-1995

	Mean Number/Plot	Relative Density %	Std. Dev. (n-1) Number/Plot	Mean (Number/sq.m.)	Mean (Number/Acre)
Perennial Shrub					
Artemisia cana	42.800	12.3	43.8	0.86	3464.1
Artemisia tridentata	230.200	66.0	222.8	4.6	18631.7
Total For Life Form	273.000	78.3	263.0	5.46	22095.8
Perennial Sub-shrub					
Artemisia frigida	19.000	5.5	19.3	0.38	1537.8
Ceratoides lanata	56.600	16.2	65.6	1.13	4581.0
Total For Life Form	75.600	21.7	53.7	1.51	6118.8
TOTALS	348.600	100.0	229.5	6.97	28214.7

2. Recordkeeping Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

The release of reclamation bonds depends on quantitative and qualitative reclamation success. Evaluation of this success is meaningless without accurate and comprehensive records. These records can be collected in a set of volumes to make a history of mine reclamation. The Reclamation History is a database of revegetation practices, as well as monitoring and assessment information, from the beginning of reclamation on a minesite.

The widespread availability of geographic information system capabilities, in conjunction with GPS locating capabilities, greatly increases both the accuracy and utility of the reclamation history records. Great care should be exercised in the planning phase of the reclamation history to select the methods used for data identification, data storage, and data retrieval.

Special Considerations

The Reclamation History database expands year by year, serving as a definitive source of data regarding date of permanent reclamation, revegetation practices, revegetation assessment and sampling, topsoil fertility, backfill geochemistry, and postmining land use. Revegetation practices and vegetation cover by species through time constitute a large part of the data array. An organized and retrievable Reclamation History, such as can be found in this database, provides many opportunities for data analysis and interpretation.

In addition, Reclamation History information provides feedback for current practices and thus allows continual improvement of reclamation practices. Revegetation monitoring and research can include investigations into the effects of soil type and fertility on reclamation species, the success of various reclamation species, the effects of postmining land use, the impact of mulching, the success of shrub pads, the success of various methods of sagebrush seeding, and the success of direct-haul topsoil.

Technique

a. Date of Permanent Reclamation

History of reclamation in a given area can be considered to start at the time regraded backfill is topsoiled and the topsoil prepared for revegetation. Backfill replacement and grading is considered a part of the process. Topsoil placement and final surface preparation can be selected to define the date of permanent reclamation, because (except in very rare circumstances) topsoil replacement and final surface preparation are only done once. In contrast, revegetation may be, and often is, conducted over a span of years. Drought, pest infestations, and seed failures all contribute to multiple revegetation efforts.

Many Reclamation Histories also begin at the time of regrading the backfill. Both dates, regrading and topsoiling, should be a part of the Reclamation History.

b. Revegetation Practices

An element that constitutes a significant component of the database is the revegetation practices for all permanently reclaimed units. These practices are presented by season and by year. Revegetation activities are conducted in the spring and the fall; therefore, each year has two seasons for which information is available. This data can be presented in the same database format shown in Figure 1 of the subsection entitled "Preparing a Revegetation Package". Maps for both seasons of each year, showing the location of all revegetation units, are included. Permanent revegetation can be categorized in the following way.

(1) Permanent Revegetation

Permanent revegetation practices are recorded any time seeding is conducted with the intention that the seeding will serve as the basis for postmining land use. Seeding of grains may occur for agricultural uses such as pastureland and cropland. Thus, seeding of annual grains can be considered, in some cases, "permanent".

(2) Functionally Permanent Revegetation

Functionally permanent revegetation practices are those that occur when the initial intention was for long-term temporary seeding, but where time has shown that the seeding will serve as the basis for postmining land use. The most typical example of functionally permanent revegetation is revegetation of road ditches and rights-of-way that were initially seeded for stabilization, but where the road has been incorporated into the postmining land use plan and the vegetation has become very well established. There is often little likelihood in such a case that these areas will be re-disturbed.

(3) Husbandry Practices

Husbandry records can be included with permanent and functionally permanent practices so that a record of such husbandry exists. Husbandry in an area does not re-initiate the bond time period, and is thus fundamentally different from permanent and functionally permanent practices.

c. Revegetation Assessment and Sampling

Data collected in revegetation research and monitoring conducted at a mine are also included in the Reclamation History. The purpose of revegetation monitoring is to prove establishment of desired vegetation as well as the progress that has been made toward postmining land use goals. As a result of monitoring, modifications and additions can be made to revegetation practices in order to enhance the achievement of those goals.

Geographic locations of vegetation sample locations can be identified using GPS and GIS overlays. Maps of sample locations should be included in the Reclamation History. Figure F-2-1 gives a sample table that can be used to document vegetation sampling results (figure follows text). This table is expanded, year by year, to cover all types of vegetation found and all areas sampled.

d. Topsoil Fertility

State regulations and the mine permit may require that topsoil fertility be assessed where topsoil has been stockpiled for more than one year. Fertility samples are collected in the backfill in those areas over which stockpiled topsoil has been spread. The information collected through the assessment program can also be used to determine fertilization rates.

Topsoil fertility data are usually presented in a spreadsheet that covers all aspects of sampling. Data are added to the spreadsheet as it is collected each year.

e. *Backfill Geochemistry*

Before topsoil can be replaced, the suitability of the top four feet of backfill must be assessed; thus, backfill geochemistry is another component of the Reclamation History. Geochemical information is collected at intervals from backfill. The cumulative backfill database is presented in the Reclamation History in a spreadsheet that can be updated as data are collected each year.

f. *Postmining Land Use*

Any postmining land use practices employed by the mine can be summarized in a history. These practices may include wildlife use, production of grains, haying, or livestock grazing. For techniques on these practices, refer to the Postmining Land Use section of this handbook.

FIGURE F-2-1

Vegetation Sampling – or use forms and methods described in preceding section

Unit or Area or Treatment					
OBS or sample number					
Sampler					
Date of sampling					
Easting					
Northing					
Aspect					
Slope					
Quadrant size					
Cover (1) or Production (2)					
% Total desirable vegetation					
% Total vegetation					
% Total litter/rock (or ground)					
% Total bare soil					
% Total cover					
% Bare soil					
% Litter					
% Rock					
Agropyron dasystachyum					
Agropyron intermedium					
Agropyron smithii					
Agropyron trachycaulum					
Alyssum desertorum					
Artemisia tridentate					
Astragalus cicer					
Atriplex canescens					
Avena fatua					
Bouteloua gracilis					
Bromus inermis					
Calamovilfa longifolia					
Ceratoides lanata					
Descurainia richardsonii					
Elymus junceus					
Helianthus annuus					
Lupinus pusillus					
Medicago sativa					
Melilotus officinalis					
Onobrychis vicifolia					
Orysopsis hymenoides					
Plantago patagonica					
Poa pratensis					

Unit or Area or Treatment					
OBS or sample number					
Sampler					
Polygonum convolvulus					
Sphaeralcea coccinea					
Stipa viridula					
Thlaspi arvense					
Tragopogon dubius					
Vicia Americana					

3. Electronic Document Management in Mining

Section editor: Larry H. Kleinman *Subsection author: Greg E. Jones*

Applicability

The following discussion is provided to describe the application of Electronic Document Management (EDM) to electronically capture, store, distribute, annotate, display and print the extensive data required by the Surface Mine Control and Reclamation Act of 1977 (SMCRA).

Special Considerations

The EDM system design may include integration of software compatible with the Technical Information Processing System (TIPS) developed by the Office of Surface Mining and State regulatory agencies. A critical issue for electronic document management is the selection and utilization of data storage and retrieval systems. With sufficient effort and associated utilization of the appropriate program, EDM can create a tangled morass of unusable data from which the only escape is to start over.

There are five commandments for the electronic management of data. The primary caution is "Never use a program that does not translate easily to another program. A corollary to the primary caution is, "Never use a program for data storage and retrieval that requires a specialist to operate." While mapping and display programs such as Arcview and Autocad require seriously specialized training, it is essential that the "man in the field" be able to access, validate, and correct the database. This is a real-world challenge. One thing about a slow, inefficient, error-prone paper system is that, given the organization of the files is acceptable, anyone can operate the system.

1. Always keep a paper copy of any data input into a data management system, including paper copies of GPS input information and paper copies of any maps generated by CAD or GIS systems. With the avalanche of data confronting the environmental specialist this may seem archaic and inefficient. However, it is the single best safeguard against paralysis of the system. In addition the original field information may be needed for demonstration, litigation, verification, or re-analysis.

2. Spend a lot of time developing and consistently implementing a well-documented filing system for paper copies of data. If hard copies of desired information can not be easilty located and rapidly retrieved, the filing system is inadequate.

3. Always use data management programs that will translate easily and correctly to another program. Programs come and go, and evolve. If the data can not move from one program to another easily, the result will be chaos.

4. Never use a program for data storage and retrieval that requires a specialist to maintain and operate. A simple to operate system may create inefficiencies and limitations, but a good base data set can always be used as input to a more complex program. However, an over-complicated system that no one can operate will lead to inability to retrieve information, or worse, data that appears good and is incorrect.

5. Whatever system is used, keep it current and stay familiar with it. A data management system needs ongoing utilization and analysis just like a dog needs exercise. If you the operator do not have a good intuitive feel for what your data are telling you, neither you nor the system are functioning properly

Technique

a. Electronic Document Management

Through the use of EDM, operators can realize an increase in manpower efficiency along with improved quality, repeatability, and transferability of data collected, reported, and analyzed in State and Federal permit documents.

b. EDM Primary Components

There are four components commonly used to transfer or exchange information relating to permit applications and/or reports.

(1) Computer Aided Drafting (CAD)

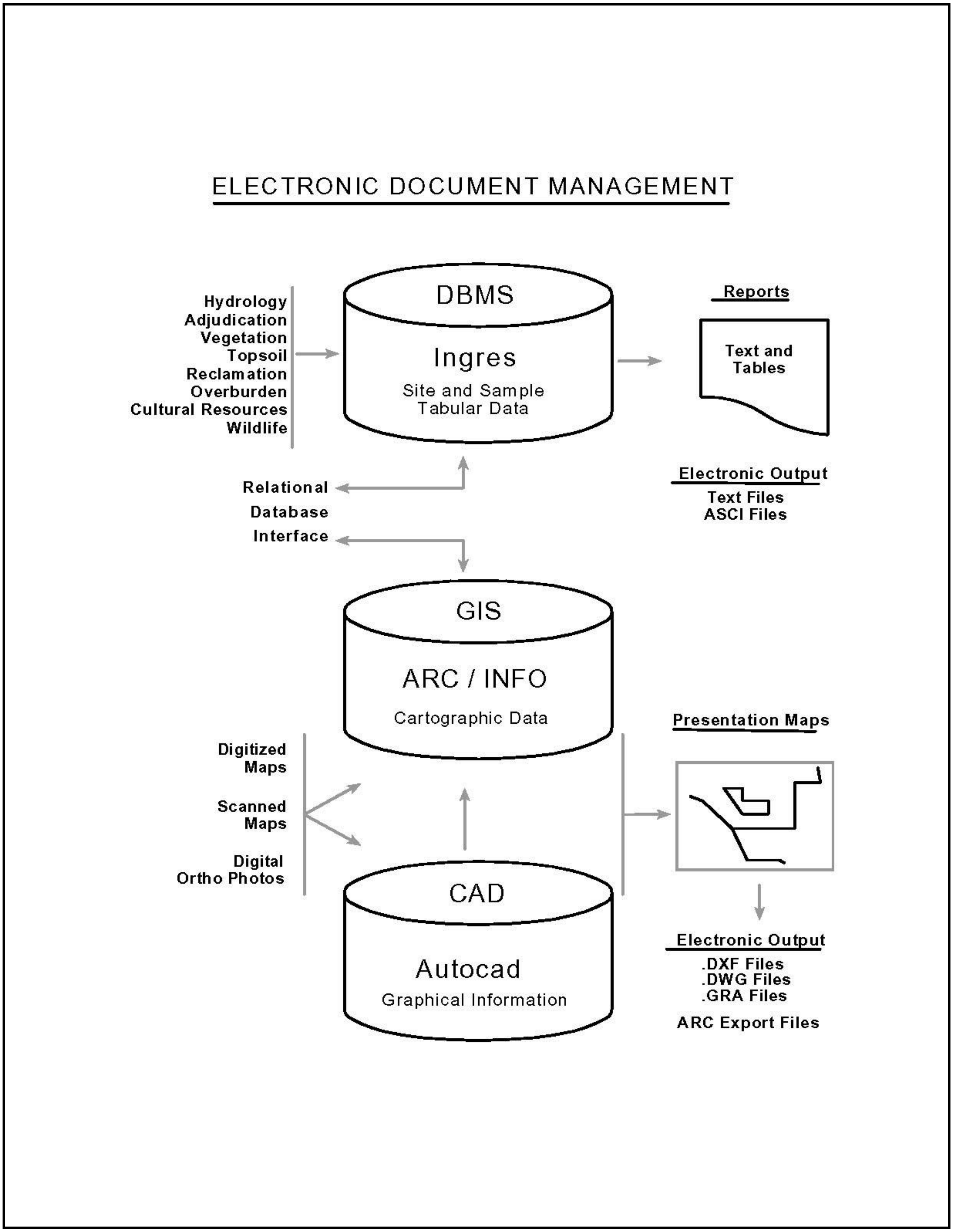
Computer-aided drafting software applies computer graphics technology to automate manual drafting techniques. The primary use of this application is for the design, drafting, and display of graphically oriented information.

(2) Geographical Information System (GIS)

Geographical Information System software is designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced geographic data.

GPS (global positioning system)

GPS techniques enrich the capabilities of both GIS and CAD by increasing the accuracy and speed with which samples, structures, and reclamation units can be located in the field. Electronic transfer of GPS information from the satellite receiver or mapping device directly to the database management system, which is typically integrated with the GIS reduces data transfer error and speeds the data management process.


ELECTRONIC DOCUMENT MANAGEMENT
Hydrology
Adjudication
Vegetation
Topsoil
Reclamation
Overburden
Cultural Resources
Wildlife
DBMS
Ingres
Site and Sample
Tabular Data
Reports
Text and
Tables
Electronic Output
Text Files
ASCI Files
Relational
Database
Interface
GIS
ARC / INFO
Cartographic Data
Presentation Maps
Digitized
Maps
Scanned
Maps
Digital
Ortho Photos
CAD
Autocad
Graphical Information
Electronic Output
.DXF Files
.DWG Files
.GRA Files
ARC Export Files

(4) Database Management System (DBMS)

Database Management System provides an organized set of data that allows flexible query and manipulation of tabular data by selecting portions of the data set for further calculation, analysis, reporting, or data exchange.

(5) Word Processing (WP)

Word Processing software is utilized for all textual portions of permit applications. Through submission of electronic text files, technical personnel may access separate portions of the application at the same time, resulting in more expeditious permit reviews.

c. Individual EDM Topic Applications

The following applications describe how an EDM system can be utilized to prepare permit documents in electronic format for submittal to a regulatory agency.

(1) Baseline Topsoil Surveys

GIS applications can be used to store, illustrate, and analyze specific topsoil information (soil type, soil depth, mapping unit) according to geographical boundaries and parameters defined in the baseline study. Through a process of overlaying or clipping a topsoil polygon coverage with other polygon coverages, detailed reports are created to describe, for example, the extent (acres) of each soil type and the quantity (yards) within a proposed permit boundary.

This application can be used to develop reports which summarize the projected total amount of topsoil available for salvage within the disturbance limits of the mine plan, for use in determining an average salvage and reclamation replacement depth. Additional analyses can be performed to define area and volume by individual disturbance year, for mass balance tables in the mine plan section.

(2) Baseline Vegetation Surveys

GIS applications are used to store, illustrate and analyze specific vegetation information (vegetation types) according to geographical boundaries and parameters defined in the baseline study. Through the same processes described for topsoil surveys, detailed reports can be created to describe the extent (acres) of each vegetation type within a defined polygon (permit boundary, disturbance area, or study area).

The DBMS is also utilized to store raw baseline vegetation data from surveys, provide printed reports of selected criteria, and provide a statistical baseline for comparison of pre- to post-mining vegetation data at the time of bond release.

(3) Legal Description and Ownership

Regulatory requirements call for the legal description of all lands within and surrounding a permit area. Through GIS applications, specific legal or ownership data are associated with known tracts of land, and spatial relationships can be established to determine the exact acreage of a permit area, by legal identification (ID) (section, township, range), or ownership (surface or mineral) by owner, address or legal ID.

(4) Wildlife

Both CAD and GIS systems can be applied to the protection of wildlife resources. Electronic data are used to accurately map and define the extent of important wildlife habitats within and adjacent to mining operations. Habitats such as wetlands, big game ranges, game bird breeding areas and raptor nest locations are documented electronically so they can be referenced to mining activities for appropriate mitigation actions.

(5) Reservoir Designs

Through the use of CAD/GIS topographic maps (five foot contours) for the mining area, reservoir sites are selected, construction contours drawn and merged with existing topography, and stage volume tables are created using CAD routines. Design information including existing topography with reservoir design contours can be placed on an exhibit with stage volume tables, cross sections, plan view, and associated water level annotation.

(6) Overburden Suitability

Surface mining operations can use maps developed through CAD/GIS applications to determine overburden suitability. These maps show suitability of overburden (by individual suitability parameter) according to the criteria described in each mine site's approved permit. These same data can then be provided to the state regulatory agency in electronic format.

(7) Hydrology

Hydrologic data, including surface flow, static water levels for wells, and geochemistry data can be stored in the DBMS. Data can be directly loaded through a custom window application or batch loaded from a file provided by contract laboratories. Use of the DBMS allows for production of reports with user defined parameters, statistical analysis for selected data, creation of graphs to monitor trends, and electronic transfer of data to regulatory agencies for compilation into larger database applications.

(8) Revegetation/Reclamation

All aspects of an EDM system can be used in the storage, tracking, analysis and reporting of revegetation/reclamation activities. GIS applications can be used to define reclaimed areas (area ID, extents, seed mixture, year of topsoiling, year of seeding...). Through the various attributes assigned to individual areas, detailed reports and maps can be created based on user defined variables.

The DBMS can be used to store interim monitoring vegetation data collected for each area. This information can be entered through a custom windowing application or batch loaded from files prepared by vegetation contractors. Various outputs are available through the vegetation DBMS system which include: cover, production, and density reports (raw data and summaries); plant species summary by area (which describes species observed, first year observed and number of years observed); and statistical summary reports for data collection parameters (standard deviation, actual sample size, computed adequate size, computed Z value, and confidence level achieved).

Reclamation exhibits illustrating backfill and reclamation progression can be prepared in CAD along with associated backfill mass balance tables. WP is utilized to textually describe each action associated with the reclamation plan along with tabular illustrations of each mine site's seed mixtures. Through application of the EDM, practically all portions of the Reclamation Plan can be provided to the regulatory agency in electronic format.

(9) Textual Information

WP software is used for all textual material included in permit documents. This software should be compatible with that used by the regulatory agency reviewing the document. Examples include text changes made in bold type to better define changes, and pages submitted with consistent pagination and revision dates.

d. Summary

An EDM system as described above can provide a powerful tool for use in complying with State and Federal regulatory requirements. Considerable cost and manpower savings can be realized, along with increased technical knowledge and analytical capabilities, consistency of information, and enhanced transfer of complex scientific data.

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REVEGETATION OF BIG SAGEBRUSH

Section Editor: Mickey Steward
Handbook of Western Reclamation Techniques, Second Edition

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SECTION 5A: SEEDING BIG SAGEBRUSH

Section editor: Larry H. Kleinman *Subsection authors: Gerald E. Schuman*

Applicability

For most sites, revegetation of big sagebrush is required where big sagebrush occurred prior to disturbance.

Special Considerations

Artemisia sp. seed is very sensitive to being placed to deep in the soil. It should actually be broadcast-seeded because light enhances seed germination. Therefore, seeding should be done after drilling of grasses and mulching practices are completed. The soil surface of the seedbed should be firm enough that the seed is not easily buried. If good quality seed is purchased and broadcast on the surface, the seed will provide opportunity for new seedling establishment for at least 4 years after the initial seeding (Schuman et al. 1998; Schuman and Belden 2002). Seed viability in the field is much greater than in seed storage conditions and it seems to lie on the soil until micro-climate relief characteristics are desirable from a moisture and temperature standpoint.

Recent research has shown that initial (1-2 years) seed germination and seedling density is related to grass competition, topsoil management, and mulching (Schuman et al. 1998). Sagebrush seedling density in the first two years was greater in direct-placed topsoil compared to stockpiled topsoil. This response to direct-placed topsoil was attributed to the improved physical and microbial characteristics of the topsoil. Direct-placed topsoil had greater soil moisture storage throughout the first two years compared to the stockpiled topsoil and also exhibited a higher level of arbuscular mycorrhiza (AM) inoculum.

Infection by AM early in the seedlings development has been shown to significantly increase its drought stress tolerance; hence, increasing its ability to survive short dry periods during early seedling stages (Stahl, et al. 1998). Mulch, straw or stubble, has also been shown to increase sagebrush seedling density compared to seeding on a bare soil surface, in the initial years of establishment (Schuman et al. 1998). The benefits of mulch, direct-placed topsoil, and grass competition seemed to have less of a long-term effect on sagebrush seedling density but should still be an important consideration to ensure establishment of the shrub at required densities to meet the shrub density standard at the time of bond release.

Research to more precisely delineate the prescription for establishing big sagebrush at the desired density to meet bond release was initiated in 1999 (Williams et al. 2002). This research evaluated the effect of seven grass seeding rates and three sagebrush seeding rates on sagebrush density and sagebrush canopy size. The authors concluded that to achieve the desired sagebrush density to meet bond release density requirements, the grass mixture seeding rate should not exceed 4-6 lb PLS/acre and sagebrush should be seeded at 2 lb PLS/acre. The reason for the recommended seeding rates is that no differences were observed in aboveground grass production in the second and third year after seeding between grass seeding rates of 4-14 lb PLS/acre and significantly greater sagebrush seedling density was achieved with 2 and 4 lb PLS/acre sagebrush seeding rates compared to the 1 lb PLS/acre seeding rate.

The 2 lb PLS/acre sagebrush seeding rate also provides a good seedbank of big sagebrush for a multi-year period and greatly reduces the probability of having to reseed big sagebrush considering the long-term field viability of the seed. The lower grass seeding rates provided adequate protection of the soil and also resulted in greater big sagebrush canopy size than was exhibited at grass seeding rates above 4 lb PLS/acre.

Utilizing the data discussed above and long-term survival data from northwestern Colorado (Kiger et al.) and the Powder River Basin of Wyoming (Schuman and Belden 2002), Schuman et al. (2001) have shown that direct seeding of big sagebrush can be achieved very economically at these higher sagebrush seeding rates even when big sagebrush seed nears $150/PLS lb. The authors calculated cost per surviving big sagebrush seedling to range from $0.01 to $0.05 depending on seed cost, sagebrush seeding rate, and survival. Therefore, further reason to seed at the higher sagebrush seeding rate of 2 lb PLS/acre.

Techniques

Big sagebrush and many of the native shrub species produce a very small seed which have large and fuzzy appendages associated with the seed making it difficult to seed with standard drill equipment. For best results these species should be broadcast on the surface of the soil after drill seeding of the grass mixture has been completed. This is assuming that the grass seeding is being accomplished in a stubble mulch. If the reclaimed area is to be straw mulched, sagebrush seeding should be done after the mulch has been broadcast and crimped into the soil surface to prevent burying of the seed by the crimping process.

Ideally, sagebrush seeding should take place in the winter months. This schedule should work well with seed availability because Wyoming big sagebrush seed matures in late fall and after-ripening occurs in late November or December. Shrub seedings done in January through March have also been very successful.

Seeding can be accomplished with a either a drill or broadcast seeder. If sagebrush is seeded during the drilling of the permanent grass mixture, the legume box should be used and the seed deliver tubes removed from the disk opener on the drill and extended to the rear of the drill so the seed is dropped on the soil surface behind the packer wheels or chains used to cover the grass seed. If the drill does not have a small seeded species box then a broadcast seeder can be attached to the rear of the drill. The other option is to make a second trip across the reclaimed area with a broadcast seeder but this is time consuming and more costly.

To enable accurate calibration of the drill or broadcast seeder, the fine sagebrush seed may need to be mixed with either rice hulls, cracked corn, or crushed walnut shell material. This ensures uniform flow of the seed and aids in seeding rate calibration because of the large numbers of seed per pound resulting in very low rates of seed dispersal.

It is very important to ensure that good quality seed is purchased or collected, because this is the single most important factor in ensuring successful establishment of big sagebrush on mined lands. Big sagebrush seed is available from seed companies both from wildland collections and seed orchard production.

Because big sagebrush seed viability has been shown to persist for at least 4 years in a seeding, there is increased opportunity for adequate moisture and temperature conditions to occur over that period of time and provide for adequate big sagebrush seedling density. The reclamationist should strive for big sagebrush seedling densities of 2-3 seedlings/m^2 in the early years of the reclamation to ensure that the 1 shrub/m^2 requirement at the end of the 10 year bond release is achieved. Therefore, sagebrush and grass seeding rates should be carefully considered based on research information cited in this section.

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POSTMINING LAND USE

Section Editor: Mickey Steward

Handbook of Western Reclamation Techniques, Second Edition

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SECTION 6: POSTMINING LAND USE

A. INTRODUCTION

Section editor: Mickey Steward

1. Federal Regulatory Requirements

Land use management at surface coal mines is unique amongst environmental management activities because postmining land use is the centerpiece of the governing environmental statute for coal, the Surface Mining Control and Reclamation Act (SMCRA) of 1977 (95th Congress, Public Law 95-87, 1987). This act states:

> "Each reclamation plan... shall include... a statement of: the use which is proposed to be made of the land following reclamation, including a discussion of the utility and capacity of the reclaimed land to support a variety of alternative uses and the relationship of such use to existing land use policies and plans...; a detailed description of how the proposed postmining land use is to be achieved and the necessary support activities which may be needed to achieve the proposed land use."

The language clearly directs the focus of mine environmental activity towards utilization of the landscape following mining. Thus, postmining land use is the culmination of surface coal mining and environmental management activities at each mine. Many state statutes and regulations reflect the Federal emphasis on postmining land use.

2. Land Use Types

While provisions are made in both Federal and State regulations for postmining land uses different from premining land use, considerable difficulties can be encountered in making a land use change. As a result, at least in Wyoming, postmining land use is typically the same as premining land use. Land uses are specifically defined by state regulation. In practice, there is no one single postmining use of the land. For example, while the single most common postmining land use in Wyoming is grazingland, that land use includes use by wildlife. Other postmining land uses that have been, or may plausibly be, employed in Wyoming are “fish and wildlife habitat,” “recreation,” and “industry.” “Residential use,” while possible, is not as likely.

3. Wyoming Land Use Types

As the "Cowboy State", Wyoming has a long heritage of interaction between the landscape, people, and livestock. Wyoming also has the particularly rich and precious resources of high wildlife and low human population densities. Postmining land uses in this state should thus conserve and enhance both this heritage and these resources. The remainder of this section will thus focus on **grazingland** as the land use that preserves the Wyoming land use heritage.

Similar to other technologies, livestock grazing is continuously evolving. Grazing practices have benefited from extensive research, from active application and modification of technology, and from increasing awareness of the interaction between man's activities and the environment.

4. Technological Advances and Utility of Land Use Implementation

Part of the challenge of establishing a postmining grazingland is incorporating the technological and environmental advances in grazing, and designing the system in such a way that the benefits of technology can be maintained. Relatively small changes in the design of a grazingland can adapt the land for use by wildlife as well. To meet this challenge, an ongoing dialogue between the mine, the regulator, and the postmining land user, along with an active program of testing and development, should be maintained during mining.

Failure to actively address postmining land use needs during the active mining and bonding period will only result in difficulties at the time bond release is sought. In addition, the benefits of a well-designed grazing program during the active reclamation period are many, and include diversification of the vegetation, increased rate of soil development, reduction of undesirable species, and enhancement of wildlife habitat.

5. Resources for Postmining Land Use Development

Local ranchers, concerned citizens, the Natural Resources Conservation Service, the County Extension Agent, the local Conservation District, the State University, and the State Land Quality authority are all sources of input and information on the development and implementation of the specifics of the postmining land use plan. In addition, the history of the region, including both successful and unsuccessful business and agricultural pursuits, can provide valuable information as the postmining land use plan is developed.

B. GRAZING

1. Early Implementation of the Postmining Land Use: Grazing as Husbandry

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

Utilization of a livestock grazing program for postmining land use provides many benefits. Proper grazing management is a powerful tool in the development and maintenance of grassland and prairie ecosystems, and can positively affect the health and reproduction of many types of grasses. Practices that improve rangelands also improve wildlife habitat, aiding in the re-establishment of wildlife in postmining landscapes. A grazing program aids in demonstrating postmining land use as well as collecting information necessary for bond release.

Special Considerations

Agreement must be made between the regulatory agency, the landowner, and the mining company before grazing can commence on permanent revegetation. Permission may also be required from the U.S. Forest Service, the State, the Bureau of Land Management, or other regulatory agencies.

Techniques

a. Benefits to Early Implementation of the Postmining Land Use During the Bonding Period

Implementation of the postmining land use during the bonding period can have many benefits, regardless of the type of land use. These benefits include the opportunity to evaluate the implementation of the use to ascertain if reclamation processes are adequate to support that use; coordinate activities with the regulatory agency to ensure their familiarity with the selected land use and its particular implementation; derive income from the implementation of the land use; and improve the postmining landscape cost effectively and without re-starting the bond clock.

(1) Grazing as Husbandry

Improving the postmining landscape without resetting the bond clock falls into the category of husbandry. Not all postmining land uses can be considered husbandry practices. However, in the State of Wyoming, it has been agreed (WDEQ-LQD Guideline No. 14, 1991) that grazing can be used as a husbandry practice.

There is no prohibition on grazing being used as a husbandry practice immediately following re-establishment of vegetation cover in the postmining landscape. The regulations usually require that **permanent revegetation** be protected by fencing or other means **from being destroyed** by livestock during the first two years following planting. In addition, again for **permanent revegetation**, agreement must be made between the regulatory agency, the landowner, and the mining company that grazing can be commenced. In some cases, this also requires the permission of another regulatory agency, most typically the U.S. Forest Service, the State, or the Bureau of Land Management.

(2) Grazing for Landscape Enhancement

Grazing, which is often viewed as detrimental to the landscape, is a very powerful tool for amending and improving the landscape. Proper grazing practices have been documented in both formal and informal studies to provide the following benefits:

(a) Stimulation of root growth, which provides individual plants with increased drought and disease protection;

(b) Maintenance of optimum litter levels, which leads to maximum water retention in postmining soils and minimum runoff, thus decreasing erosion;

(c) Removal of excess biomass, which improves plant growth and reproduction, and leads to increased palatability and decreased senescence of individual plants;

(d) Creation of surface microsites, which provides locations for germination and establishment of new individuals and creates surface roughness to enhance water retention;

(e) Seed dispersal and colonization from adjacent native areas, which leads to diversity and elimination of an agricultural appearance; and

(f) Weed suppression, which is usually required by State law, and can assist in hastening natural successional processes.

The keys to grazing as an agent of landscape enhancement are discussed in the following sections: Establishing and Controlling a Grazing Program on the Mine Site; Creating Livestock Pastures; Water Sources for Livestock; Moving Livestock; Vegetation Quality for Grazing; Timing of Grazing; and Grazing, Wildlife, and Wildlife Habitat.

(3) Grazing as a Source of Income

Finally, the mining company can realize increasing amounts of income from ongoing use of the postmining landscape, providing financial verification for the company's contention that the postmining land use has been achieved. This income, while small in relation to the income to be derived from mining, can significantly defray revegetation costs over time, thus leading to an overall reduction in mining costs.

b. Grazing Management

Grazing is integral to the development and maintenance of grassland and prairie ecosystems, and to the health and reproduction of many types of grasses. Proper grazing management can and must take the place of the large herds of herbivores that formerly roamed the Great Plains. Proper grazing management will ensure the preservation of open space and vegetation for prairie wildlife habitat. Practices that improve rangelands also improve wildlife habitat, thereby assisting the mine in reaching another important goal, that of re-establishing wildlife in postmining landscapes.

Grazing is simply a means of managing the grassland resource. Grazing is but one of the many possible reclamation management tools, but good livestock management is an essential tool for landscape management. Re-establishment of the grazingland land use will fail without expert stock management. However, the resource that is the centerpiece of the program is not the livestock but the landscape itself. Proper management of the landscape will ensure that livestock production goals are optimized.

For the mining company, developing a grazing program early in the reclamation cycle can reap benefits in addition to those outlined above. Because postmining land use is central to SMCRA, the mining industry must unequivocally demonstrate that the approved postmining land use has been achieved. A long-established program will support, with a continuous grazing history, the information that must be collected in the two years previous to seeking bond release. An established grazing program can facilitate the collection of the bond release information because bond release data will be collected within the framework of a well-established and smoothly functioning postmining land use program.

2. Establishing and Controlling a Grazing Program on the Mine Site: Initial Planning

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

While there may be no regulatory requirement for a specific grazing plan each year, a detailed written plan for grazing will significantly improve program implementation. The annual plan should include computation of grazing days by pasture, and address water, mineral, and supplementation requirements. The plan should include a map and a grazing sequence. The map should be kept current with respect to permanent fence, gate, and water locations. This grazing plan should be developed at least three months before implementation of the annual program is anticipated, and should be carefully reviewed with the grazier.

Grazing sequencing can be complicated, particularly when husbandry goals are being incorporated. The Environmental Engineer (EE) should allow plenty of time for the development of the annual plan, and should seek review by his or her manager, by security personnel, and by safety personnel prior to implementation.

Special Considerations

Selecting the proper grazier can be very difficult, but is extremely important to the success of the program. The grazier must exhibit enthusiasm, flexibility and cooperation, and genuine care and concern for the livestock. Because the grazing program is likely to be a showpiece item, the grazier must perform to showpiece standards.

Techniques

a. Defining Program Goals

Before other aspects of a grazing program can be established, the EE or specialist who has been given charge of the program should carefully define the **goals** of the program. Consideration should be given to all the potential benefits discussed in the subsection entitled "Early Implementation of the Postmining Land Use; Grazing as Husbandry". Thought should be given to the specific application of these concepts to the particular mine site. Consideration should also be given to the information discussed below, as well as to the other topics in this section.

Paramount consideration should be given to the degree of support, both financial and programmatic, that can be expected from mine management. The desires of management should be incorporated in the program. Some managers will be extremely interested in the program and will provide many ideas and much support. Other managers may be less supportive. If the EE is unsure about long-term commitment to the program, the best advice is to develop a program that is simple to terminate. The stability of the program will be of critical importance to the grazier, as will be discussed below, and will affect both the cost and timing of the program.

Once a program is developed and is working properly, it should be highlighted through education and tours as part of the overall mining effort. This will aid in maintaining support for the program and will also provide a focus for employee pride and interest in the company. However, a poorly managed and executed program will do more harm than good in meeting company objectives. Thus, the EE charged with implementing the program must be thoroughly invested in the success of the program.

b. Selecting a Grazier

Unless a mining company is willing and able to allocate significant resources in terms of manpower and money to a ranch-type program, a good working relationship with a grazier is needed to implement a grazing program. While the EE must take complete responsibility for the grazing program, the EE typically can allocate only limited time to the actual implementation of the program. Thus, the grazier is the EE's greatest asset in developing a postmining grazing program.

Selecting a grazier can be extremely difficult. In ranch country, practically everyone you meet claims to be an expert on livestock and grazing, and many of these "experts" are so mired in the way things have always been done that the EE will continually battle with them over every aspect of the program. The EE must locate a grazier who is enthusiastic and cooperative, who is willing to give more than lip service to the goals of the program, who is flexible and easy to work with, and who truly exhibits care and concern for his or her livestock. Without question, the EE should visit the operations of a prospective grazier and watch the grazier in operation. When negotiating with a prospective grazier, the following issues should be given careful consideration:

(1) Flexibility

When the EE begins discussion of the program goals, does the prospective grazier immediately discount the goals with his or her ideas of how it won't work, how impractical the goals are, or how to do it differently? This is a paramount warning signal that this grazier will not make a success of the program.

(2) Condition of Grazier's Current Operations

What is the condition of the range on the lands where the prospective grazier is currently grazing? Pastures as bald as an egg, with well-established trails along fences and water, do not bode well for the success of this grazier on your reclaimed ground.

Are the grazier's operations neat and tidy? If his or her property is dilapidated and unsightly, these characteristics will transfer. Be sure to check the water locations and fences -- poor conditions indicate a grazier who will not have the interest and enthusiasm to properly implement your program.

(3) Livestock Condition

When visiting the grazier's current operations, observe whether the livestock are calm and healthy (beware of a grazier whose livestock run from him!!). You don't need to be an expert to recognize skinny, sorry animals.

If at all possible, observe the prospective grazier as he or she works livestock. Is he or she calm, efficient, and careful with the stock? Lots of yelling and running are sure indicators of a grazier who will not work well in your program.

(4) Self Motivation

Does the grazier have a plan for the necessary stock numbers and manpower needs of your program? The grazier should be able to produce a coherent plan.

Finally, while a "know-it-all" cowboy is the opposite of what the EE needs, a prospective grazier who can and will contribute ideas and thoughtful attention to the goals of the program will be a valuable resource to the EE. A selfmotivated grazier who is invested in the goals of the program will make or break the program.

A final word of advice: Often, for political reasons or simply out of convenience, the mining company will want to hire the neighbor next door or the rancher who currently is leasing lands from the company that have not yet been mined. This can certainly be a success, but the prudent EE will resist this idea if it runs contrary to program goals. Active selection of an appropriate grazier can sometimes overcome the inertia of using the neighboring rancher. On the other hand, don't fail to investigate the neighboring rancher. For convenience and ease of program implementation, nothing beats an adjacent operator.

c. Deciding on the Species and Type of Livestock

Many species of livestock are available for a grazing program, and the temptation to develop an unusual program can be strong. More than one mine manager has asked for buffalo on the reclaimed land. Before the EE selects the species and type of livestock for his or her grazing program, all subsections in this section should be carefully reviewed. The selection of the species of livestock should follow naturally on the heels of an initial program review. Most especially, the EE should consider:

(1) Is there a grazier available who operates the species of livestock under consideration, and are the livestock themselves easily available?

(2) What are the front-end costs for facilities, especially water, fencing, and handling for the species of livestock under consideration?

(3) How easy is it to handle and move the species of livestock under consideration?

(4) Do the livestock under consideration offer any health or safety risks to the mine workforce?

As with any endeavor, the program with the greatest possibility of success is that with the fewest opportunities for failure. Simply put, a mine in cattle country is probably best off running cattle. Sheep can also be considered. Whatever the choice, it is prudent to save the more esoteric grazing programs for the time when the grazing program itself is well established. Those buffalo may prove to be more expensive and more difficult to handle than first imagined.

Most of the discussions that follow in this section on postmining land use will center on cattle grazing. Cattle are extremely easy to manage. They are readily available and have predictable grazing and behavior patterns. The novice program manager will have a very good chance of success if cattle are selected as the grazing animal. However, the selection process does not end with the species of livestock. Following the selection of livestock species, the **type** of livestock must be selected. The types of livestock include cow-calf pairs, dry cows, weanlings, yearling heifers, yearling steers, and bulls. Each has its advantages and disadvantages.

Of all the animal types, dry cows or bred cows are the easiest to manage. A dry cow is a cow without a calf. Dry cows and bred cows are well-behaved and easy to move. However, unless the grazier is running a cull cow program, dry cows and bred cows are usually only available in the fall and winter. In the spring it is the cow-calf pair that is typically available. Young calves can be difficult to move, even with their mothers, and frequent movement may negatively affect their gain. Cow-calf pairs are best run on reclaimed land after the calves are two months old.

Weanling calves are not a good choice for reclaimed land grazing. They can be skittish and may become ill. Once these animals have reached yearling status, they are good grazing candidates. Yearling steers are frequently used for grazing programs because there is no worry about accidental breeding. Steers will also gain weight more rapidly than heifers. However, Steers can be friskier than heifers and more difficult to train. Steers can also be afflicted with water belly, a urinary tract problem that is difficult to treat and often fatal.

Spayed yearling heifers are docile and easy to move; however, they will not show the weight gain of steers. Yearling heifers for breeding can be profitable, but their management includes the added management of the reproductive season. The confined pastures typical of the reclaimed grazing program make for excellent breeding pastures. The EE should be cautious of the grazier with a long breeding season. Bulls, whether with cow-calf pairs or with heifers, can get restless once breeding has been completed, and the good grass and small pastures typically found on reclaimed land will shorten the breeding season.

The final selection of animal type should be based on the needs of the grazier and the security of the grazing situation on the mine. Ease of handling should also be a major consideration. While there is a great deal of talk about the relative merits of animal **breeds**, this decision is best left to the grazier. The relative docility of Herefords or Salers, for example, is not something on which the EE needs to pass judgment. Occasionally, mine management will desire one breed over another, Longhorns over Angus, for example. If this can be accommodated, there is no reason not to do it, providing the proper grazier can be located.

d. Facilities and Specialty Equipment for the Grazing Program

Running cattle during the spring, summer, and fall requires very little in the way of equipment. Of paramount importance is water, which is discussed in greater detail elsewhere in this section. Following water in importance is fencing, which is also discussed as a separate subsection. Depending on the time of year, fly tags or some method of fly control will be necessary. The EE should discuss the specifics of fly control with the grazier, keeping in mind that proper pasture rotation will reduce fly problems. Typically, the grazier will supply fly control.

When grazing reclaimed ground, because of the uncertainties of reclaimed land geochemistry, it may be wise for the mine to supply mineral supplementation for the cattle. This will minimize complaints regarding animal health based on, however, erroneously. the condition of the mine soils. There is no need to conduct a soil sampling program for mineral deficiencies. The local feed store can suggest a full-range mineral that will be adequate for the needs of the program. The EE should confirm his or her selection with the grazier prior to obtaining the mineral.

Devices for actually feeding mineral to the cattle will be needed. Many commercial devices are available for this purpose, but portability is the primary concern. Plastic 55-gallon drums cut in half lengthwise are inexpensive and are difficult for the cattle to tip over. Using two holes drilled in each end, halves can be equipped with a stout string and easily pulled from one paddock to another. The halves can be connected in trains of six or seven with no difficulty. The trains can also be used to feed supplement. The mine may supply mineral and mineral feeders, unless otherwise desired by the grazier.

The final consideration for facilities is some reliable means to load and unload the cattle. If the cattle are properly trained and are being properly managed, the load-out facilities and processes for delivering and removing the herd as a whole, bulls for breeding, or sick and treated animals, can consist of portable panels and a stock trailer. For large numbers of animals being loaded and unloaded from a stock truck, a portable load-out chute will be necessary. As in all aspects of cattle work, proper handling of the animals will reduce the need for special facilities. Typically, the grazier supplies the load-out facilities.

The EE should carefully discuss and agree upon the facilities needed for the program with the grazier well before the program is implemented. The grazing contract should contain all of the agreements in writing.

e. Obtaining Concurrences and Permissions

Initiating a grazing program on reclaimed ground can require many concurrences and permissions. The EE should allow at least three months, and better six, for obtaining the necessary concurrences and permissions. It is usually necessary to incorporate the general program elements in the mine permit. Specifics of the program and permission for first time grazing must be discussed and agreed upon with the regulatory agency and the landowner. Other regulatory agencies may be involved in the program, particularly the U.S. Forest Service and the Bureau of Land Management.

The mine manager and department manager must concur on the need for the program. Many times the program must be coordinated with the company land agent, or the person otherwise responsible for managing company lands. The safety manager should review and approve the program. It is also wise to bring operations personnel into the loop early in the process so their comments can be incorporated in the program. Comments and suggestions from security personnel are also very useful.

It is often wise to obtain the advice of the local County Agent, the Natural Resources Conservation Service, any local Conservation Districts, local Game and Fish personnel, and any wildlife consultants for the property. Integrating the grazing program with wildlife use of the reclaimed surface will achieve the best possible results for your program.

3. Establishing and Controlling a Grazing Program on the Mine Site: Writing the Grazing Contract

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

The grazing contract must be written to give the Environmental Engineer (EE) in charge of the program maximum control. All aspects of the grazing agreement must be addressed in the contract.

Special Considerations

Writing the grazing contract by the grazing day provides the best means to control consumption of the resource as well as a payment schedule that accurately reflects that consumption. When calculating fees, consideration must be given to the amount of work expected of the grazier. Grazing day calculations should be reviewed each time the contract is renewed.

Techniques

a. Writing the Grazing Contract and Establishing Expectations for the Grazier

There are three ways of writing a grazing contract: by the acre, by the animal, or by the grazing day. By the acre is the method apparently most simple, but it is almost impossible to retain control over animal movement and the timing of grazing if the grazier is paying for the property by the acre. The grazier will be inclined to graze as long and as hard as possible to obtain the best value for his dollar.

While more controllable than an acreage contract, a grazing contract by the animal, or more specifically, the animal-unit, is fraught with similar hazards. In this case, the grazier may be inclined to overstock the property or conversely, under-use the resource.

(1) Payment by Grazing Days

The EE can exercise most control over the grazier through payment by grazing days. Payment by the grazing day forces the EE to make a realistic evaluation of the grazing resource, provides a means to control consumption of that resource, and provides a payment schedule that accurately reflects consumption of the resource. Calculation of the number of grazing days available is a major controlling variable of the grazing program and should be carefully researched. Grazing days are calculated as:

$$\text{Grazing Days} = ((\text{AFP/Acre} * \text{PU}) / (\text{FC} * \text{EAU}) * \text{AA} * 365)$$

(a) AFP/Acre = Annual Forage Production per Acre
This number can be estimated from baseline permit data, revegetation data, or the County Agent. Dry forage is the variable commonly used.

(b) PU = Palatability * Utilization
Palatability for reclaimed forage is usually fairly high because it is mainly grasses. A typical number is 80 percent (0.8), but the number can drop to 50 percent (0.5) or less if the vegetation is dry, old, or weedy. A reasonable estimate is 75 percent (0.75), but this should be evaluated case-by-case.

Utilization is the amount of the forage resource the EE wants consumed. This number depends upon the time of year, and can be higher when the vegetation is dormant than when it is actively growing. Utilization of actively growing vegetation is typically 55 percent (0.55). Utilization of dormant vegetation can be as high as 70 percent. A reasonable estimate is 50 percent (0.5), but this should be evaluated case-by-case.

(c) FC = Forage Consumption
When animals have free choice feed, forage consumption can range up to 35 or 40 dry pounds per day. Winter feed rates are usually calculated at 25 to 35 pounds per day per animal unit. A reasonable estimate is 30 pounds per animal unit, but this should be evaluated case-by-case. Be sure this number is in the same units (pounds or kilos) as the Annual Forage Production.

(d) Equivalent Animal Units (EAU)

1.0 AU = Cow-calf pair

0.5 AU = Weanling calf

0.7 AU = Yearling animal

0.8 AU = Dry or cull cow

1.5 AU = Bull

These numbers can be modified to some degree at the discretion of the EE, with agreement from the grazier. The designation is time-sensitive, and is based on the probable forage consumption of the animal. Consultation on the proper assignment of animal unit values can be obtained from the County Agent, the Conservation District, or the Natural Resources Conservation Service.

(e) AA = Available Acreage
This is the acreage that is available for grazing. Be sure to remove acres that are disturbed or otherwise in use.

b. *Renewing the Contract*

Grazing day calculations should be reviewed each time the contract is renewed, and any pertinent knowledge gained from grazing the reclaimed ground should be used to modify the formula where appropriate.

Cost per grazing day can be extremely variable, but should be consistent with long-term lease and grazing agreements in the area. Because the grazier is being asked to operate in non-typical ways, it is usual to grant a slightly reduced grazing fee. In 1994, a reasonable grazing day fee on reclaimed lands in Campbell County could vary between $0.35 and $0.50 for non-snow conditions. Consideration for the amount of work expected of the grazier must be incorporated in the grazing day fee, as must local grazing fees.

c. *Payment Adjustment*

When grazing days are used as the basis for the grazing agreement, the grazier can adjust animal numbers and timing of grazing at his discretion. One cow for 100 days and 100 cows for one day equate to the same number of grazing days. However, the goals of the grazing program must be considered when adjustments are desired. With grazing days, payment adjustments can easily be made for animal loss or removal. Provisions should be made in the contract for removing animals from the leased area in case of drought. The contract should also address any absolute time limits that may be placed on the program. For example, it may only be possible to graze from May to September. These constraints should be clearly stated.

The contract should address all other aspects of the agreement, including facilities and equipment, the need for Mine Safety and Health Administration (MSHA) training for the graziers, whether or not four-wheelers or horses can be used on the property, and the obligation of the grazier to fulfill the requirements of the grazing contract. The initial condition of the property and who will be responsible for fence repair and water facilities should also be included, as should the frequency at which the grazier intends to check the stock, and the response time for gathering strayed animals. Contract language should otherwise follow standard legal format for land use agreements. Maps or exhibits may be needed to complete the contract.

The terms of the contract are extremely important. The grazier will always desire maximum stability in the contract. Typically, however, a grazing contract is for one year. This gives the EE a straightforward route to extricate himself or herself from the contract, if necessary. In addition, it gives both the EE and the grazier the opportunity to negotiate price changes based on market conditions. After a good working relationship is established with the grazier, the contract period may be extended.

4. Establishing and Controlling a Grazing Program on the Mine Site; Implementation

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

Developing a grazing program on reclaimed lands can be time consuming. However, the rewards will far outweigh the difficulties. The Environmental Engineer (EE) in charge of the project must be given the support and resources to conduct a successful program. When this occurs, the program can be an ongoing source of satisfaction to all involved.

Special Considerations

The successful grazing program should be continually growing. The program will expand as more reclaimed land becomes available, and improve as the successes and failures of each year are applied to the following year.

Techniques

a. Training and Education

Training and education of the EE, the grazier, mine site employees, mine management, and regulatory personnel will all contribute to program success. When possible, both the EE and the grazier should be exposed to different grazing programs, and both should keep current on grazing literature. Records should be kept of the annual grazing plan, and the successes and failures of each year should be discussed and applied to the following year. Mine site employees should be kept informed of the goals and the specifics of the program each year. Mine management must definitely be kept aware of the successes and setbacks of the program.

The EE should plan to write progress reports for the regulatory agency, and memos for the workforce and management. Multi-media presentations and tours are a great way to obtain program support. A photographic record of the program is also very useful, particularly when requesting bond release.

b. Expanding the Program

Because reclaimed lands are continually expanding, the grazing program will also continually expand. Planning for expansion will depend on program goals and should be discussed well in advance with the grazier, who may need to supply additional animals. In addition, the EE must budget both time and money for fencing and water additions, and contact the regulatory agency before expanding onto formerly ungrazed lands.

The grazing program will eventually become a major focus of the reclamation effort, and will reap many rewards for the company. It is important, therefore, to spend the time needed to continually update and improve the program, and to monitor to ensure that program goals are being met. The program must be responsive to the needs of the landscape.

c. Livestock Tips for the Environmental Engineer

While it is unreasonable to expect every EE to be an expert in range and livestock management, there are a few key actions that can go a long way toward ensuring the success of a grazing program. First and foremost, take the time to check the pastures occasionally, at least once a week during the grazing season. If the mine site has security people, they are often willing to check the stock for you every day. However, you or the security people are **not,** *repeat* ***not*** a substitute for the grazier. Look for the following:

(1) The Development of Trails

The development of trails is a surefire sign that the livestock are remaining in the pasture too long. The EE should expect some temporary degradation of the pasture around the water source. With proper management, this will disappear during the next growing season. However, beware of distinct trails from all corners of the pasture to the water or along the fences. Livestock should be removed from a pasture immediately **before** these trails develop. It is the responsibility of the grazier to perform this task and he must be responsive to the concerns of the EE.

(2) Animal Health

Scan the herd for animals with droopy ears, snotty noses, sore feet, or sluggish or irregular behavior. If this is observed, contact the grazier immediately. Most sick animals can easily be treated if they are identified early. While herd health is not the responsibility of the EE, a dead animal laying out on the reclaimed ground is not good publicity for anyone. However, the EE should refrain from the temptation to work directly with the grazier's stock. This can lead to uncomfortable relations with the grazier and liability for the EE.

(3) Ample Water and Minerals

Do the animals have enough water and is that water cool? Water stress very often forces the animals to search for better water, and escaping animals on the minesite are a headache no one needs. While in the paddock, check the supplements, if any, that have been put out for the animals. Lack of bloat block in a pasture with lots of alfalfa can lead to disaster.

(4) Fencing

Take a quick look at the fences in the pasture. Any wire that is down should lead to a call to the grazier.

(5) Strayed Animals

Occasionally, despite everyone's best efforts, livestock will stray from the paddock. This can be minimized by good stock handling and proper pasture management. However, the EE should have a pre-arranged plan for this situation. Typically, mine site personnel will notify Security of the situation and Security will contact the grazier directly. Make sure a procedure for stray livestock is developed, is in writing, and has been properly communicated to everyone.

5. Creating Livestock Pastures

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

To a large extent, the grazing program is controlled by the pasture plan. The Environmental Engineer (EE) should spend plenty of time developing the plan, and take into consideration the advice of many. The pasture design must support the goals of the program while maintaining maximum flexibility and growth potential in the system.

Special Considerations

As in all other aspects of a grazing program, the prudent EE will take the time to develop a reasonably detailed plan of pasture locations. The pastures should be mapped, and each year the new plan for pasture rotation should be placed on the map, along with any pasture upgrades. The date the pasture is first brought into the rotation is a useful piece of information to have on the pasture map. Unfortunately, it is easy to let the pastures grow helter-skelter, only to find out one year that there is no adequate map of the grazing facility. Don't succumb to the temptation to leave the map upgrade for "later in the year."

Techniques

a. Pasture Size

Pasture size is of great importance, and is very dependent on the number of animals and the timing of grazing. Calculations related to pasture size are discussed in further detail in the subsection entitled "Timing of Grazing". Husbandry goals such as removal of biomass and alteration of the surface are greatly affected by pasture size. The general rule is, the smaller the pasture, the better. However, small, permanently fenced pastures can be prohibitively expensive, and have a nasty habit of being disturbed by unforecast mine activities such as road building or tank installation. Pastures are always a compromise between goals, budget, and convenience. Nonetheless, the size of the pasture is a powerful grazing tool, and its value is well worth any extra effort needed to optimize the pasture design.

Central to the definition of pasture size is the concept of uniform application of grazing pressure. Pastures should be designed to receive uniform grazing pressure. The other, equally important, concept is timely removal of grazing pressure. Retention of adequate residual is the secret to good pasture management. Pasture size must support both of these concepts.

When herd effect is important, the best practice is to have as many animals on the ground as there is grass available for them. This usually means large numbers of animals and small pastures. To achieve this, a good practice, particularly in the initial stages of the program, is to establish a few permanent perimeter fences and subdivide the interior of the pasture with electric fence. High tensile one-wire electric fence whose location is set for several grazing seasons is a good compromise between man-hours and flexibility. The perimeter fences should be installed to prevent stock break-outs into mine work areas. Once the EE has an understanding of the grazing system, it may then be possible to permanently subdivide some of the larger pastures.

It is important to keep in mind that the livestock are being used to manage the grass resource, not that the grass resource is being sacrificed for the convenience of the livestock. Thus, it is often necessary, particularly on reclaimed ground, to set up pastures specifically designed to minimize a weed problem, trample down excess vegetation, or break up crusted soils. These objectives are legitimate, and can be very successful. In such cases, grazing intensity should be managed carefully to ensure condition loss does not occur to livestock.

b. Pasture Shape

A circular pasture on flat ground is the theoretically ideal pasture shape because there are no corners or irregularities to diminish the uniform application of grazing pressure. Except in irrigated situations, however, a circular pasture is neither reasonable nor desirable. However, the concept of uniform application is relevant under any condition. Thus, to the extent possible, pastures should be as equal as possible in all dimensions, and with as few corners and tight spots as possible. Extremely rough terrain is not likely to be a consideration on reclaimed ground, but the EE should avoid long skinny pastures and pastures with more than six sides.

c. Location of Supplements, Including Water

Keeping in mind the principle of uniform application of grazing pressure, supplements should be evenly distributed about the pasture to minimize over-utilization of certain areas. Supplements such as minerals and fly control devices are attractants. Their use can be optimized by placing them away from water to draw the stock away from watering areas, which tend to be overused. Attractants should not be placed in areas that tend to become trails, for example, along fence lines. This will only lead to faster and more permanent trail development.

Placing supplements next to the water is almost always an unbearable temptation for the grazier. It is easier for the grazier, and he or she can be sure the livestock are finding the supplements. Remember, however, that supplements are attractants. The livestock will find them. Remember also that the livestock are out in that pasture 24 hours per day. Curious as livestock are, it is extremely unlikely that they will fail to completely explore every square inch of the pasture. Do not succumb to the grazier's tendency to place supplements close to the water. It is likely that the EE will need to keep a close eye on this as it is contrary to all program goals.

d. Adjacency

Another consideration in developing a pasture plan is isolated pastures. Unless isolated pastures are desired for special purposes such as for bulls outside of the breeding season, for horses that are being used in the program, or for sick pens and recovery pastures, they should be avoided. Part of the planning program is to connect all the pastures to the maximum extent possible. This will certainly minimize the possibility of animals getting loose during pasture moves and will reduce the workload for all concerned.

e. Type of Fencing

Next to water, and, in reality, a far distant second in importance to water, is the type of fencing to be used on reclaimed pastures. Fencing should never take the place of adequate pasture, stock, and water management in controlling livestock. A properly trained herd inside properly managed pastures will need very little to restrict them to the pasture. Fences are a poor substitute for good water and good management. On the other hand, loose stock on the mine site are a very real safety threat, so the issue of fences must be diligently addressed. Fences designed to be the ultimate barrier between livestock and active mine areas should be well constructed and well maintained. Fences must also meet regulatory requirements, which typically are designed to facility the movement of wildlife such as deer and pronghorn antelope.

The EE must constantly be aware of the needs and plans of the mine when developing a fencing plan. It is almost certain that fences will be installed in areas that will later be needed for other purposes. Minimize fence removal and re-installation to the extent possible by working closely with Engineering, Operations, and Construction.

(1) Wildlife

Careful consideration should be given to wildlife when constructing fences for livestock. Even the minimum possible amount of fencing can represent a barrier to wildlife. State Land Quality or Game and Fish guidelines should be followed for fence construction, particularly with respect to spacing between the wires and installation of a smooth wire on the bottom.

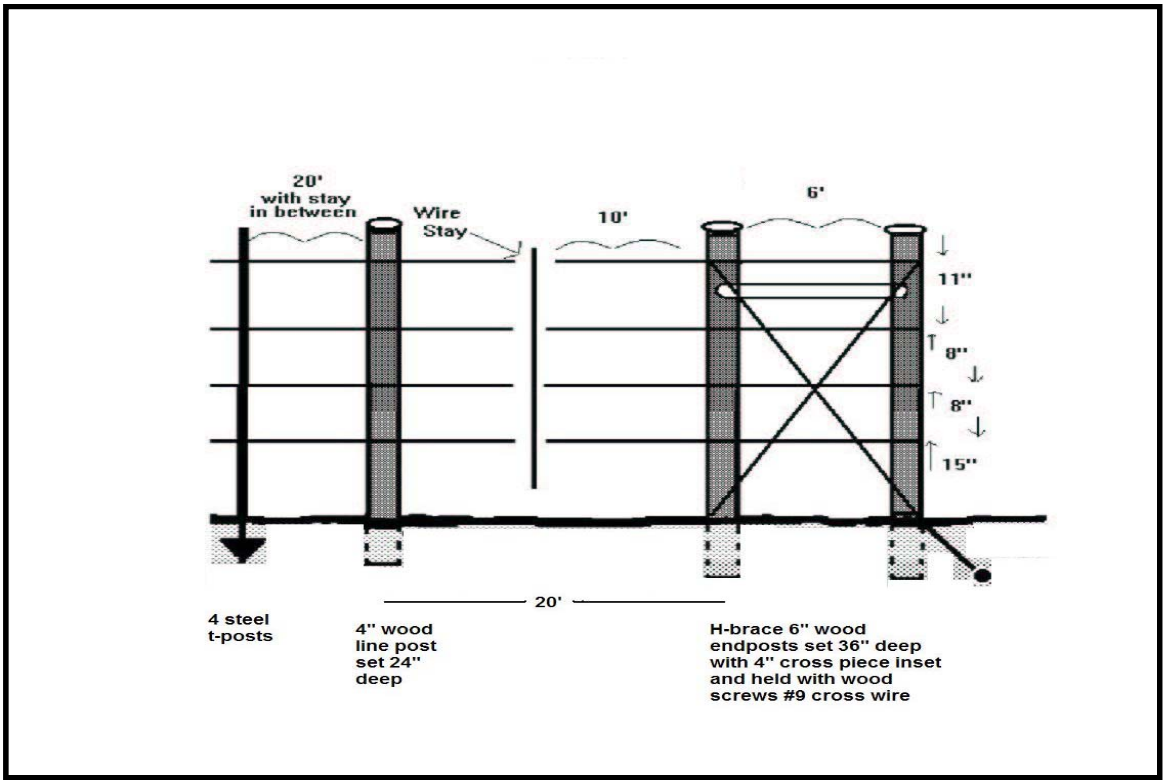
Another wildlife consideration is exclusion fencing. Exclusion fencing is used to manage and defer grazing in wetlands and riparian areas. While complete exclusion is not usually necessary, these areas should not be grazed during wildlife breeding seasons, and the timing of grazing of these areas must be carefully managed. For more information, see the subsection entitled "Fencing Practices and Wildlife."

(2) Permanent Perimeter Fence

Where fences will be the ultimate barrier between livestock and active mine areas, fence construction should follow State guidelines. Using “Gaucho” barbed wire and stays will reduce the need for posts. However, be warned that gaucho wire, a lighter gauge and springier type of barbed wire than conventional barbed wire, is difficult to work with, and graziers and fencing contractors may go to great lengths to convince the EE of its undesirability. Nonetheless, field tests have shown this wire to resist snow burden and be more resistant to breakage than conventional barbed wire. It is a fencing tool that should be given careful consideration.

The following figure shows a permanent perimeter fence design that has worked well in many locations. The figure includes information on stays, post depths, deadmen, and construction that should be considered and tailored for the particular location.

Where fences will not be the ultimate barrier between livestock and active mine areas, a three-wire perimeter fence built solely with t-posts and h-braces only at the corner, or 1-wire high-tensile electric fence work very well. These fences are relatively easy to remove. The electric fence is a very safe bet IF it is hot. Never run an electric fence at less than 7000 volts and you will never have an excursion.



Fence

Construct a four-strand wire fence, using 15-½ gauge wire. The top three strands will be barbed wire and the bottom strand smooth. Posts are set 20 feet apart, with wire stays between every post. Wood posts are to be placed every fifth post.

Braces

To be placed every quarter-mile, at cross fences, the bottoms of draws, and other locations as specified by the EE. A deadman will be placed at all corner and gate braces. The deadman will be tied to the base of a vertical brace post and extend 3 feet into the ground on an angle with the brace cross-wire. The minimum dimensions of the deadman will be 1 foot by 4 feet. Metal or treated wood can be used as a deadman.

Brace should be constructed of 7 foot by 6 inch diameter uprights, with a 6 foot by 4 inch diameter cross-post, securely nailed to the uprights at each end with at least three 40d spikes. The uprights should be notched to hold the cross-post. Cross-posts can be wood or metal.

To construct brace wires, twist two 15-½ gauge wires together. Place 15-½ gauge wire in a loop with ends securely spliced and wires stapled to the post on three sides. Use a fence stretcher to stretch wire before twisting. Twist resulting wires to form a taut tie.

Stretch Gates

24-foot stretch gates will be placed every half-mile and wherever fences meet, or as specified by the EE. Four stays must be used in each gate. Where permanent electric fence is in use, insulated wire should be buried below the stretch gate to carry the charge onward to the next fence section. Do not skimp on this wire or how it is buried. Good electricity is essential to fence success.

General Requirements

All staples holding wire, except in the braces, will be loose enough to allow play in the wire during changes in temperature.

Line posts and cross brace posts will be 6-½ feet by 4 inch diameter. Brace uprights will be 7 feet by 6 inch diameter. All wood posts must be fully pressure treated lodgepole pine, ponderosa pine, or douglas fir. Steel posts must be 5-½ foot "T" posts, C.F. & I. Silver Tip or equal.

Staples will be not less than 9-gauge bright, and two inches long.

Earthen fill around wood posts must be tamped and compacted unless the post is driven directly into the ground.

(3) Gates and Braces

There are as many ways to construct gates and braces as there are fencing contractors. Work out an acceptable procedure for your situation. Keep in mind that contractors tend to skimp on brace construction, so good construction specifications are absolutely necessary, or your fence will not last.

When building gates, remember two things:

- there is no such thing as too many gates, and
- never try to push livestock uphill to a gate, especially a gate that is not equipped with some kind of a trap or funnel.

(4) Electric Interior Fence

Both portable and permanent electric fencing are fantastic livestock management tools. They do have drawbacks that can be surmounted with experience and patience. However, they are unsurpassed in providing portability and flexibility in the management program. Temporary electric fence makes good temporary interior fence and can be used to micro-manage grazing utilization. Electric fence is also useful for moving animals (more on this under "Moving Livestock").

The number one rule for electric fence is high voltage. If a fence delivers 7000 volts, it will be respected. The GROUND must be good to deliver this kind of shock, so all efforts must be concentrated on creating a good ground. Believe it or not, the instructions that come with the fence charger should be followed to the letter. It is a very prudent investment to purchase the largest, portable, solar charger available and install ground rods as instructed. This will save hours and even days of headaches and stress.

Livestock **must** be trained to respect electric fences previous to being introduced to electric fence as the sole means of livestock control, particularly on the mine. Typically, training consists of no more than placing the cattle in a small pasture for a day or two, and then fencing across it with electric fence. The animals will test the fence and then learn to avoid it of their own accord, in a stress-free, familiar environment.

Animals can be trained to move into electrically fenced areas by being called and caked. If they are accustomed to other moving techniques that are quite and stress free, these methods may be employed. The key is to have the animals move into a new pasture without pressuring the fence. Moving techniques are discussed in greater detail under "Moving Livestock." A few days of “caking and calling” works for almost anyone, and will ensure obedient and docile animals on the minesite.

Never use electric fence as a management tool in situations where the animals are likely to be running away from something or otherwise stressed.

If sufficiently frightened, livestock will go through an electric fence, causing poor reinforcement training and considerable trouble for the grazier.

Electric fencing is simplified by good equipment and a four-wheeler. High-tensile permanent electric fence can be installed where fence movement is not expected. Portable electric fence can be installed where fence movement is desirable. The secret to electric fence in either case is a GOOD GROUND. Most electric fence failures are attributable to poor grounding.

Patience is a valuable asset in using portable electric fence, as the wire can be easily tangled. A four-wheeler can be a real timesaver when installing and removing electric fence. Use top quality equipment, especially posts. Economy posts will deteriorate rapidly in strong sunlight, causing inconvenience for the grazier. Use a large lunch cooler to hold the battery out in the field or use solar chargers, which are very reliable if properly used and maintained. A one-piece cooler rather than a cooler with a separate lid is the best type for battery storage.

Be sure to buy a good fence tester (this is worth saying again, "Buy a good tester and ALWAYS keep it with you!"), and be sure to take the time to give the fence a good ground. Once the stock are conditioned, very little is needed in the way of electric fence -- usually one wire alone will be sufficient.

After the grazing season is over, take the time to maintain and repair the equipment. Store the equipment in a dark, dry place to ensure maximum equipment life, and don't forget to take that battery out of the cooler or disconnect the battery in the solar charger.

When installing electric fence to subdivide permanent perimeter fences, give thought to how the livestock will be moved. With portable electric fence, three lines are needed to maintain two paddocks -- one for the livestock to be in and one to move them into. Following initial set-up, the back wire can be leap-frogged ahead to form the next pasture. It is usually best to run the electric fence around the water tank to give full access to the tank. In this way, the water will need to be moved only every other pasture. More detail on this is presented in the subsection "Water Sources for Livestock."

Portable electric fence and pronghorn antelope are a real problem. Because antelope are so skittish, they will panic and run through an electric fence. There are no perfect solutions (and many people have tried to find one!!) for this except to allow the pronghorn to acclimate to the fence, to keep fence lengths reasonably short and out of pronghorn travel paths if possible, and to plan to check and repair the fence frequently. Another alternative is to go with one-wire high-tensile fence of a more permanent character. This fence is resistant to break-through and the antelope go under it without problem.

In the long run, as the grazing program evolves and becomes stable, it is likely that the use of portable electric fence can be minimized, although permanent electric fence can be a very cost effective part of the program. Water management can supplement fence management. However, if there is **any possibility** that you will use electric fence as a management tool, take the time to train or re-train your stock before starting them in the mine site pasture rotation. Two days of work prior to initiating the grazing program will save many headaches.

6. Water Sources for Livestock

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

Nothing is more important to livestock than water sufficient in both quantity and quality. Lack of this resource can cause more serious problems than deficiencies in other resources, and thus should be a primary focus of effort for both the grazier and the Environmental Engineer (EE). Good water availability makes it possible to maximize grazing management opportunities.

A water system should be as flexible as possible, anticipate future development, and be planned for worst-case water demand. With these considerations in mind, it is possible to develop a very successful grazing program, even if other factors are less than optimal.

Special Considerations

Water is far and away the most important livestock necessity. A stock animal without water for more than four hours is an animal under stress, particularly when temperatures exceed 75 degrees Fahrenheit. Stress leads to undesirable behavior and loss of condition. It is also inhumane. However, water is a good pasture management tool and can aid in good livestock distribution in the pasture. Thus, requiring the animals to move a certain distance for water does not constitute a stress, as long as the distances are small.

Over time, the grazing program will grow. The water system must be designed and over-designed with expansion in mind. Finally, there is no such thing as a fool-proof water system. Contingency plans, storage capacity, and redundant systems are essential for the health and comfort of the animals, the utilization of the pasture, the needs of the grazier, and the peace of mind of the EE.

Techniques

a. Amount of Water Needed

A hot cow will drink upwards of 25 gallons of water a day, and every cow in the herd will want to drink at the same time if water is limited. If water is always in abundant supply, the demand on the tank will be consistent and mobbing will not occur. Let the water run out once or twice, however, and mobbing will become the order of the day. The cattle will rush in when other animals do to ensure their share of the pie. Thus, it is important for water to always be available.

The water system should be designed with extremes in mind – extreme heat and extreme demand. A system designed for average water consumption needs is an inadequate system. The system should also be designed to accommodate herd expansion. In some years it may be desirable to run fewer animals for a long period; in some years, project goals may call for many animals for a short period of time. Once again, the water system should anticipate the needs of the program.

b. Water Quality

(1) Water Chemistry

Water chemistry should meet the standards of the state governing agency for livestock water. Livestock are averse to water with strong odors, and are averse to petroleum-tainted water. Consideration should thus be given to water source. Typically, the plant well or a water well designed specifically to supply livestock watering needs are the best choices. Stock pond water quality is usually sufficient for livestock, but the water supply is unreliable. As water levels decline, muddy conditions can lead to muddy animals, bogging, and, possibly, coccidiosis, a disease fatal to calves and difficult to treat.

(2) Water Temperature

Stock will not drink water warmer than 90 degrees Fahrenheit. Water consumption is reduced when water temperatures climb above 80. The preferred temperature is between 50 and 75 degrees in both summer and winter. The water delivery system should be designed to keep water temperatures in the preferred range, as livestock gains and health are adversely affected by extremely hot and extremely cold water. Unfortunately, the most flexible water handling system, the reticulated surface waterline, is also the system most subject to temperature extremes, even if white pipe is used. Thus, some design compromise is required.

c. Water Storage and Distribution System

(1) Water Source

Water can come from surface run-off or from groundwater. Surface run-off from intermittent and ephemeral drainages is usually captured behind earthen embankments. However, stock ponds are not a reliable source of water for a minesite grazing program. Ponds will often run dry during the course of the grazing program, or fail to fill adequately during wet periods. In addition to unreliability, the ponds are often heavily utilized by waterfowl, and this use is inconsistent with livestock watering during certain times of the year.

A more reliable source of surface water can be obtained from permanently flowing streams, if these are available on the mine site. Unless access is carefully managed, however, use of permanent streams can conflict with riparian management goals such as erosion and pollution control. Some means to utilize pit pumpage via surface features can be useful, if pit pumpage can be guaranteed.

Groundwater can be made available to livestock directly through springs, access to pits where water has accumulated, or through wells. When pit water is used, care should be exercised to ensure water quality is acceptable. Costs can be reduced if the livestock system can be integrated with a pre-existing mine well system. Otherwise, a dedicated well must be developed.

(2) Water Delivery

Whatever the source, a water delivery system must be included in the water system design. In the case where livestock have direct access to groundwater, running water, or ponds, no additional delivery system may be necessary. However, it is unlikely that a completely passive system will be successful in meeting pasture and reclaimed land management goals. Most likely a reticulated waterline system will be needed to deliver water to reclaimed pastures.

Early in a grazing program, it may be necessary and prudent to deliver water to livestock by means of a truck and tank of some kind. Oil field water trucks, pick-up mounted firefighting tanks, and hydroseeders have all been used as temporary and very mobile water delivery systems. In the long run, a more permanent system will be needed, especially as livestock numbers and program complexity grow. Portable systems can and should continue to serve as back-up systems.

(3) Redundancy

In no other area is redundancy more important than in water delivery. Redundancy can be made available in the form of alternate delivery systems, as mentioned above. It can also be made available in the form of storage capacity. A system with two days of storage capacity is usually sufficiently protected from system failure. However, redundancy will be of no use if a means is not in place for regular checking of livestock water. Although problems in a minesite grazing program are uncommon, water deprivation is the most likely, and poses the greatest safety hazard because the stock will escape the pasture in search of water. As mentioned above, four hours without water on an extremely hot day can cause significant livestock stress and risk of livestock excursions.

(4) Reticulated Water System

A reticulated water system is simply a **network of pipeline** that delivers water to a series of pastures. The network usually originates at a large storage tank, and may be hooked into a redundant system that can allow delivery from another tank. The best type of reticulated system is one where the water can be delivered from the storage tank to all points by **gravity**. A pump-driven system is a system full of headaches and should be scrupulously avoided unless there is no choice.

The NRCS or virtually any hydrologist or pipeline contractor can aid the EE in designing the reticulated water system. The static and dynamic hydraulic head and the extent of the system, as well as the desired delivery rate, must all be considered when designing the system. The EE will do best to be extremely conservative in the selection of the line size and in the selection of the material type. It is unfortunately easy to be misled into installed a system too small to meet demand.

For the systems typically used in a mine situation, 1-1/2 to 2 inch polyethylene line, typically SDR 17 or 11 (or even 9) is a good choice. Smaller line can be used as terminal line, if it is certain that extensions will not later be required. Avoid PVC line as it is easily damaged by settling or vehicles. Avoid the temptation to save money by under-designing the line. If large numbers are expected, a 3-inch mainline with 2-inch feeders would not be out of place. A line that cannot deliver the needed water will hamstring the entire grazing program.

(a) Air and Pressure Relief Valves

Consider that a reticulated system may need air relief and pressure relief valves. Use the most simple and durable valves on the market for these items. Expect the reticulated system to become air-locked occasionally, and develop, in writing, the standard procedures for relieving air lock.

(b) Maintenance

Absolutely critical to the system is a regular schedule of maintenance. Performing preventive maintenance before the livestock arrive on the minesite and winterizing the system annually are essential to program success. Preventive maintenance should include periodic flushing of the entire waterline with chlorinated water. Systems maintenance is an opportunity for lots of headaches for the unwary, the lazy, or the EE with insufficient resources.

(c) Line Burial

Line burial is an absolute must, but, given the uncertainty that accompanies mine operations, shallow burial (approximately four to six inches) may be necessary. Shallow burial is sufficient to protect the line from sun, livestock, and vehicle damage, and to protect the water from temperature extremes, yet sufficiently shallow to allow easy movement of the line. Shallow-bury lines require good winterization techniques and sufficient quality of pipeline to resist winter bursting.

Deep burial should be considered where winter grazing is planned, or where deep burial is absolutely necessary to protect the line from mechanical damage and temperature extremes. Deep burial is not recommended at early stages on reclaimed areas because of the settling that is typical of those areas. Repairing a line buried six feet deep is a real pain.

(d) Valves, Tees, Reducers, and Hydrants

Valves, tees, reducers, shut-off valves, and hydrants are essential parts of the reticulated water system. Check valves should be installed between the well and the storage tanks, and between the storage tanks and the delivery line, particularly if two storage tanks are being used. Delivery valves should be placed on tees off the main system, with reducers placed in the tee such that the actual delivery valve will accept a garden hose (if cattle numbers are less than 150) that will connect to the tank float. Reducers should not be used if cattle numbers are large, but rather quick-connect systems that will not impede flow from the delivery line into the tank.

The system should be liberally equipped with delivery valves. Valves represent a relatively small increase in pipeline price, and dramatically increase the utility of the system. As many valves as possible should thus be installed in the system.

When the system is deep buried, hydrants can take the place of valves. Hydrants should be individually equipped with shut-off valves, so one broken hydrant doesn't drain the entire system.

Hydrants and delivery valves are of far greater utility on a reticulated water system than permanent tanks. Permanent tanks restrict the way in which pastures can be utilized, and frequently lead to over-utilization around the tank and under-utilization at margins of the pasture.

For shallow-bury systems, shut-off valves should be installed wherever the systems branches. In this way, the entire system need not be completely primed with water for the entire period of utilization. This reduces wear on the system and the possibility of algae build-up. It also provides a means to isolate pipeline breaks and aids in the systematic elimination of air lock. Deep-bury systems should also be equipped with shut-off valves, although it is usually not practical to install a shut-off valve at every reticulation point on a deep-bury system.

(5) Storage Tanks

It is usually unwise to scrimp on selection and installation of a storage tank. Be wary of bargains. A used tank may have a damage and repair history that will later cause problems or leaks. Tanks have been known to slough repair caulking, thus hopelessly plugging the waterline. Old tanks and repaired tanks can leak, a situation difficult to repair when demand on the tank is high. Polyethylene tanks are economical and a good value for summer systems. Steel tanks may be better for winter systems, and steel is certainly the material of choice when tank burial is a consideration.

(a) Tank Placement

Tank placement is an important issue. Spend the time and money to put the tank in the highest possible location. This will be re-paid many times over as the system expands.

(b) Storage Capacity

The storage tank should have at least two days of storage capacity for the maximum number of animals anticipated. The two days of capacity should be for maximum projected intake for each stock animal. For example, for cows, projected maximum intake should be at least 25 gallons per day per animal.

(c) Maintenance

Storage tank maintenance should never be neglected. Small leaks should be repaired before they become big leaks. The tanks should be flushed at least annually with chlorinated water or its equivalent. In areas where wells are contaminated with bacteria, quarterly flushing is recommended. Tanks should be regularly inspected to ensure valves are operating properly and tank integrity is being maintained. Inspection and maintenance forms for the tank, and for the system as a whole, are a good idea.

(6) Stock Tanks

(a) Storage Capacity

The stock tanks themselves should have as much storage capacity as possible yet be as mobile as possible. Water delivery rates will dictate to some extent the size of the tank. It is far more efficient to use as small as stock tanks as possible with as great a delivery as possible. This helps to minimize cattle hanging around the water tank. Typically, 800-gallon circular tanks mounted on tank carriers are a good choice for reclaimed pastures. The 800-gallon tank is small enough to be man-handled when necessary, but large enough to provide the capacity for several hundred animals if water supply is good.

Several tanks can be wagon-trained together, if necessary, to provide sufficient capacity for larger numbers of animals. Tanks need not be drained before being moved, if they are not being moved a great distance. Otherwise, the tank should be drained through the drain hole provided, after the livestock have been moved to the next pasture, and then leapfrogged to the pasture ahead of the cattle. If is essential to have water tanks set-up and full when animals arrive in a new paddock. Setting up water with 200 hundred thirsty cows bellering around you is a harrowing experience and totally unnecessary with good planning.

(b) Tank Carriers

Tank carriers are useful additions to the water management system. These must be constructed, as they are not commercially available. A tank carrier can be made from two axles welded together in a framework that matches the configuration of the tank bottom. The carrier is equipped with a hitch, a ball, and jacks to allow the tank carrier to be transported, to be leveled when necessary, and to take weight off the axles when the tank is in operation. The following figures show a tank carrier that has been used successfully as part of a water management system.

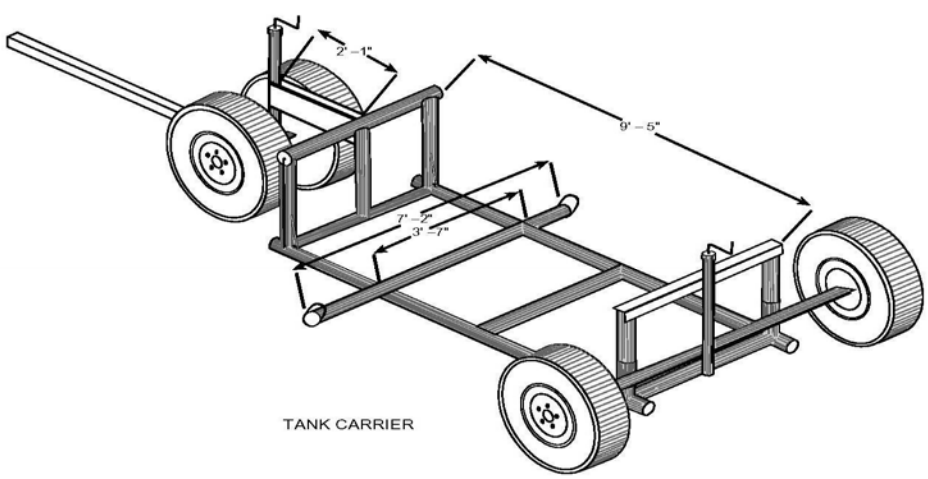
Tank floats are an important consideration. They must be sturdy and resistant to livestock damage. It is not unknown to have an entire water system drained by a curious cow knockomg a float out of the tank. While conventional ball floats work in the system, tanks can also be equipped with a vertical slide float encased in a plastic traffic pylon. The pylon is then centered in the tank, providing protection for the vertical slide float. The float is hooked to a hose, which leads, in turn, to the water distribution valve.

Experience has shown that the best set-up for a portable tank water valve is to thread a pipe through the drain hole and connect the float directly to that pipe. “Tru-test” valves are very reliable in this application. This method is virtually problem-free, even if light-weight polyethylene tanks are used. The tank can easily be emptied by removal of the plug at the base of the float.

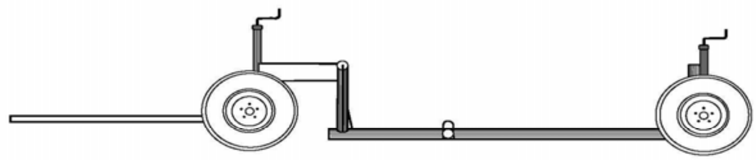
If one side of the tank is not protected from livestock by fencing, it is usually necessary to **sleeve** up to the entire length of a flexible water hose with a piece of PVC or polyethylene pipe. This will ensure that the water supply is not cut-off by an animal standing on the hose. Even when HDPE line is used, it is advisable to sleeve the connection between line and tank to prevent damage to this essential connection.

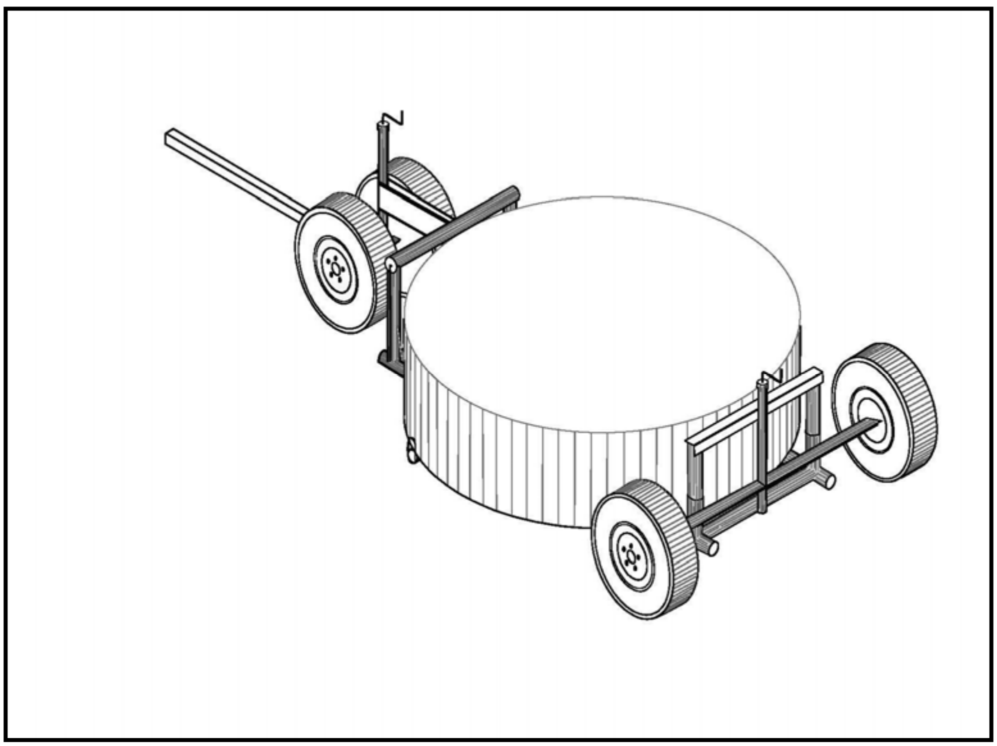
While a portable tank system may seem to be troublesome, there are significant rewards to be gained from its utilization. The location of tanks can be altered frequently to reduce damage of the grass resource around the tank. Each year the tank can be placed differently to minimize damage. Finally, tanks can be moved from valve to valve to modify utilization patterns within a pasture, thereby greatly reducing the need for interior fencing.

When moving livestock from tank location to tank location within a pasture, it is wise to call and cake the animals to familiarize them with the new water location. Never leave more than one tank location active in a pasture at the same time. This defeats the purpose of the grazing management plan.



NOTE: USE 2 7/8" P1PE (OUTSIDE DIAMETER) AND AN 8' FIBERGLASS TANK WITH DRAIN PLUG ALL MEASUREMENTS ARE APPROXIMATE





7. Moving Livestock

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

Cattle moving can be pleasant and enjoyable for all parties. The cattle generally reap the benefit of new pasture from a move. The Environmental Engineer (EE) reaps the benefit of pasture management and favorable public relations. However, on a mine site, there is no aspect of livestock handling during which proper stock handling is more essential than during cattle moves, particularly across active work areas.

There are as many ways to move cattle as there are persons conducting the move. Decent stock dogs are a life-saver to the single-handed stockman. This is equally true for a well-trained horse. However, for simplicity and ease of use, **attracting** the livestock into the desired location is a technique readily available to anyone.

Special Considerations

As with any other organism, livestock can be most easily induced to move by attraction rather than repulsion. Attraction, coupled with positive expectations generated by training and stress minimization, will result in straightforward and successful livestock movement on the mine site. Keep in mind that some types of livestock are better tempered and more compliant than others. Buffalo, for example, have not yet been bred for docility, while most types of cattle have. Some types of stock, such as horses, are curious enough that they can be manipulated through their own curiosity. In all cases, patience on the part of the handler will reap benefits. "More haste less speed" is axiomatic in livestock handling.

Techniques

a. Livestock Psychology

Livestock psychology is simple. If the animal is frightened, it will run away, or try to run away. It will also become less predictable. Rarely will an animal become aggressive, especially a cow or calf. If an animal has learned that food or fresh forage will become available as the result of some action on its part, that animal is likely to perform that action. The following discussion centers around the psychology of cows, but the general ideas are applicable to most types of livestock. This method of moving is not intended to replace other established methods of moving for livestock, but to describe a method that is not well-understood and is under-utilized.

Cows do not like sudden motion or movement on the part of others. Even in slow motion, if a cow is approached head-on, it will usually turn away to one side or the other. Cows do not like to be stared at. This will usually cause them to turn away, back up, or stop. If the "personal space" around a cow is invaded by something or someone other than a cow, the cow will move away. If a cow is approached from the rear and from the side, it will move ahead and away. It is difficult to sneak up on a cow exactly from the rear, so the reaction of the cow in this case is difficult to predict.

Cows are very Newtonian in the sense that, once in motion they tend to remain in motion; once at rest they tend to remain at rest. If a herd of cows is moving along in the desired direction, everything possible should be done to maintain the flow. Once stopped, cows will start to think about what is happening to them, usually with the end result that they become uneasy and more difficult to handle. Because of the herd tendency, a cow that is moving along with other cows is usually a content cow. Advantage should always be taken of this fact.

Cows do not like loud **unpredictable** noise. Thus, they will move away from loud unpredictable noise. On the other hand, if they have a favorable association with a certain type of noise, for example, if a person calls or whistles for the cows every time they bring food or a treat, the cows will move toward the noise. This is also true if the noise emanates from a pick-up or a four-wheeler. Cows usually recognize the person or vehicle as well as the sound, and will cue both visually and aurally when responding.

Cows do not easily enter confined spaces unless prior experience tells them no harm is likely to befall them. Thus, it is particularly difficult to force a cow into a strange, confined space. This is important to remember when attempting to load a sick or injured animal out of a pasture and into a stock trailer.

For the most part, cows are docile and usually quite willing to cooperate with what you have in mind. Aggressive pushing, chozing, or chasing stock is always an indication of ignorance on the part of the stock handler. Even cows that have been mishandled for a great part of their lives can be handled quietly with the right techniques, and over time can be re-trained to be very easy to handle.

b. Livestock Training

Once again, the elements of training are simple. Livestock are attracted by food, water, and supplement. Cattle are particularly fond of cow cake, a grain-based energy and protein supplement. Investing in a ton of cake for a season of grazing is a very cheap way to have animals come to you or go where you desire. Given the time savings and the wear and tear on equipment and humans, attracting cows with cake is a very prudent tool for livestock handling.

Similar to the technique of familiarizing cows to electric fence, training cows to come when desired should be conducted in a small, homogeneous pasture. Training calves is a little more difficult, and takes a little longer, but the same principles apply. Start by setting out approximately a pound (about half this for calves) of supplement per animal. If cow cake is used, this can be poured on the ground in a long thin line, meanwhile calling to the herd in a positive, encouraging voice. It is a very unusual cow that will fail to run to cow cake.

Adding voice reinforcement will usually bring cows from far corners of a pasture, even when they cannot actually see cake being offered. If training begins during a period when grass is extremely lush and tall, some difficulty may be experienced in attracting the cows. Even in these situations, however, most cows have sufficient prior familiarity with cow cake that they will come.

After a day or two of simply feeding and calling the cows, begin to use a brightly colored bucket containing a few pieces of cow cake to provide visual reinforcement. Shake the bucket to generate noise. The cows will soon learn to recognize the sound of cake in a bucket. Continue to feed about a pound of cake for each animal. Wait until all members of the herd are close to you before you actually set out the cake. This ensures that all animals will receive at least a little reinforcement training.

Then, for the next two days, enter the pasture, shaking the bucket and calling to attract the cows to you. Cake amounts can be reduced to half or quarter pound levels within four or five days. By this time, the herd should be fully acclimated to you and your attracting routine. At this time, begin moving the cows through a gate or an electric fence to acclimate them to movement. Cows quickly learn that an open gate means fresh forage, and will often push past you through an open gate with no further encouragement.

In general, it is better to bunch cows up a bit at a gate and then open the gate rather then open the gate early. This is because a herd of cows headed for a little treat will act as a unit. Stringing the herd out eliminates this desirable herd effect, and some cows are sure to stop and start thinking about what's happening, bringing the whole moving process to a stop. However, during moves where complete movement of the herd is not necessary, simply open the gate, call the cows, and let them move themselves at their own pace. Cows will always move to an ungrazed pasture from a grazed pasture, usually quite rapidly. Have patience; there is usually no need for a speedy pasture-to-pasture move.

The exception to this relaxed approach to cattle moving is when roads or other livestock barriers must be crossed, or when the livestock move has the possibility of delaying mine operations. In this case, the move should be carefully planned in advance, and plenty of trained helpers should be on hand to avert possible disasters. In addition, as described below, certain simple tools can be employed to facilitate the move. Most important of all, plenty of communication and coordination is needed between operations.

Once the cows respond readily to calling and bucket noise, they are ready to be taken onto the mine site. The training process should take no more than five days for initial training and only two or three for "refresher training". Remember to use cake for reinforcement for the mine site moves -- a few pounds are usually sufficient to keep all animals interested. It is the same theory of positive reinforcement that works so well with humans. If cows are called time after time and not offered a reward, they will slowly (or sometimes quite rapidly) decide there is nothing in it for them, and will not move.

The same process that works for moving cows from pasture to pasture also works well over much longer distances. Over longer distances is it often useful to have one or two people on horseback or on foot at the rear to keep the cattle moving. In front should be a person with the bucket, a truck, or a four wheeler. If the cows are used to being attracted by someone on a four-wheeler, do not make the mistake of trying to push them with the four-wheeler. Most of the cows will be confused. Some will come toward the four-wheeler in expectation of cake. Some will move away from the four-wheeler, but usually not in the direction desired. The four-wheeler is best used as part of the attractant end of the business, not least because it can carry one or two hundred pounds of cake.

As mentioned above, animals do not move well through a gate that is not located in a bit of a trap. At times, cows will decide they do not want to cross paved roads. This is especially true with young animals. Patience and keeping the herd moving will usually overcome this aversion. Feeding a few pieces of cake to the greedier cows as they move along will help coax the rest of the herd in the desired directions.

Cows will not readily move out onto places that appear strange. Thus, when moving animals across a haul road for example, all elements of the move should be kept as familiar as possible. The same voice, the same bucket, and the same behavior will all contribute to a smooth move.

c. *Crossing Haul Roads and Highways*

The key ingredient to crossing haul roads, highways, and other active areas is communication. Communicate well in advance with shift supervisors, managers, security personnel, and safety personnel regarding the timing, location, and manner of the move. Often it is most convenient to conduct a cattle move on the minesite during shift change or during lunch breaks. When moving across the highway, it is courteous to notify the highway patrol, especially if the move will occur across a busy highway.

When cattle are not familiar with the area across which they are being moved, an alley comprised of electric twine and pylons can be devised to guide them. This should not be electrified. The cow caller with his bucket or four-wheeler should lead the herd exactly the same as they have been trained. This is not the time to try a new method or to assume that, because calling alone usually works, no cake is needed this time. Haul road moves, which are usually smooth and painless, can be invitations for disaster.

During road moves, security and supervisory personnel can be used to block the road on either side. If trucks are not available, persons with flags are acceptable. Be sure that blocking personnel are at least 100 yards from the cattle. Otherwise, they may disturb the stock, and interrupt the smooth flow of animals.

Often it is best to have a few extra people on hand in case animals begin to stray. One or two people on foot at the rear of the herd will help to keep the herd in motion. At no time is it more important than during a haul road or highway move for workers to employ cow psychology (as discussed above) to the maximum extent. However, it is easily possible to move hundreds of cows across unfamiliar spaces with a caller, two blockers, and two follow-up personnel.

d. *Stock Moving Equipment*

Whenever possible, it is always best for cows to move themselves. However, if time is limited and distances are great, or if a cow must be transported to the veterinarian or the sick pen, some equipment is needed to effect the move.

(1) Unloading Stock

If stock are brought to the mine site in a large tractor-trailer rig, a portable unloading chute will be necessary. These can be purchased, and sometimes rented, from a local livestock equipment supplier. Be sure the chute is in good working condition, particularly the floor of the chute. Never hurry animals during unloading. The more calm they are upon arrival, the less likely will be a mishap of some kind during or following unloading. Nothing is more undesirable than a broken leg, or a group of wild animals that immediately breaks through a fence and runs for the neighbors. Of course, if the recommendations given above are followed, neither occurrence is likely.

If the stock are brought to the mine site in a stock trailer, no chute is necessary. However, the task of unloading will be eased if the trailer is backed up to a rise or small hill, so the stock need not jump down from the trailer. If the trailer floor is wet and slippery, running and jumping will likely lead to injury.

Once unloaded, the stock should settle rapidly. If not, some cake will draw their attention away from their new surroundings, and allow time for settling. Be sure that the fences are tight and water is available **before** releasing stock in a pasture. Mineral supplement should also be available. When releasing stock in a pasture with alfalfa, it is best to provide bloat block for five days prior to release.

(2) Loading Stock

If stock are to be loaded onto a large tractor-trailer rig, it is best to trail them to a dedicated load-out facility. Many problems can occur during loading onto such a rig. It is generally true that the truck driver will assist in loading the animals. It is also generally true that the trucker will use yelling, pushing, and a hot-shot (an electrical stimulating device) to assist in his loading efforts. Come to terms with the trucker before you start loading the truck. Be sure to discuss with him how loading will occur and the group size to be loaded. It is best to bring the truck to the load-out, park it, and turn it off before loading begins. Truck noise can be frightening to the cattle.

A series of small pens and a narrowing alley to the load-out chute will assist in easy loading. If the cattle are calm and familiar with trucks, they will almost load themselves. If the cattle are unfamiliar with loading, loading very small groups (like 2!) at a time will be more time effective in the long run than trying to push bunches up the chute.

A more common problem on the mine site than group loading is the need to load one sick cow or the bulls into a stock trailer. In this case, a portable corral is extremely useful. If arranged so entrance to the trailer is achieved through a funnel or alley, it is likely no load-out chute will be needed. Most tame cows and bulls will jump into the stock trailer if the distance up does not exceed about 18 inches.

Even broken-legged cows have been loaded successfully into a stock trailer in this manner, even without portable corrals. The keys once again are patience, accommodation of cow psychology, and some forethought about the arrangement of the stock trailer. Cow cake can be used to coax a group of animals containing the target animal(s) into the corral, and the unnecessary animals can then be sorted off, leaving the target animal(s) in the corral.

8. Vegetation Quality for Grazing

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

Forage is the general term for the food necessary to support livestock. Forage requirements vary greatly for different classes of livestock at different times in their life cycle. It is not the purpose of this subsection to discuss in detail this information, which can be more adequately obtained from other sources. Instead, this subsection relates basic forage requirements to conditions most likely to be found on reclaimed mines sites.

Special Considerations

Cattle need protein, energy, and minerals for a balanced forage. Adequate quality forage is usually available during any period of active vegetation growth. When vegetation is no longer growing, and has become senescent or dormant, forage quality will be insufficient for livestock growth and health. Under these conditions, forage supplements must be available to achieve livestock needs.

Techniques

a. Active Vegetation Growth and Vegetation Variety

(1) Cool Season and Warm Season Grasses

The typical reclaimed landscape is dominated by cool season grasses. These grasses begin to grow early in the year and provide excellent forage until they begin to go dormant, usually in late June on the Northern Great

Plains. At this time, warm season grasses become preferred forage because their period of growth typically extends later in the summer. In addition, certain warm season species such as blue grama (*Bouteloua gracilis*) on the Northern Great Plains will cure with a higher protein rate than cool season grasses.

The Environmental Engineer (EE) who desires a successful postmining land use program should become familiar with the phenology and characteristics of species that will be planted in the postmining landscape.

Successful establishment of palatable warm season grasses is an important aspect of a well-rounded forage program. Without palatable warm season grasses, the period during which livestock can graze on the mine site without supplementation is limited to the active growth period of cool season grasses. Depending on the location, warm season grasses can be difficult to establish, or certain species can be easily established but are not palatable. Prairie sandreed (*Calamovilfa longifolia*) is a good example of an easily established warm season grass that is not particularly palatable, except as a cured forage in the winter.

The prudent EE will work hard at warm season grass establishment, not only for regulatory requirements, but for the adequate establishment of the postmining land use.

(2) Forbs

Forbs are also an important part of the grazing program. Alfalfa (*Medicago sativa*) is an excellent forage and is heavily used by cattle, deer, pronghorn antelope, elk, and many species of birds and mice. It is an introduced species that deserves a place in the reclaimed landscape. Its deep roots and ability to fix nitrogen make it useful for soil development and retention.

(3) Shrubs

Shrubs also play an important part in livestock and wildlife forage. For example, four-wing saltbush (*Atriplex canescens*) is native to the Northern Great Plains, is reasonably easy to establish, has been shown to be persistent under the proper grazing regime, and is excellent forage for livestock and wildlife. For these reasons, it should be a component of the postmining landscape wherever it is native.

The shrub component of the reclaimed vegetation community can be successfully manipulated with grazing practices. The effects of timing of grazing on different vegetation lifeforms is discussed in the subsection entitled "Timing of Grazing".

b. Livestock Supplements

When the reclaimed landscape is not a well-balanced mix of cool season grasses, warm season grasses, forbs, and shrubs, or if winter grazing is practiced, livestock will usually require protein and energy supplementation in addition to the usual mineral supplementation.

Often perplexing to the novice grazier and the EE is the sight of cattle standing in knee-deep grass but grazing little and losing condition. This often occurs by mid-summer where the vegetation is dominated by wheatgrasses. As the grasses begin to go dormant, it is wise to supply a supplement such as Crystalyx, Nutralix, Loomix, or cow cake. The grazier and EE should jointly decide on who will supply what supplement **before** the grazing season begins. In addition, supplement use should be frugally implemented to ensure that supplement costs do not outpace income from the grazing program.

Using the same logic applied to mineral (presented in the discussion about the grazing contract), the mine may decide to supply supplement to accommodate any possible forage deficiencies. In addition, supplements provide an excellent opportunity for managing vegetation and accelerating succession. Cattle that would not be otherwise interested in old, dry grass can be induced to forage with the use of a sweet supplement such as Crystalyx. This can greatly aid the EE in eliminating excess biomass from a pasture.

Winter grazing on reclaimed ground almost always requires protein supplementation. However, as mentioned above, careful study of nutrient requirements is necessary for maximum economy. Dry cows before their third trimester, for example, require surprisingly little in the way of protein.

9. Timing of Grazing

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

Roots, litter, adequate grazing pressure, ADEQUATE RESIDUAL, and proper timing of livestock movement will lead to pasture enhancement and successful postmining land use. Proper grazing, including the integration of native pastures where possible, will also enhance vegetation cover, production, and diversity, those features of the postmining landscape necessary for bond release.

Special Considerations

Nothing is more important to proper pasture management, diverse and productive vegetation, and successful postmining land use than the proper timing of grazing. It is also, by far, the most controversial subject in range and pasture management, and can have far reaching influences.

As with the subsection "Vegetation Quality for Grazing", it is not the purpose of this subsection to present and comment upon the many philosophies of timing of grazing. The interested reader is referred to standard range management texts, to the various holistic range management programs, and to the periodical entitled "Stockman Grass Farmer", published out of Jackson, Mississippi. Presented here are only those activities and observations that have proven useful on the Northern Great Plains.

Techniques

a. Important Aspects of Grass Growth

There are a few basics of grass growth, the understanding of which are necessary to good grass management. While grass growth is ultimately controlled by the genetics of the grass, grass growth occurs in response to sunlight, proper temperature, and adequate moisture. If sufficient water is available to the grass and it is not too cold, grass of some kind will continue to grow. While grasses spend a certain period of the growth phase storing energy in their roots, they also can grow by drawing on that energy reserve, although sufficient water must be available to mobilize this resource.

Good pasture management thus includes good root management, because roots are the storehouse for the grass. Grasses do not grow from the tip, as do trees and shrubs, but from elongation of the grass stem from a point called the internode. Close grazing will eliminate the internode, requiring the grass to establish another stem. This requires more resources than does continued elongation of an existing stem, and may weaken the plant if it occurs excessively.

Grazing removes senescent material and stimulates growth. This, in turn, creates a desirable, "tender" plant for the cow to graze. However, uncontrolled grazing will lead to repeated grazing of individual plants, much to their detriment. In addition, excess removal of biomass reduces the biomass available to form litter, a protective coat of dead plant material that enhances the capture of water by reducing raindrop impact and runoff. The timing and type of grazing must thus be controlled to preserve the health of the individual plants and the overall pasture. Learning to gauge the amount of residual to leave in a pasture is essential to long-term grazing success.

Without grazing, there is no impetus for the grass to produce multiple stems. This lack of stimulation inhibits stem proliferation. At the end of the growing season, a grass will become dormant, and the growth that was produced during that growing season will become senescent. Failure to remove this senescent growth reduces the ability of the grass to produce new growth the following season. This results from a type of "self-competition", where shading and simple occupation of space by dead grass reduces the capacity for new growth.

The twin results of undergrazing are usually a bunchy, stemmy grass of little interest to livestock. In fact, these so-called "wolfy" plants are a real management problem on reclaimed lands, as they fail to provide the ground cover necessary for good nutrient and hydrologic cycling.

The task of the grazier is to optimize these aspects of grass phenology in order to produce a diverse, productive pasture that stays green for as long as possible. As discussed in the subsection entitled "Vegetation Quality for Grazing", green grass is the most forage.

Equally important as the surface appearance of the plants is the growth and development of the root reserve. A pasture with well-established root reserves will withstand drought and adverse conditions such as grasshoppers far better than a pasture with poor root reserves. A pasture with good root reserves will stay greener much longer than a pasture with poor root reserves. A pasture with optimum litter cover (enough to capture the rain, but not so much to choke grass growth) will also stay greener longer, because more water will have been captured in the soil, and the protective litter will retard evaporation from the soil.

Adequate litter and standing residual, extensive roots, and timely biomass removal are the real keys to green grass. Litter, roots, and biomass removal are also the keys to vegetation cover and production, two requirements for bond release on reclaimed grounds.

b. Overgrazing -- The Challenge of Livestock Distribution

(1) Grazing During Vegetation Dormancy

Overgrazing means removal of biomass in such a way and in such an amount that the vigor, and possibly the life, of the plant is imperiled. While sufficient physical damage can occur during dormancy to jeopardize the life of the plant, this usually requires grazing and hoof damage far in excess of what will kill a plant during its active growth phase. Thus, dormant plants can usually be grazed far more heavily than can actively growing plants. The danger of winter grazing comes in the removal of so much biomass that litter cover is critically reduced, leading to water runoff, a condition to be avoided at all costs.

Heavy winter grazing can increase productivity and diversity during the growing season, probably by the removal of standing dead biomass, the mechanical breakdown of litter, and surface manipulation of the soils. These beneficial effects are lost, however, if grazing of the area continues into the growing season with no opportunity for the pasture to recover.

(2) Grazing in the Active Vegetation Growth Phase

Pastures in their active growth phase can be approached in two fashions, each of which is beneficial under different circumstances. If the size of the pasture cannot be closely controlled and the grass is growing rapidly, a moderate stocking rate and continuous grazing for approximately half of the period of active growth will result in optimum stimulation of the pasture. This type of grazing helps to maximize forage production and extend the period of green grass because the high availability of forage causes the cows to "top" the grass, without damaging or eliminating the internode.

"Topping" is essential to the maintenance of well-established pastures that are already in good condition. This type of grazing also enhances root development, because the plants are not being stressed to the extent that reserves cannot be stored in the roots.

In opposition to light, continuous, grazing during the period of active grass growth, intense, time-controlled grazing may be employed. If the size of the pastures can be closely controlled, livestock will quickly consume all available forage, and can then be removed with time remaining for the grass to re-grow. This type of grazing can cause grass plants to spread rapidly. There is a danger that the root system can be weakened by this type of grazing, but this can easily be avoided by providing sufficient growing time, not only for top growth, but for root growth and energy storage. A simple rule of thumb for actively growing pastures is to avoid re-grazing until grasses have re-grown three leaves.

Intense, time-controlled grazing is also an especially useful way to remove weeds during their usually limited period of palatability. This type of intense grazing pressure early in the spring on pastures infested with cheatgrass, for example, will remove a lot of cheatgrass biomass (which is actually excellent forage in its early stages) and still leave plenty of time for the perennial grasses to come on strong. However, the grazier must watch the pasture closely to prevent damage, especially in the critical period as grass growth slows. This is the period when grass is most vulnerable to damage because it has no means (that is to say, water) to recuperate its losses. This leaves a plant to go into the next growing season in a weakened state.

Both topping and intensive grazing are useful and effective. The real problem with grazing is that there are never enough cows when the grass is really growing, and always too many cows when the grass has stopped growing but is not yet senescent. As mentioned above, from the standpoint of the grass, it is hard to have too many cows when the grass is dormant. Too many cows on **dormant** pasture is far more likely to harm the cows than it is the grass, unless the ground is grazed to barren-ness. For this reason, even the most heedless grazier is unlikely to kill grass in the winter time. Conversely, cattle will continue to thrive long after damage has begun to occur to the vegetation during the growing season.

c. When to Move the Cows

With all these tricky judgment calls to be made, how does the grazier, and especially the EE who has the job of supervising the grazier, know when it is time to move the cows? From a practical standpoint, and assuming that all supplements and water have been properly located, the time to move the cows is when the proper level of residual has been reached As a general rule, in a paddock situation where stock are reasonably evenly matched with paddock size, the first day the cattle will be confronted with excess forage, the second day with adequate forage. The third day will be somewhat forage deficient, but will need to continue to grazing to optimize forage availability.

Reaching the optimum residual forage point is difficult for the novice grazier or the EE to identify in the beginning. Thus, other, somewhat easier signs can be used. One of these is to move the livestock just before trails start to appear in the paddock. From an even more practical standpoint, the time to move the cattle is just as trails **start** to appear. The cattle themselves may become restless and anticipatory as the time to move approaches.

The grazier must have a sharp eye for seeing incipient trail development, or anticipating it from experience, and be well enough ahead of the game to be ready for the move. It is not unusual for distinct trails to develop in a pasture during the time it takes the grazier to set up the next water location and electric fence. Fortunately, grass usually grows back, but damage can occur rapidly.

Another sign that it is time to move is when most of the pasture appears to have been grazed to some extent by the herd. Cows tend to graze concentrically around their favorite features -- water tanks and supplement barrels. If these are properly distributed, and the pasture is the proper size and shape, cattle will also range out over the pasture grabbing a bite from all over. This predilection for concentric grazing is a strong argument for portable, or at least readily movable, tanks. Movable tanks ensure that the center of the grazing circle is not in the same location year after year.

Another practical moving clue is to move livestock from a pasture after it rains a sufficient amount to induce growth. This gives the grazed pasture an opportunity to use the moisture for re-growth. It also keeps the cattle from really churning up a small pasture, although this is not always a detriment. Lots of pockets and hoof marks mean lots of places to capture water, and this is especially important in a pasture that has neither good litter nor good vegetation cover. So, three clues: trails, grazed stems, and rain. Experience, of course, is the best guide to pasture movement, but even experience is rooted in these three clues. At times, the cattle themselves will tell you when it is time to move. Particularly in small, closely-controlled pasture situations, the herd will be at the gate anticipating your arrival after two days in the pasture.

d. *Integrating Native and Reclaimed Grazing*

Whenever native ground can be integrated in space or time with reclaimed pastures, this should be done. This allows for native seeds and stems to be brought onto the reclaimed surface, which in turn increases vegetation diversity, one of the criteria needed for bond release. The fragment of native pasture to be included need not be large, and if physical inclusion is not possible, grazing a native pasture within two days of grazing a reclaimed pasture will result in seed carryover in the livestock excrement.

e. *Reducing Cool Season Grass "Super-competition"*

Cool season grasses have proven to be both the success story and the problem on many reclaimed lands. Their rapid establishment and growth helps to quickly meet cover and production goals and to begin the processes of soil development and water retention. On the other hand, the rapid establishment and growth will outcompete the more fragile forbs and shrubs, and will actually choke out desirable species such as sagebrush (*Artemisia tridentata*), a species that is difficult enough to get going as it is.

The twin remedies for cool season grass super-competition are reducing the seeding rate of the cool season grasses, and grazing them as early as the end of the first growing season. A light grazing will not damage or destroy the grass, but may keep the grasses in check while the warm season grasses, the forbs, and the shrubs get going.

f. *Encouraging Shrub Growth*

The degree to which shrubs are a natural part of the grasslands ecosystem is a hotly contested topic in certain circles. Certainly, if shrubs occur in significant numbers in an area, then there are certain aspects of the environment supporting shrub growth. Grazing can be used to enhance those aspects of the environment. However, grazing should not be used to create a grazing disclimax through the elimination of all other plants. This is akin to maintaining a desirable body weight through bulimia. It is neither healthy nor desirable.

As discussed above, manipulation of cool season grasses will encourage shrub growth. On the other hand, if shrubs are not desirable, grass growth can be encouraged to outcompete the shrubs. However, as discussed in the subsection "Vegetation Quality for Grazing", the greater the diversity of **palatable** forage, the more desirable for the livestock. In addition, the shrub lifeform helps to trap snow in winter for increase in soil moisture, and provides shelter for young animals, both livestock and wildlife.

The trick with grazing is to keep the shrub niche open, and this generally means managing the amount of grass. With plenty of grass, cows will seldom graze shrubs anything but lightly during the growing season, so shrubs do not need to be protected from grazing. If anything, lack of grazing on reclaimed lands will lead to the demise of a promising shrub population.

g. *Coordinating the Grazing Program with the Vegetation Sampling Program*

During the seasons that vegetation sampling in an area is anticipated, it can be useful to coordinate the grazing program and the sampling program in such a way as to minimize the necessity for range cages. Range cage placement is expensive and time-consuming, and can be avoided if sampling activities are conducted in advance of the grazing program. This may not be possible in all pastures, but even partially avoiding the use of cages can save time and money.

When convenient, collecting a little information both before and after a pasture is grazed can greatly increase knowledge about the degree of pasture utilization, the palatability of the various species, and the cover remaining following grazing. Quantitative information can greatly facilitate grazing decisions. Thus, when vegetation sampling is being conducted for other reasons, the EE can obtain additional knowledge at a small incremental cost.

10. Grazing, Wildlife, and Wildlife Habitat

Section editor: D.G. Steward *Subsection authors: D.G. Steward/R.S. Shinn*

Applicability

The relationship between grazing, wildlife, and wildlife habitat can be very controversial. Fortunately, on the Northern Great Plains, practices that are good for livestock and pastures are also good for wildlife and vegetation communities. These practices include: optimizing vegetation cover, production, and diversity; encouraging soil development; maximizing infiltration; and minimizing run-off.

Special Considerations

Livestock pastures can be constructed to benefit wildlife, particularly by restricting the use of nesting areas during the reproductive season and maintaining adequate residual following grazing. Fences can be constructed to minimize detrimental effects on wildlife for little or no additional cost. Because a trained and tranquil cow that has plenty of forage is also a cow very unlikely to cross a fence, the most minimal of fences, which are also those least likely to harm wildlife, are effective for livestock control.

Not only are wildlife a natural resource in the postmining landscape, they are also of potential economic benefit to the end user. The benefits can include tourism and hunting, and may be of substantial economic benefit to the landowner. Thus, postmining land use should include wildlife for economic as well as aesthetic and moral reasons.

Techniques

a. *Livestock as a Management Tool for Wildlife and Wildlife Habitat*

One of the primary benefits of livestock grazing is that it can be used as a precise and cost effective tool for the manipulation of vegetation. Grazing pressure can be used to direct vegetation community development and mediate competitive effects between various plant species. There is no other tool more flexible and cost effective than grazing. Thus, even if a postmining landscape dedicated to fish and wildlife habitat is anticipated, grazing, especially during the bonding period, can help to manipulate the vegetation in the desired direction.

There is no doubt that the grazing tool can wreak havoc in the hands of an unskillful or uncaring user. On the other hand, grazing can accomplish, at a profit, what would cost thousands of dollars in man-hours, equipment hours, and consumption of fuel and chemicals. Controlled grazing is as useful to the development of the postmining landscape as is seed, a seed drill, or a disk.

b. *The Effects of Grazing on Vegetation*

(1) Stimulating Growth in Young Vegetation

A common misinterpretation of the effects of grazing is that young vegetation will always be destroyed by grazing. In fact, light grazing of young vegetation can stimulate growth, a fact that is commonly employed to enhance the growth of winter wheat. The point is that, under certain circumstances, grazing can be a very useful tool; under other circumstances it can be very destructive. To borrow a phrase, grazing doesn't kill vegetation, people (and their bad management) kill vegetation. It is inefficient to forbid the use of a valuable tool simply because the tool can be misused. It is better to ensure training and adequate control on the use of the tool.

(2) Encouraging Shrub Communities

Another common misinterpretation is that shrub communities can be encouraged only by employing destructive overgrazing or by no grazing at all. This belief results from observation of widespread grazing mismanagement. However, in Campbell County, Wyoming, for example, controlled grazing has been used to good effect to encourage shrub growth by reducing competition and manipulating the timing of grazing.

Sagebrush growth can be encouraged by reducing cool season grass competition as soon as possible after planting of the reclaimed surface. Heavy grazing while the grasses are dormant is one way to achieve this goal; another is to graze new vegetation lightly towards the end of the first growing season.

On the other hand, if the goal is to encourage the growth of species such as snowberry (*Symphoricarpos occidentalis*) or wild rose (*Rosa woodsii*), winter grazing and fall grazing should be minimized -- just the opposite. Like any other skill, the benefits of grazing management can only be realized if the grazier is experienced, knowledgeable, and trained. Fortunately, vegetation will always respond positively to good management, and mistakes, even serious ones, can be rectified with time.

(3) Improvement of Riparian Vegetation

One final note: Grazing is generally considered destructive to riparian vegetation. Once again, it is the timing and manner of grazing that destroys this type of vegetation. Properly controlled grazing can improve riparian vegetation, encourage the growth of trees and shrubs, and increase stream baseflow. Just as a hammer can be used to build a house or tear a house down, grazing can be used to stimulate or destroy vegetation.

c. Conclusion

Despite many strong arguments in favor of joint land uses, there is a significant contingent of people who believe grazing should be eliminated or minimized in the postmining environment. This view typically devolves from observation of the problems that are caused by improper and poorly planned grazing practices.

Overgrazing, or landscape destruction as a result of poor grazing practices, often occurs when the land user has no vision of the landscape, no understanding of the consequences of the different aspects of grazing, or is unable to integrate good grazing practices into his particular financial environment. On the other hand, some people have adopted the viewpoint that grazing has no place in the landscape under any circumstances, even if the lack of grazing is detrimental.

Lack of knowledge is the basis for **both** overgrazing **and** the belief that all grazing is bad. Thus, ongoing training, testing, education, and demonstration are necessary adjuncts to the development and continuation of grazing in the postmining landscape. Grazing, wildlife management, landscape management, and reclamation are all areas of endeavor that are not yet true sciences, but semi-qualitative engineering practices. To continue to progress in these areas and to continue to develop the beneficial aspects of grazing and habitat development, training, testing, education, and demonstration must be part of any postmining land use program.

Reclamation specialists today have unparalleled opportunities to experiment, to create, and to foster the advance of science and technology. These opportunities can and should be conducted in an economic framework that results in overall financial benefit to the company supporting these endeavors. Thus, the prudent and thoughtful engineer will carefully plan and review all programs related to grazing, wildlife, and postmining land use to ensure they are maximally beneficial, not only to the landscape, but also to the company and to the overall science and engineering of reclamation.

C. WILDLIFE

1. Forage Enhancement for Wildlife

Section editors: D.G. Steward *Subsection author: Bonnie C. Postovit*

Applicability

Forage availability and quality are important factors governing the number and variety of wildlife that use an area. In most reclamation efforts, the primary goal should be to provide a wide range of forage species which will attract and maintain a diverse wildlife community. In addition, it is often possible to focus some effort on providing forage for one, or a group of, target wildlife species.

Special Considerations

Reclamation can provide diverse forage, which will, in turn, promote a diverse wildlife community. Food habit studies can be used to guide reclamation efforts to enhance an area for one or many target species.

Techniques

a. Forage Diversity

Diversity of forage depends not only upon diversity of vegetation species, but also on diversity of **lifeforms**. The forage and habitat provided by a mix of lifeforms--grass, forb, shrub, tree--will attract a wide variety of wildlife.

(1) Non-native Species

While reclamation regulations may mandate the use of vegetation species that were present prior to mining, the potential for habitat enhancement through judicious use of adapted, non-invasive, “non-native” species should not be overlooked. For example, alfalfa is a seasonally favored forage of some big game and upland game bird species, and Russian olive trees provide forage (and nesting habitat) for a variety of songbirds.

Thoughtful incorporation of such plant species as revegetation elements can serve to increase the forage variety. On the other hand, no one would suggest seeding *Kochia*; although it provides a high-quality food source for numerous wildlife species, as it is considered an undesirable weed. Still, *Kochia* and many of the weedy species that initially invade young reclaimed areas provide a valuable cover and forage bridge until seeded species establish and mature.

b. Target Wildlife Species

Target wildlife species may be selected as the primary focus of revegetation efforts. Target wildlife species should occur in the area, or have the potential to occur, if provided with the proper forage (or other habitat elements). While it is technically possible to stock an area with a non-occurring species, there may be elements of habitat other than forage (e.g. weather extremes; water availability; nesting, loafing, or denning cover) that are beyond the capability of reclamation to provide.

(1) Food Habits

When a target species (or suite of species) has been selected, food habits should be researched to determine what type of forage should be established. For common or well-studied species, food habits information may be available in publications from State or Federal wildlife agencies. Food habits studies for other species can be obtained from wildlife research journals, available through university libraries or wildlife departments. Because wildlife species' food habits may vary regionally, it is wise to base plant selection decisions on research nearest the locale in question.

(2) Seasonal Variations in Food Habits

Food habits for wildlife species often vary seasonally. To maximize habitat enhancement, reclamation efforts could emphasize the forage element that is most limited in the area of consideration. However, seasonal forage selection must be functional and practical. For example, it would make no sense to plant winter forage for a species whose winter range would not include the area.

2. Water Resources

Section editors: D.G. Steward *Subsection author: Bonnie C. Postovit*

Applicability

Premining water sources such as creek channels, playas, springs, and stock ponds are vital to both aquatic and terrestrial wildlife. This is especially true in the arid West.

Special Considerations

Creating water sources on reclaimed lands greatly increases the abundance and diversity of wildlife that will occupy an area. Impounding or diverting water must be conducted according to applicable regulations regarding water rights.

Techniques

a. Design

Availability and attractiveness to wildlife need to be considered when designing water features for the postmining landscape.

(1) Availability

Availability includes both physical accessibility and temporal availability. Sources such as stocktanks should be designed to allow use by wildlife. A tank can be partially sunk in the ground, or a ramp constructed to the rim of the tank, to allow game birds and other small animals to drink. Escape ramps should be constructed in tanks, to allow animals to crawl out should they fall in. Ramps can be made of concrete block, rocks, metal, or wood, and should be securely attached.

While some water features (playas, small seeps) are intended to be temporary, some perennial water sources (deep ponds, groundwater-supplied reservoirs) should also be incorporated into reclamation plans where possible. Perennial water greatly enhances the value of an area to wildlife.

(2) Attractiveness

Attractiveness of a water source to wildlife can be enhanced by providing adequate cover. Dense vegetation, shrubs, trees, or rockpiles can be used to provide cover around the water source, and along escape routes. Where possible, pond perimeters and other features should be fenced to prevent livestock from degrading water quality and shoreline vegetation. Livestock can be limited to a small access area, or better yet, provided with a separate watering facility (e.g. a trough fed by a gravity-flow pipe).

b. Type of Water Source

Several types of water sources can be created, depending upon the site involved, and type of use targeted. These sources include: reservoirs, channel pools, playas, wells, and rainfall catchments.

(1) Reservoirs

Reservoirs serve a wide variety of wildlife as permanent or semi-permanent water sources. The size of a reservoir is, of course, dependent upon its drainage area and the amount of water available. Both large and small reservoirs are useful to wildlife. Some species are only attracted to larger bodies of water. However, a single large reservoir often will not provide as much habitat value as several smaller ones, which help distribute wildlife use over a greater area. A combination of large and small reservoirs provides the most potential for wildlife diversity. See the subsection "Providing Interim Wildlife Habitat" in the Wildlife section for reservoir design modifications that enhance wildlife value.

(2) Channel Pools

Channel pools in a reclaimed drainage can serve as reservoirs for aquatic life during dry seasons. Pools should be designed to hold water long after active runoff has ceased. Under natural conditions, alluvial discharge often maintains such pools; this characteristic may not be a feasible component of reclaimed channels. A persistent pool could still be created by excavating basins in the channel bottom, and lining them with impermeable material.

However, channel pools may fill with sediment if the volume of runoff is not sufficient to provide periodic scouring flows.

(3) Playas

Playas are shallow, undrained basins that provide a seasonal water source for wildlife. Constructing a playa depends upon creating an area of non-draining topography. State and Federal regulatory agencies should be consulted to determine if this will require a variance from standard mine regulations. The size of the playa will be determined primarily by the precipitation available and the acreage of the non-draining topography. To allow water to persist, clay-type soils should be used in the center of the basin where water is expected to accumulate.

(4) Wells

Wells developed to supply livestock water can easily be modified to provide an attractive wildlife water source. Any associated water tanks should be modified for safe use by wildlife (see part a(1) above). In addition, overflow water can be piped to a fenced area to create the effect of a seep or spring, exclusively for wildlife use.

(5) Rainfall Catchments

Rainfall catchments, sometimes called "guzzlers", are self-filling sources of drinking water for wildlife. They have been used very successfully to enhance wildlife habitat in desert areas. Catchments involve constructing an apron of impermeable material (concrete, asphalt, metal roofing, etc.), sloped to conduct all precipitation into a basin in the center or at one end. Generally, the basin is a buried steel tank or concrete basin. Whatever is used, safe wildlife access to the water is imperative. Catchments constructed of sturdy material require a minimum of maintenance.

To reduce evaporation, the catchment area is often covered and semi-enclosed, with the opening facing away from the prevailing wind and in a northerly direction where possible. Considerable volume of water can be provided by a relatively small collecting area: roughly 900 gallons can be accumulated by a 15 by 15 foot apron in a 6-inch precipitation zone.

3. Rockpile Design and Construction

Section editors: D.G. Steward *Subsection author: Bonnie C. Postovit*

Applicability

Rock outcrops and other rock features are important elements of wildlife habitat that are removed during mining.

Special Considerations

When material is available, rockpiles can be used as a wildlife habitat enhancement feature on reclaimed land. Rockpiles are used by a wide variety of fauna and for a number of functions. Design and placement can enhance rockpile functions. Examples of varied rockpile design and placement are shown in the following figures.

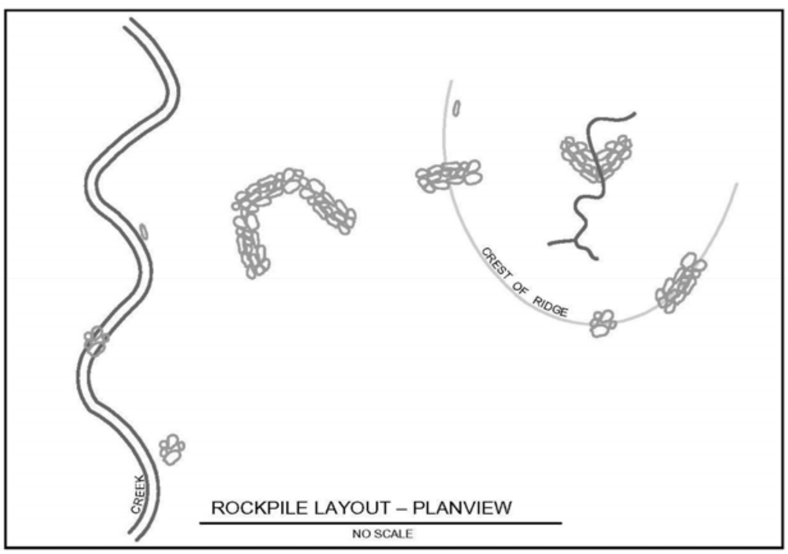
Techniques

a. Material

Material is important in constructing a usable rockpile. Medium (chair-sized) to large (sofa-sized or greater) rocks work best in constructing rockpiles. When such rocks are placed together, there will be good-sized openings under and between them. Rubble piles, like natural talus areas, can be valuable for small mammals, but they are of limited use to larger animals. Large rocks are also better, because they are not likely to be covered during topsoiling, or completely obscured by vegetation growth. Concealed rocks present a real hazard to reclamation machinery or postmining agricultural operations.

b. Design

Proper design of rock structures can enhance their value for specific functions such as denning, shading or sunning, perching, and nesting. A rockpile can be designed to fulfill more than one function. In constructing any type of rockpile, it is important to overlap and pile rocks together to create stable, protected spaces under and between rocks. Rocks merely lined up in a row, or fitted tightly together like a stone wall, do not provide the niches necessary to shelter animals. Rockpiles should be a **minimum** of two rocks wide and three or more deep. Rockpile length can vary, with intended function and material availability, from 10 to 50 or more feet.



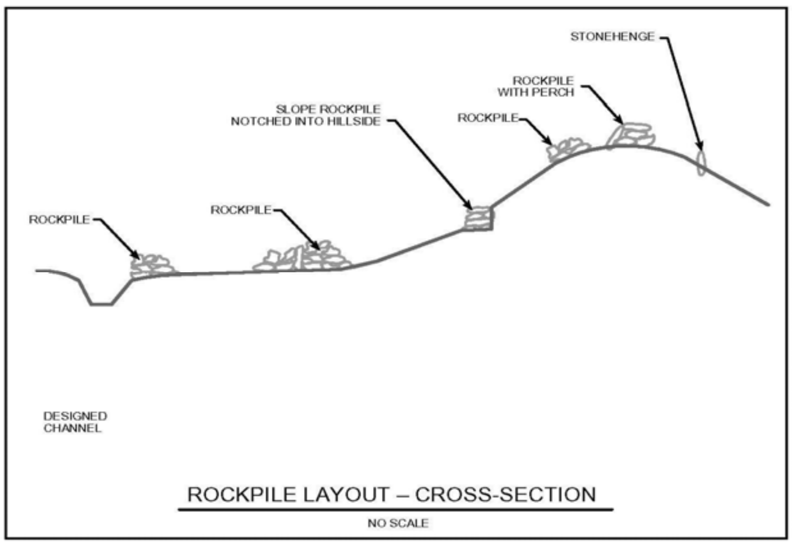
(1) Denning Sites

Denning sites can be created for rabbits, foxes, coyotes, and other mammals. Medium to large rocks should be placed securely against each other at angles, so that hidden cavities are formed at the base of the pile.

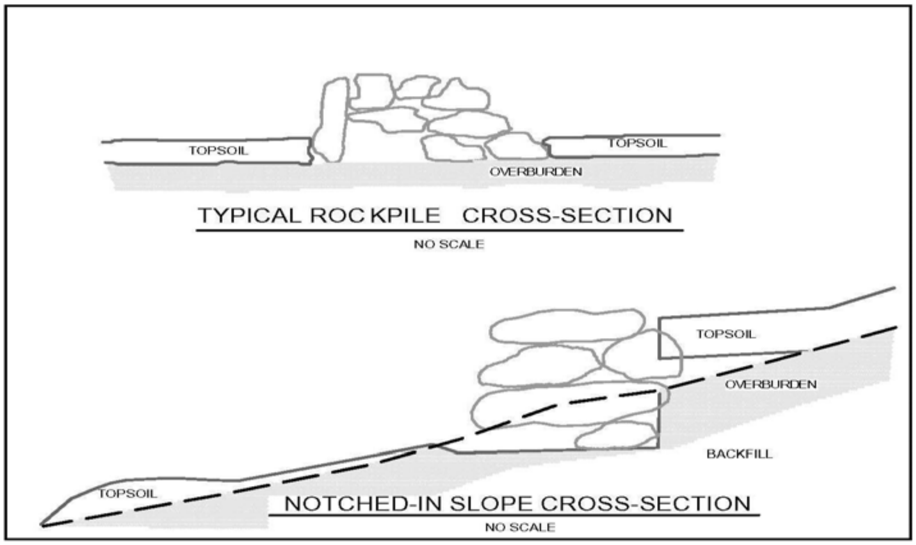
Constructing the pile prior to topsoiling allows the base of the pile to be covered with dirt, further concealing and protecting den spaces. A rockpile on a slope can be "notched" into the hillside, as shown in the accompanying figure. Rockpiles intended as denning sites for fox-sized animals should be at least 10 to 15 feet in diameter.

(2) Shading and Sunning Areas

Rockpiles constructed as shading areas are particularly useful to wildlife in treeless areas. Deer, especially, are attracted to such features during hot summer months. Sunning sites are attractive in cooler seasons, for rocks store and radiate heat from the sun. The same rockpile can serve for both shading and sunning if it is built long, on an east-west (or southeast-northwest) axis. This creates shading sites on the north/northeast side, and protected sunning areas on the south/southwest side. A long rockpile set perpendicular to prevailing winds will also be used as a wind shelter.



Avoid the appearance of a flat, featureless wall. The length of the pile should be curved or zig-zagged: horseshoe, "V", and "W" shapes, for example. The bends create varied niches and microclimates along the length of the pile. If large, flat rocks are available, they can be tilted at an angle, or placed as overhangs to augment the shady side.



(3) Perching Sites

Rockpiles provide perching sites for a wide range of birds, from songbirds to raptors. Many songbirds staking out breeding territories sing from an elevated perch. Rockpiles are welcomed, especially if trees, shrubs, and fenceposts are scarce. In level topography, almost any medium to large rock will be used. A long rock, set erect ("Stonehenge style"), can be attractive to perching birds of all types. Such rocks should be at least as high as a fencepost (four to five feet).

(4) Nesting Sites

Rockpiles can mimic the outcrops used as nesting sites by ferruginous hawks and some other raptors. For this function, a rockpile needs to have a level spot, big enough to hold a nest, a few feet (or more) above the ground. Smooth rocks (like sandstone) do not serve this purpose as well as rough ones (like scoria). Material can slide or blow off of smooth surfaces.

c. Placement

Placement of rockpiles affects both aesthetics and function. Varied placement and size of rockpiles is illustrated in figures above. A number of factors should be considered to maximize the value of rockpiles.

(1) Naturalize Appearance

While a "Stonehenge-style" rock or two can serve a particular purpose, judicious placement of rocks is necessary to avoid numerous features with extremely unnatural appearance. Artificial rock features can actually help naturalize the appearance of reclaimed areas if placed at the peaks of hills and rims of draws, where outcrops frequently occur in nature.

(2) Improve Habitat Diversity

Rockpiles are also an important tool to increase the habitat complexity of areas that possess little topographic diversity. Rockpiles on flat areas provide escape cover, perches, and shelter that would otherwise be minimal. Rockpiles placed at pond and creek channel margins improve cover for wildlife that access the water source. Aquatic habitat can be enhanced by placing a rockpile where water will partially (or completely) cover it.

(3) Enhance Biological Function

Topographic placement can enhance their function. A shading site on the north- or east-facing bank of a draw or gully is a good example.

Placement of rockpiles intended for nesting raptors can increase their attractiveness. Visibility of approaching dangers is greatest on elevated sites, and in the middle of open areas.

Placement of sunning sites should take into account likely patterns of snow drift. A sunning rockpile located just below the leeward brow of a ridge is likely to drift in with snow and be less usable during winter.

(4) Stabilize Erosive Areas

Rockpiles placed at the windward edge of a ridge or at the peak of a hill can serve to reduce wind erosion. A linear rockpile at an abrupt downward break in slope can help protect the edge from excessive erosion, as well as provide the aesthetic appearance of rimrock. Even when intended as erosion stabilization features, rocks should be clustered and overlapped to increase wildlife habitat utility, rather than strung out individually.

d. Construction Considerations

(1) Equipment Types

Construction of most rock features can usually be handled by bulldozers. Some require placement of individual rocks, requiring a loader or large track backhoe. Such equipment is usually needed to selectively place the upper rocks on taller structures, and the large flat rocks for ledges or overhangs.

(2) Minimizing Dirt

If a large amount of dirt is dozed into the rock pile, the utility of the feature can be severely reduced. While it is impossible to build a rockpile free of dirt, there are two ways to minimize dirt content. Utilizing larger rocks on a compacted surface reduces the amount of dirt a dozer will push with the rock. It may also be helpful to collect all the necessary rock material first, then build the rock feature next to the material pile. This allows the operator to focus on just moving the rocks.

D. References

Wyoming Department of Environmental Quality, Land Quality Division (WDEQ-LQD). 1991. Guideline Number 14 - Recommended Procedures for Developing a Monitoring Program on Permanently Reclaimed Areas. WDEQ-LQD, Cheyenne, Wyoming. 9 p.

E. Citations

95th Congress, Public Law 95-87. Surface Mining Control and Reclamation Act of 1977. August 3, 1987.

Section Editor: Bonnie C. Postovit
Handbook of Western Reclamation Techniques

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SECTION 7: WILDLIFE

A. Introduction

Section editor: Bonnie C. Postovit *Subsection author: Bonnie C. Postovit*

Like soil, water, and vegetation, wildlife is a resource that must be protected from undue impact during mining and other surface disturbing activities. Soil and water are the basic resources that support vegetation; water and vegetation maintain wildlife. Wildlife is an indicator of the health of the entire resource system. Robust, diverse wildlife populations are a sign that the supporting resources are functioning together properly.

Although the response of wildlife to mining ultimately depends upon the management of soil, water, and vegetation, there are specialized mitigation measures that apply directly to wildlife, and these measures are presented in this section. Subsections on fencing, powerlines, and roadways examine Techniques to modify the impact of those aspects of mine development. Another subsection details ways to provide habitat for wildlife during the mining or other surface-disturbing process. A separate subsection deals with raptor nest relocation; a mitigation measure developed in response to Federal laws that protect raptors and their nests, eggs, and young. The final subsection, on animal control, describes management strategies to use when wildlife interfere with mining, reclamation, or other surface operations.

For many people, wildlife *defines* the West. The treatment of this high-profile resource during mining, reclamation, and other surface operations will, to a great extent, color public attitude toward energy, mineral extraction, and other surface disturbing activities.

B. Fencing Practices and Wildlife

Section editor: Bonnie C. Postovit

Applicability

Fencing is necessary to prevent animals from entering hazardous areas, and may be needed to temporarily protect reclaimed areas.

Special Considerations

Fences should be constructed and located to present the least possible hazard to free-ranging wildlife. Pronghorn are not willing or skilled jumpers, and where possible prefer to go under fences rather than over. Large-scale mortalities can occur when herd movements are blocked by fences during severe weather, causing pile-ups and starvation. Smaller-scale mortality occurs when pronghorn become entangled while jumping over fences. Deer jump fences readily; however even they sometimes entangle their hind legs in the top two strands of a barbed wire fence. Fawns, especially, are prone to entanglement.

Techniques

a. Selective Exclusion

The following text briefly describes fencing considerations and general design dimensions for excluding various animals. A thorough discussion of fencing and fence design may be found in Wyoming Department of Environmental Quality - Land Quality Division (WDEQ-LQD) Guideline 10 (WDEQ-LQD, 1979).

(1) Excluding Livestock and Pronghorn

Livestock and pronghorn access can be controlled with a four-foot high "sheep-tight" fence. Such a fence is usually constructed of woven wire topped by two strands of barbed wire. Because blocking pronghorn herd movements can cause significant mortality, this type of fencing should be limited. Such a fence may be necessary in the immediate vicinity of pits and operations areas to keep livestock and pronghorn from the hazards of highwalls and heavy traffic. It is not generally necessary to exclude deer from such areas, as they typically negotiate such hazards readily.

(2) Excluding Livestock and All Big Game

Prohibiting livestock, deer, elk, and pronghorn access can be accomplished with a seven to eight foot woven wire fence. Alternatively, a six foot woven wire fence can be topped with two strands of barbed wire. Such a fence may be needed if all grazing is to be excluded from an area. Where deer (or elk) are present, such a fence may be necessary to keep game animals from entering hazardous areas or to temporarily protect vegetation.

(3) Excluding Livestock Only

Prohibiting livestock, but not wildlife, access can be accomplished with a three- or four-strand wire fence. Such a fence can be used to control livestock within an area, but allow relatively free range by wildlife. The following dimensions are recommended by the Bureau of Land Management, and may be found in the publication "Proceedings: Regional Fencing Workshop" (BLM, 1974). To exclude cattle, a 44-inch, three-strand wire fence is sufficient. For excluding sheep, a 38-inch, four-strand fence can be used. If both are present, a 44-inch, four-strand fence is necessary.

On any such fences, a smooth bottom wire allows pronghorn to go under easily. On cattle-tight fences, this wire can be placed 16 inches above the ground. For sheep-tight fences the wire should be only 10 inches high.

b. Avoiding Wildlife Hazards

Avoiding hazards to wildlife is important in fence location and design. Where large areas must be fenced, it is necessary to plan for safe and easy animal movement.

(1) Create Passages

Create passages where major herd movements may be blocked. Deer are known to use underpasses and "deer gates", but pronghorn will not. Antelope passes can be created by installing cattle-guard-type structures. Rather than relying on specialized structures, it is better to use a fence design that permits wildlife movement under or over.

(2) Eliminate Sharp Corners

Eliminate 90° corners where animals are found to "pile up" during mass movement. Construct shallower angles where a fence must turn or narrow down.

B. Reducing Powerline Hazards to Wildlife

Section editor: Bonnie C. Postovit *Subsection author: Howard R. Postovit*

Applicability

Powerlines present an electrocution hazard to raptors (birds of prey) and other large birds, such as herons. Raptors and other birds are protected by Federal law. Proper design of powerlines can minimize or eliminate electrocution and other hazards.

Special Considerations

Power poles provide attractive perch, nest, and roost sites, especially in relatively flat and treeless areas. This is a positive impact of powerline construction. However, the size of some birds makes it possible for them to simultaneously contact two charged objects (phases or conductors) or one charged object and a ground wire. Most problems occur on distribution lines, particularly at junction poles and transformers. New lines can be constructed to raptor-safe specifications, and older lines can be modified if an electrocution problem arises.

Power poles greatly increase perching habitat, which can increase predation on Sage-grouse and other gallinaceous birds, as well as on lagomorphs and prairie dogs. When possible, powerlines should be buried or equipped with perching deterrents to eliminate excess perching habitat.

Techniques

a. Design Strategies

High voltage transmission line towers or H-frames seldom pose an electrocution hazard because of the distance between the phases. However, H-frames can be detrimental to raptor populations because these structures commonly attract nesting raptors, but offer no substantial support for a nest. Nests built on H-frames are regularly destroyed by wind during the breeding season, resulting in loss of eggs or young.

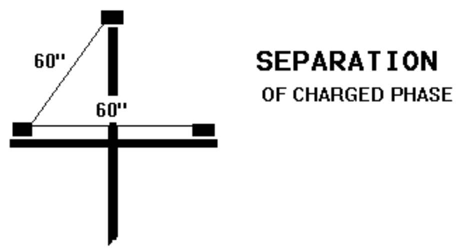
Raptor-safe designs for power poles and lines have been developed through cooperative research between power companies, government agencies, conservation organizations, and private consultants. The resulting designs all but eliminate the possibility of electrocution. The most complete manual on this work is: *"Suggested practices for raptor protection on power lines--state of the art in 1981"* (R. R. Olendorff et al., 1981). When contracting powerline construction for an operation, it is important to specify that lines be of a "raptor-safe" design. Power companies and electrical contractors should be familiar with the Olendorff et al. publication.

b. Modification Strategies

Modification strategies can take one of four forms: separation of phases, insulation, perch management, and nest management. It is generally not necessary to modify all poles of an existing line. Any poles where electrocution has occurred should be modified to prevent further losses. Other non-safe poles (particularly junction or transformer poles) showing signs of regular raptor use (whitewash or pellets on the ground below) could also be modified to eliminate the potential for electrocution. Poles or H-frames where repeated unsuccessful nesting attempts are documented can be modified to prevent or enhance nesting.

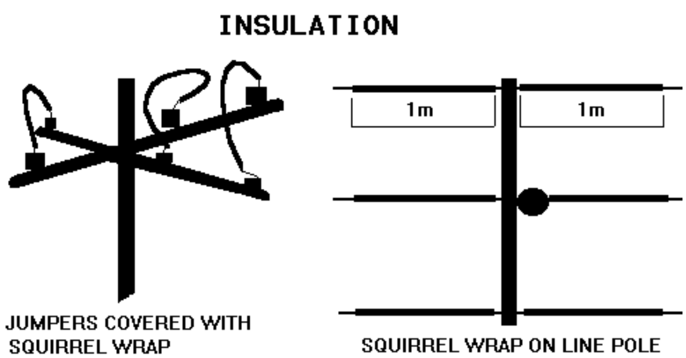
(1) Separation of Charged Phases

A 152-centimeter (60-inch) separation of charged phases is considered necessary to prevent electrocution of birds the size of golden eagles. Separation on a 3-phase line can be accomplished by raising the center line, or lowering the cross-arm that bears the outer two lines. When proximity of a charged part and a ground wire is the problem, a gap can be cut in the ground wire (Olendorff et al., 1981.).



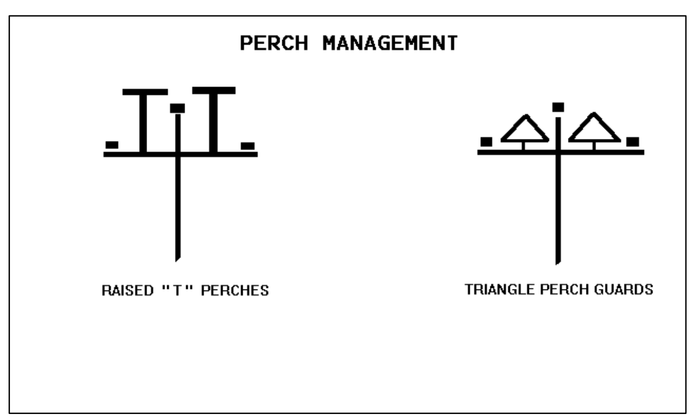
(2) Insulation

While reconfiguring existing poles can be very expensive, insulating is relatively cheap and simple. Covering jumper wires with rubber "squirrel wrap" has been effective in reducing electrocutions at junction poles. The same strategy can be applied to wires on transformers. On problem line poles, insulation can be extended one meter from the pole along all phases.



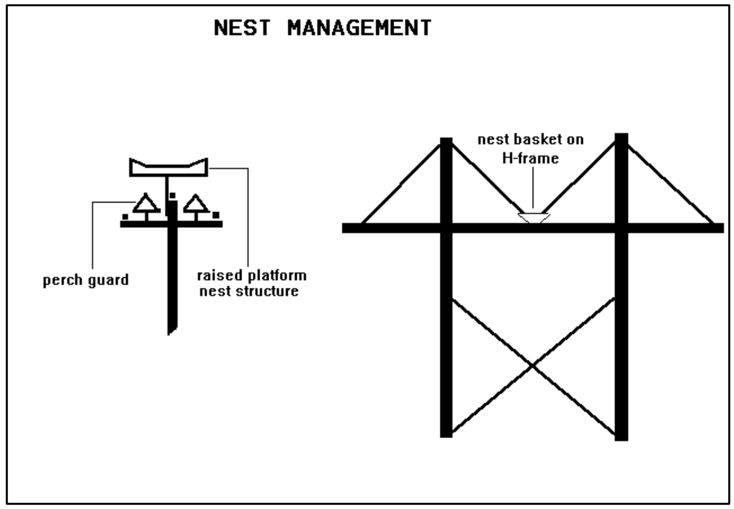
(3) Perch Management

If neither separation of phases nor insulation is feasible, a pole can be modified to prevent birds from perching or nesting between wires on cross-arms. Alternatively, new perches can be attached to the pole to allow continued use by raptors while eliminating unsafe perches.



(4) Nest Management

Poles can be modified to prevent nest construction or to increase nest stability. Techniques used to deter perching can be used to preclude nesting. Artificial nest structures such as nest baskets or platforms can also be attached to a pole or H-frame to provide a stable support for a nest.



C. TRAFFIC AND ROADWAYS

Section editor: Bonnie C. Postovit *Subsection author: John D. Berry*

Applicability

Traffic and roadways can seriously impact wildlife movement or distribution.

Special Considerations

Access and haul roads present formidable obstacles to movement or distribution of some wildlife species. Road traffic can affect wildlife directly, by collision, or indirectly, by disturbance.

Techniques

a. Reducing Conflict Between Traffic and Wildlife

Certain measures can be implemented by companies to reduce potential conflicts. These measures may include fencing, underpass installation, employee education, and altering work schedules.

(1) Fencing

Fences can be used to direct wildlife across or away from roads. Fence designs can target certain species (see the subsection entitled "Fencing Practices and Wildlife").

(2) Underpasses

Underpasses can be built in areas of critical migration routes for certain big game species. These areas are generally documented during the premining inventory, so underpasses can be incorporated in the initial construction phase. Fencing is needed to direct animals to underpasses. This option is obviously very expensive and requires considerable upkeep to maintain. Pronghorn antelope do not appear to use underpasses.

(3) Employee Education

Employee education and notification can be implemented to reduce wildlife/roadway conflicts. Safety lectures can include information on wildlife behavior to teach employees what to expect, and how to avoid collision hazards. Periodic notices can be posted to remind employees of seasonal migrations or activities which would increase the occurrence of animals around roadways.

(4) Work Schedules

Work schedules can be altered to reduce traffic disturbance in sensitive wildlife areas. Strutting grounds, fawning areas, and raptor nest locations are areas which are seasonally sensitive. Road closures during sensitive periods or during certain times of day can reduce conflicts.

D. Providing Interim Wildlife Habitat

Section editor: Bonnie C. Postovit *Subsection author: Bonnie C. Postovit*

Applicability

Temporary habitat enhancements can help alleviate the impacts of mining on wildlife.

Special Considerations

Some reclamation features, such as shrub stands and trees, take time to mature and achieve value to wildlife. Interim substitutes can be used to serve the functions intended for the permanent features. Some mine features, such as sedimentation reservoirs and highwalls, are of potentially great value to wildlife. Properly modified, such features can serve as important interim habitat during their existence.

Techniques

a. Tree and Shrub Substitutes

Interim substitutes for shrubs and trees include brush piles, snags, and artificial nesting structures.

(1) Brush Piles

Brush piles provide escape cover and den sites for small mammals, lagomorphs, and predators. Trees or shrubs salvaged from stripping operations can be piled on newly-reclaimed areas. These brush islands will persist for several years, until vegetation is mature enough to provide cover for wildlife. The base of a brush pile can be formed of logs or larger branches piled at angles to create cavities. Smaller branches and brushy material can be piled on top to increase protective cover. Brush piles should be at least 10 to 15 feet in diameter and 4 to 5 feet high to furnish cover for a variety of small and medium-sized animals for several years.

(2) Snags

Snags are valuable habitat features for perching and nesting. Snags can be created by erecting a felled tree. The best trees for this purpose have numerous sturdy branches and long, single, straight trunks. The base of the tree must be sunk several feet into the ground for stability. Snags are put in place using normal power pole setting equipment and procedures. They provide instant tree-like habitat, and can last several years. Treating the lower part of the trunk with creosote may help prolong the life of the snag.

(3) Nesting Structures

Artificial nest structures, such as platforms and nest boxes, are commonly used to provide habitat for raptors and other birds. Designs vary depending upon the target species. For example, ferruginous hawks will use low or high platforms, but appear to dislike wind guards or shading that obstructs the view from the nest. Golden eagles and red-tailed hawks prefer higher platforms. Shading can be provided by installing plywood "wings" on two sides.

Platforms can serve until trees are established. In areas devoid of trees, they can be a valuable form of permanent habitat enhancement. A well-constructed platform will last for many years.

The same cannot be said of nest boxes. Need for maintenance is a commonly-overlooked aspect of nest boxes. Bluebirds, for example, will not reuse a box unless old nesting material is cleaned out annually. Kestrel nest boxes likewise need periodic cleaning. There is dubious value in erecting numerous nest boxes without a provision to properly maintain them. An example of a nesting box design is given on the following page.

b. Temporary Water Source Enhancement

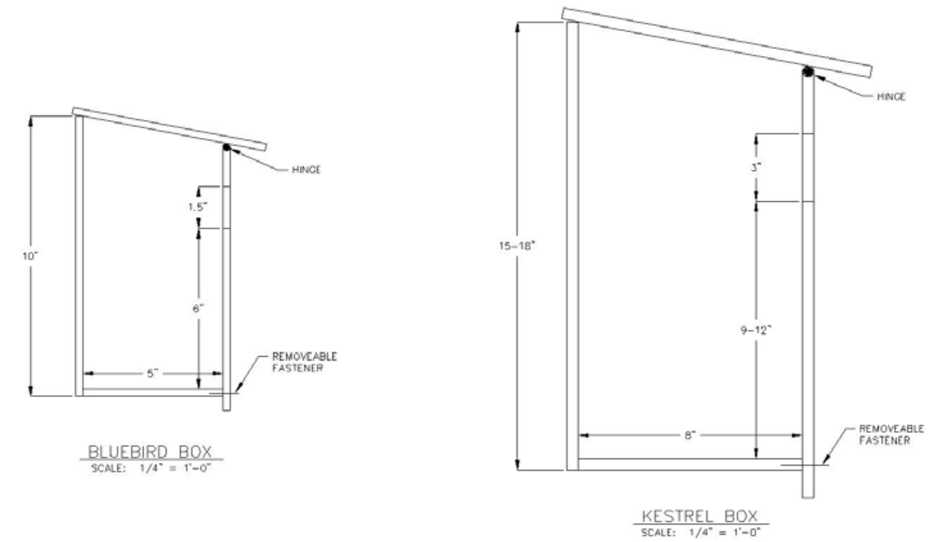
Reservoir modifications that can enhance temporary water sources include vegetation plantings, islands, peninsulas, shallow shoreline areas, and escapeways.

(1) Vegetation

Vegetation plantings can speed natural wetland colonization processes. It can take several years or longer for cover and food species such as sedges, rushes, and cattails to colonize a new water source; especially if the source is relatively isolated from natural areas. A temporary reservoir might come to the end of its existence just as it was achieving high wildlife value. Transplanting clumps of

FIGURE 3

NESTING BOXES



vegetation along the shoreline of a reservoir will quickly boost the value of the reservoir to waterfowl and other wetland users.

Transplanting can be accomplished very simply with hand shovels and five-gallon buckets. The goal is not to plant a pond's entire shoreline, but to establish numerous clumps of swiftly-spreading plants. Transplanting is best accomplished in spring or early summer. When digging plants, it is vital to remove good-sized portions of roots or tubers intact. When replanting, the roots should be well-covered with soil. Plants should be set where water (or at least saturated soil) will be present during all seasons.

(2) Islands

Islands provide secure resting and nesting places for waterfowl. Islands can be created at any time by placing material (dirt, rocks, large round bales) in a channel or reservoir. The low water line should always leave the island surrounded by water, and the high water line should not inundate the entire island. Islands are improved if they can be vegetated to provide nesting cover.

(3) Peninsulas

Peninsulas increase the amount of shoreline, which increases the value of a reservoir for wildlife habitat. Peninsulas generally need to be incorporated during the reservoir design and construction process. The more shoreline that can be incorporated into pond design, the greater its eventual wildlife value.

(4) Shallows

Shallow shoreline areas are absent from many constructed reservoirs. Reservoirs with uniformly steep sides are of little value to most wildlife. Shallow areas are vital to shorebirds as well as resting waterfowl. A gentle slope also makes it easier for all animals to access the water source for drinking and shoreline foraging. While the economics of reservoir size to volume generally dictate a small, deep design, one side (or a portion of one side) could be altered to provide a shallow stretch of shoreline for wildlife use.

If shallow areas are impossible to construct, escapeways are needed to prevent wildlife loss in plastic-lined or very steep-sided reservoirs. Creating an escapeway can be as simple as tacking down a length of burlap, or other rough fabric, from the rim of the reservoir to below the low water line. Escape ramps or ladders can be made of wooden planks, metal grating, or other material that gives a wet animal traction.

c. Highwall Modifications

Highwall modifications could be considered where a highwall will be inactive for a period of years. Features that enhance the safety and value of highwalls for wildlife include travelways, talus piles, and potholes. These same modifications can also be incorporated permanently into any highwall segment that is to be developed as a bluff in the postmining landscape.

(1) Travelways

Travelways allow animals to move from the top to the bottom of a highwall. Inactive pit areas often provide attractive shelter and shade for animals. A long, unbroken stretch of highwall can impede wildlife movement and hinder these uses. Leaving or creating ramps of material against a highwall at intervals of a few hundred meters allows animals easier passage. Sometimes the natural sloughing of a highwall helps form such travelways for wildlife. If it is possible (from a safety standpoint) to allow or augment such sloughing, this can be desirable for wildlife.

(2) Potholes

Potholes in cliffs are used as shelter and nest sites by species ranging from packrats to owls. If a highwall has few or no natural cavities, and the material has enough stability, potholes can be excavated along the face at different heights. These cavities need not be large; most species that would use such holes would need less than one meter in width, height, and depth.

(3) Talus

Talus, or piles of loose rock, at a highwall base can break up the uniformity and monotony of a long, flat, highwall face that otherwise offers little shelter. Talus provides hiding and denning places for small and medium-sized mammals. These piles can help form the travelways mentioned above.

E. Raptor Nest Relocation

Section editor: Bonnie C. Postovit *Subsection author: Howard R. Postovit*

Applicability

Raptors (birds of prey) and their nests are protected from destruction by Federal law. If nests can be successfully relocated, resource recovery will not be impeded.

Raptor nest relocation is more than simply removal of an obstruction to mining; it is management of a valuable wildlife resource. Raptor nests can be relocated to maintain an existing pair during mining, or encourage a new pair to establish in a particular area.

Special Considerations

Because nests are protected by law, State and Federal special purpose permits must be secured prior to relocation. Knowledge of raptor biology is necessary to determine a nest's activity status and select appropriate relocation sites. Decisions regarding relocations should be made with the advice of a wildlife biologist experienced with raptors.

Techniques

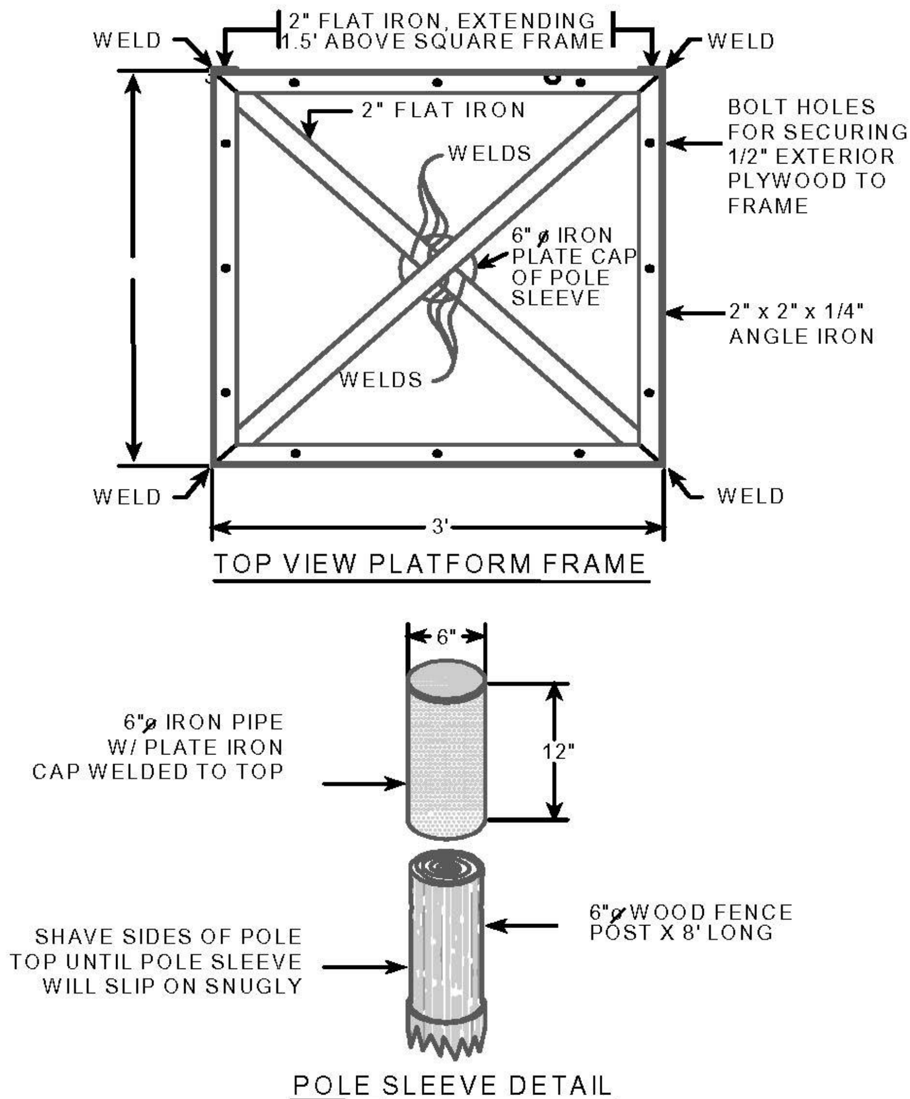
Background information is needed to develop a mitigation plan and implement successful nest relocations. An initial inventory is needed to determine what species nest in an area, and locate all nests. Annual monitoring is then needed to check known nests for activity, and search for any new nests.

Once raptor nest locations and histories are known, a mitigation plan can be developed to address nest sites that are in the path of mining. Wherever possible, a nest should be scheduled for relocation during the non-breeding season at least one year prior to disturbance. Advance planning helps avoid the possibility of having to alter or suspend operations to avoid an active nest.

Nest relocations should have specific goals. For example: in-kind replacement of a nest site; maintenance of a specific raptor pair; or enhancement of nesting habitat in an unoccupied area. Decisions regarding location, platform (or substrate) type, and timing should be made on a case-by-case basis by an experienced biologist. If a relocation is intended to maintain an existing pair, the nest must be relocated within the pair's territory. If the intent of relocation is preservation or enhancement of nesting habitat, the nest can be moved to a location where interference from existing pairs is unlikely. **Relocation plans must be submitted to the U. S. Fish and Wildlife Service and the State wildlife agency well in advance to obtain the necessary permits.**

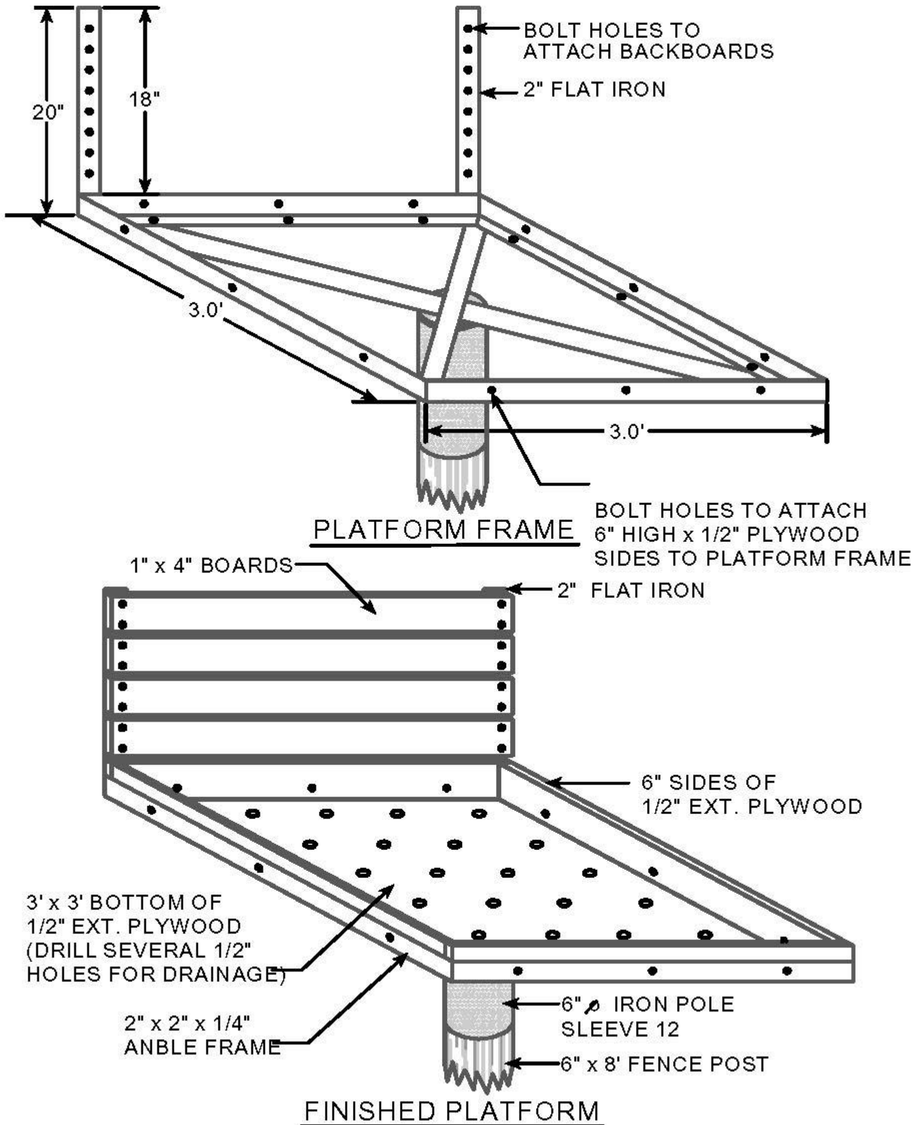
Relocation of eggs or young is a technique generally undertaken only in emergencies. There may be instances where an active nest must be moved, for example, when raptors nest on an unstable highwall, or on a temporarily inactive piece of equipment. Unlike nest relocation during the non-breeding season, this method involves potential and immediate risk to the birds. Emergency relocations of active nests with eggs or young must be supervised and conducted by a biologist experienced in raptor behavior and care. Federal and State permits are necessary for "hands-on" work with raptors.

Platform design for the relocation is given on the following pages.



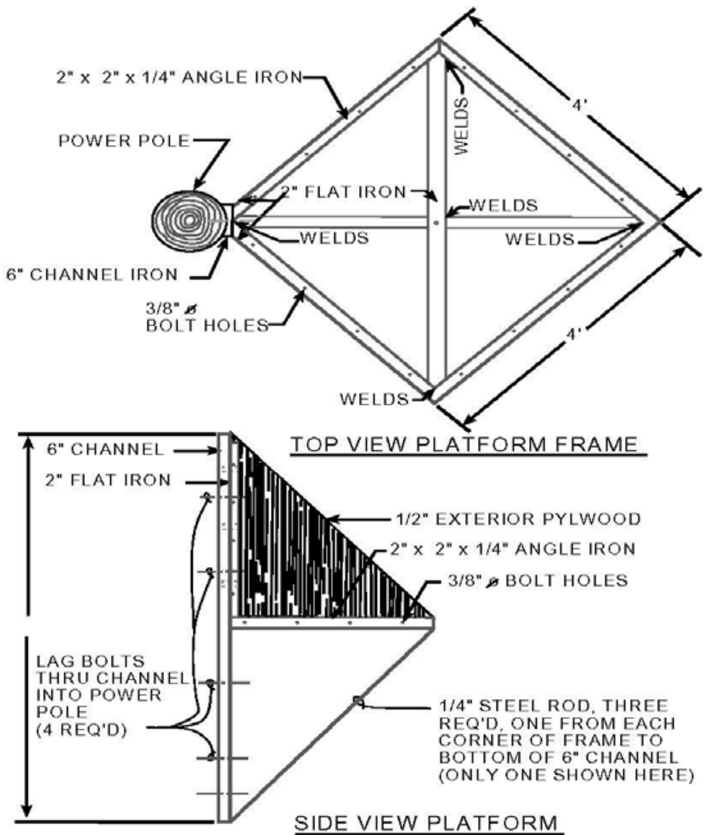
FERRUGINOUS HAWK PLATFORM

DESIGN BY: POSTOVIT, 1984

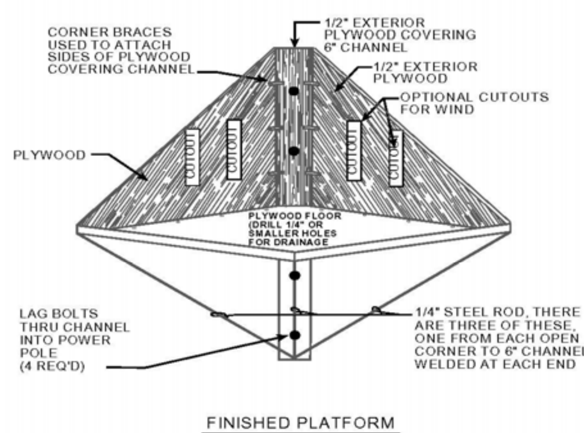


FERRUGINOUS HAWK PLATFORM

DESIGN BY: H. POSTOVIT, 1984



GOLDEN EAGLE PLATFORM
DESIGN BY: H. POSTOVIT



GOLDEN EAGLE PLATFORM
DESIGN BY: H. POSTOVIT, 1981

F. ANIMAL CONTROL

Section editor: Bonnie C. Postovit *Subsection authors: Bonnie C. Postovit/John D. Berry*

Applicability

Animals must be excluded or removed from areas where their presence is not desired, and from areas that may be hazardous. Animal control measures include physical barriers, visual and audio scare devices, application of repellent substances, and animal removal. Raptors nesting in unsuitable areas are a special case of animal control (for more information see the preceding subsection entitled "Raptor Nest Relocation").

Special Considerations

Successful establishment of reclaimed vegetation may require appropriate animal control measures. Such control measures should be viewed as temporary; established reclamation should be self-sustaining under natural conditions. Control instituted to prevent animal access to hazards must be maintained for the duration of the hazard. Control is also necessary where animals damage materials, present a human health problem, or interrupt mine operations.

Techniques

a. Physical Barriers

Physical barriers are a very reliable form of animal control. Barriers can be used to keep big game from decimating vegetation plantings, to prevent bird perching and/or nesting in operations areas, and to prevent rabbit and rodent damage. Barriers include fences, cages, wrap, netting, flashing and screening, and perch-proofing.

(1) Fences

Fences are best used for preventing access over areas larger than a few square meters. Fence design depends upon the species that need to be excluded. Barbed wire, woven wire, electric fence, or chain link can be used to exclude big game and livestock. For more information on fencing, refer to the subsection entitled "Fencing Practices and Wildlife", or the subsection entitled "Creating Livestock Pastures" in the Postmining Land Use section.

Finer material, such as poultry netting or hardware cloth, can be used if rabbits or rodents are the targets of exclusion. Small animals can easily intrude through gaps at ground level and may even burrow under fencing. Staking the bottom of the fence may help prevent intrusion, but below-ground extensions are a more certain means of preventing access by small mammals. For best protection, extensions should be L-shaped, extending at least 15 centimeters below ground level, and 45 centimeters out from the fence. Even these measures will not stop those rodents that are good climbers or burrowing specialists.

(2) Cages

Cages are useful for individual trees, or localized shrub plantings. Such vegetation features may need protection until they are established to the point that they will not be entirely consumed or permanently harmed by grazing or browsing. Cages can be made of woven or welded wire, or hardware cloth. The simplest cages for vegetation are cylinders of woven wire.

Although cages are smaller than fences, sturdy construction is imperative to prevent destruction by large animals. Most types of wire are rigid enough to stand without support. However, where big game or livestock are present, cages should be held erect and in place by fenceposts or rebar. Livestock, in particular, will vigorously rub and scratch on any rigid object in their environment, so cage supports must be designed to withstand such activity. As with fencing, below-ground extensions of enclosure material may be needed to discourage small mammals from burrowing under a cage.

Cages may be open-top or fully enclosed. Open-top cages are necessary for trees. With open-top cages, the *height* and *diameter*, in combination, must be adequate to prevent the targeted species from reaching the tree's trunk and most of its branches until it is large enough to withstand browsing. For example, a two-meter high cage set very close to a young tree's trunk would not necessarily prevent severe browsing damage by deer and elk. Fully-enclosed cages can be used for shrubs or other small- to medium-height vegetation. Cage size should be ample to allow room for expected plant growth.

Cages should not be removed until the trees or shrubs are mature enough to withstand browsing and rubbing. Eventual cage removal should be timed to reduce impact to the unprotected vegetation. This might be during the rest period of a grazing rotation, or in the middle of spring green-up when forage is abundant. Repellent substances (see below) can be applied at the time of cage removal to further decrease the attractiveness of the plants.

Another type of "cage" is the plastic mesh tube frequently used to protect seedling shrubs and trees. This material photodegrades within a few years and may not persist long enough to protect the plant to the point that it is capable of sustaining itself.

(3) Tree Wrap

Wrap is designed to prevent damage to tree bark. Immature trees may need wrap to avoid damage from browsing, rubbing, and gnawing. Various plastic and paper wraps are available commercially. Burlap can also be used as wrap material. Light wire such as poultry netting can be used as wrap, but wire does not flex or expand like plastic, paper, or fabric, so care must be taken to ensure that the material does not gouge the growing trunk. To prevent rodent damage, wraps should extend to, or slightly below, ground level. Wraps should be inspected at least once each season, to be sure they are still attached and effective.

In some instances, mature trees may need "wrap" to prevent lethal damage, as from beavers or vigorous livestock rubbing. Chain link fencing material fastened directly around the trunk has proven successful in preserving trees under such assault.

(4) Netting

Netting is the best means of preventing waterfowl and other birds from using contaminated water sources. Fabric or light wire netting can be stretched over cables or rods spanning the area in question. Caution is advised in selecting netting: the netting size must be small enough that birds do not become entrapped in the openings. Flagging can discourage birds from trying to perch on or push through the netting. Heavy snowfall will affect most netting, necessitating annual repair or replacement in some cases.

(5) Flashing and Screening

Flashing and screening are used to exclude gnawing rodents from wooden structures. Flashing must be used around the entire perimeter of the area to be protected, and could be extended in an "L" out from, or under, the base of a wall. Air vents, floor drains, and other openings should be covered with sturdy screening (hardware cloth). When food or other attractions are present, attempts to rodent-proof an entire building are costly and probably futile. It is more effective (and less costly) to place attractive items in well-protected bins.

(6) Perch-proofing

Perch-proofing is used to prevent birds from habitually occupying areas where their droppings and noise are unwanted. Commercial products to prevent perching include sticky substances (which can be rendered ineffective by dust) and perch guards (needle-like wires or bristles). Perch-proofing is not an effective strategy in an area where the availability of potential perches is great.

b. Scare Devices

Visual and audio scare devices can be used to augment other control measures. Used alone, they may not be tremendously effective. Some labor is often involved, for relocating devices frequently may be necessary to maintain their effect.

(1) Visual Scare Devices

Visual scare devices can be as simple as scarecrows or aluminum pans hung on strings. A number of products are available commercially, including flagging, reflective tape, and mock predators. The movement and/or shape of visual scare devices is intended to startle or alarm animals. Used alone, such devices are not tremendously effective. Animals that frequent mining areas are accustomed to strange sights and noises; they often easily habituate to new stimuli. For greatest effectiveness, visual scare devices should be moved or altered every few days to decrease the opportunity for habituation.

(2) Audio Scare Devices

Audio scare devices include species-specific alarm calls and non-specific loud or unpleasant noises. Commercial broadcast speaker systems are available with pre-recorded distress calls of a few bird species, including starlings and finches. Sound systems with loud or ultrasonic noise bursts are used for other species. Explosive devices from firecrackers to rockets to propane cannons have also been employed to decrease depredation and drive animals from an area.

Any non-automated device or strategy will involve labor-intensive monitoring and operation. Even automatic devices require some labor, as frequent repositioning is necessary for greatest effect. In a situation where animals become habituated to daily mine noise and blasting, audio scare devices used alone are of questionable value. However, they may be worthwhile as part of an integrated animal control approach.

c. *Repellent*

Repellent substances are chemicals that can be sprayed on vegetation or scattered on the ground to inhibit grazing or browsing on treated areas. A number of products are available commercially. The usefulness and efficiency of these substances appears to depend upon site-specific factors; not everyone agrees on the value of any one product. It may be wise to contact local extension services, nurseries, and landscapers to determine which products have been most successful against the target animal(s) in a given area.

Repellent application is moderately labor-intensive. The substances must be reapplied at regular intervals, particularly during the active growing season and after precipitation events. While these products can be used alone to inhibit depredation, as with most control measures, they function best in a combined approach.

d. *Animal Removal*

Animal removal, through relocation or lethal means, may be necessary in specific cases. However, the need for removal can often be eliminated, or greatly diminished, with proper management. Poor housekeeping (and sometimes intentional feeding) lures animals into places where they are not desired. Mice, skunks, bats, raccoons, feral cats, pigeons, and other animals create mess and carry the possibility of disease. Eliminating animal attractants, wherever possible, will reduce human/animal conflicts that necessitate removal. Necessary components of proper management include prohibiting feeding; storing seed and other edibles in rodent-proof bins; and clearing out or fencing off potential den areas provided by wood and rubbish piles. If a removal situation occurs, it is important to not only resolve the incident, but to develop a plan to prevent a recurrence.

Before considering or attempting removal, an operator should contact a State game warden to determine whether removal is legally possible, and whether State and/or Federal permits will be required. If removal is a legal option, it may be best to contract the task to a reliable pest control firm or licensed trapper. This takes advantage of professional experience and expertise, and may ultimately be the cheapest and safest means of accomplishing removal.

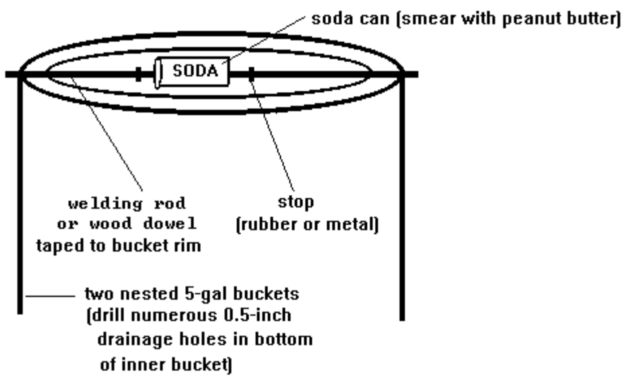
(1) Trapping

Trapping can be used to kill or relocate unwanted animals. Snap traps are suitable for small rodents; live traps can be used for animals of any size. It is important to note that relocation may fail due to underestimation of a wild creature's homing ability. And, while relocation may seem a more humane strategy, animals moved outside their own territory are probably more vulnerable to predation, and may be harassed or killed by others of their own kind.

When live-trapping medium to large mammals, heavy gloves should be worn to prevent bites when handling the trap and releasing an animal. If a skunk is the target animal, cover the trap with an opaque tarp when it is set. The trap handler can then approach, move, and open the trap unseen. This greatly decreases the chance of the skunk spraying.

Fatal diseases like rabies and Hanta virus are not common, but those who handle live or dead animals must take sensible precautions. Rubber gloves and face masks are simple safeguards to prevent skin contact with, or inhalation of, infectious agents. Any wild animal bites should be reported immediately to health officials. Consult a physician or public health service regarding the need for precautionary immunization.

Trapping can be labor-intensive due to the sheer number of animals and the need to empty and reset traps frequently. Some traps are designed to capture a number of animals before they must be emptied and reset. A continuous-capture water trap can be constructed from easily available materials.



Fill bucket with a mixture of antifreeze and water. Empty when needed.

LAUREL'S BETTER MOUSETRAP

(Design details provided by L. Vicklund)

(2) Poison

Rodent removal can be accomplished through the use of poisons. A number of effective poisons are available commercially. Because of safety considerations, the use of poisons should be consistent with mine site practices involving hazardous substances. Material Safety Data Sheets (MSDS) for each product must be available and on file.

Poison baits should be clearly labeled, and set within an outer protective box. Small entry holes in the outer box prevent non-target animals from accessing the bait. Baits placed along walls or other barriers are more likely to be encountered by small mammals than those put in the middle of an open floor. Entry holes in the bait boxes should be cut at the corners where the box meets the wall, to intercept normal rodent travelways.

(3) Cats

Cats can be very effective in controlling a rodent infestation. However, it is irresponsible to encourage feral cats to colonize and reproduce uncontrolled. Feral cats can adversely effect many non-target wildlife species, and they can carry rabies and other diseases. Even carefully controlled domesticated cats can have a significant adverse effect on small birds, particularly during the fledging stage, when entire broods can be exterminated by a barn or house cat in a matter of minutes.

Cats maintained for rodent control should be vaccinated annually, and neutered or spayed. A water source and limited food should be available year-round, to keep the cats in the designated area. Humane maintenance of an animal requires labor and a little expense, but the rodent control value received in return can be quite high.

e. Raptor Nesting Control

Raptors nesting on highwalls or other operations areas can limit or stop mining activities. Raptors, their nests, eggs, and young, are protected by Federal law. A conflict situation may cause a delay of weeks or months, while operations are altered or suspended until the young fledge from the nest.

To avoid potential raptor nesting/mining conflicts, it is extremely important that thorough raptor surveys be conducted early each breeding season; especially in and near mining areas where nesting cannot be tolerated. State and Federal agencies are more likely to issue permits for raptor manipulation if a company has demonstrated willingness to document potential conflict situations as early as possible each year.

Deterrence and relocation are methods used to control raptors nesting in unsuitable areas. Deterrence is used to discourage nesting attempts early in the breeding season, prior to egg-laying. Deterrence can be accomplished through barriers, removal of the nesting substrate, audio scare devices, or other disturbing activity. Relocation of raptor nests is discussed elsewhere in this section.

NOTE: Federal and State permits are required for any disturbance or manipulation activities involving nesting raptors. If raptors show an interest in a particular site (frequent perching, roosting, carrying nesting material), consultation with Federal and State agencies should be initiated immediately to determine which methods of deterrence should be employed. Deterrence is not always successful; the birds may not move, or may move to a site that is even less suitable (from a mining standpoint) than the original site.

(1) Barriers

Barriers such as a wire cage or a tarp can be used to cover a potential nest site on a highwall.

(2) Removal of Nesting Substrate

Substrate removal involves making the nest site permanently incapable of supporting a nest. Highwall faces can be scraped or blasted to remove ledges or potholes. Trees, windmills, old buildings, and other structures adjacent to mining activity can be removed. This strategy can be employed as a preventative measure, even when no raptors have shown interest in a site.

(3) Audio Scare Devices

Audio scare devices, such as propane cannons and pistol-launched noisemakers, can discourage raptors from using a potential nest area. These methods can be quite labor-intensive. Cannons need to be repositioned frequently (every other day) to maintain effectiveness, and field personnel must visit the site daily to employ pistol rockets.

(4) Human Disturbance

Other disturbance can include flushing the birds from the site at every opportunity, or simply increasing general mining activity in the area of nesting. Disturbance should be used in conjunction with other methods, as raptors may simply tolerate increased disturbance. Also, it may not be feasible to schedule work in an area for a period of time long enough to discourage nesting activity.

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DRILLING

Section Editor: Mickey Steward

Handbook of Western Reclamation Techniques

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SECTION 7: DRILLING PROGRAM

A. INTRODUCTION

Section editor: D.G. Steward

The purpose of this section is to provide a framework for identifying and conducting the activities associated with a drilling program. Drilling is done for a variety of reasons at coal mines. While the section does not address drilling in the pit for blasting, it does address the many other reasons drilling is conducted.

Overburden chemistry can be sampled as part of the drilling program. From this information, estimates of the volume and location of materials requiring special handling in the reclaimed area backfill can be made. Special handling of certain materials is often required by the state program permit for the mine operation. Documentation of the backfill geochemistry and the proper placement of specially handled materials may be required by the permit, and can be used to support bond release requests. This documentation is provided through the drilling program.

Wells can be installed as part of the drilling program. Monitoring wells in native and reclaimed lands may be required by permit and regulation, dewatering wells may be used to facilitate pit advance, and production wells provide water for the mine facilities and support operations.

Drilling is used to obtain information on coal quality, quantity, structure, and location. This information is used to maximize efficient coal extraction and comply with customer contract specifications. Drilling also provides geotechnical information that aids in pit configuration, and helps to identify mining limits by providing data for cropline and slope stability analysis.

Finally, drilling is used for miscellaneous projects that cannot always be specified beforehand. Three examples are: installation of ground wires for electrical substations, assessing the extent of soil or groundwater contamination, and obtaining geotechnical data to facilitate design for structure foundations, reservoir embankments, and slope and highwall stability.

Much of the drilling that is conducted for one purpose can also be used for another. For example, sampling of overburden during the installation of dewatering wells adds to the data base for overburden quality. It is important, therefore, to view the drilling program as an integrated program and plan for the maximization of results from every hole drilled.

Drilling is heavily regulated by state and federal agencies. These operating techniques have been developed to aid in the execution of a drilling program, and to help ensure that all elements of the program are addressed. While some of these elements are not uniformly applicable to all types of drilling, each element is presented in order to fully identify all aspects of the program that require decisions and/or action.

Weather, equipment, personnel, regulatory constraints, mine plan changes, changes in management, and management emphasis can alter the best planned program. Flexibility is essential. A problem anticipated and planned for is no problem. In addition to listing the necessary elements for the various types of drilling, this section provides a basis for early anticipation and avoidance of potential problems. Good planning will lead to a timely and efficient program. The foremost ingredient in a successful program is a timetable of the necessary elements, which assures timely availability of results.

TIMETABLE FOR ANNUAL DRILLING PROGRAM PLANNING

ITEM	DATE	REASON
Communicate with mine personnel and budget drilling program for the upcoming year	September	Typical time for submitting budget
Prepare and circulate request for contractor bids	January	Best prices
Choose successful bidder	February	Facilitate optimum scheduling
Schedule driller	February	Facilitate optimum scheduling
Execute the program	July-September	Good weather
Collect and review analytical data	October	Prompt analysis of samples collected
Submit logs and required reports	November-December	Prompt closure of field season

NOTE: Regulatory requirements for drilling can change rapidly. State and Federal regulatory agencies should be contacted prior to the planning phase of any drilling program to ensure current standards and requirements are met. It may also be necessary to comply with State Engineer and Oil and Gas programmatic requirements in your state. Failure to meet regulatory requirements can have severe consequences so this effort must be pursued assiduously.

Acknowledgements
The assistance of Mike Nicholson, Bob Stowe, Robin Kerschner, and Marlys Hansen in completing this drilling program is greatly appreciated.

B. PRE-DRILLING REQUIREMENTS

1. Identifying Drilling Needs

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

The first step in the planning of any drilling program is to identify the mine's requirements for the upcoming year. Permitting and regulatory requirements must be considered throughout the planning process.

Special Considerations

While planning for a drilling program must be fairly exact, a certain amount of flexibility is necessary, in the budget as well as the program itself. This allows for changes and additions that may become necessary during execution of the program.

Techniques

a. Meetings

Hold meetings, at least annually, with mine personnel to discuss the drilling schedule, and receive input on the drilling requirements for all departments. Drilling may be required for operations, permitting, or special projects. Be sure to receive input on possible conflicts that may affect the efficient completion of the drilling project. Locations of any buried pipelines, cables, and other utilities should be identified and staked to prevent hazardous situations and/or interruption of services.

b. Operations Requirements

Coal quality exploration drilling provides the necessary information to allow planning for efficient removal of overburden, and extraction of coal of the requisite quality to meet contract requirements. Coal structure exploration is necessary for coal seam location and correlation. Drilling of dewatering wells allows for more efficient mining operations. Production wells provide water for the mining facility and support operations.

c. Mining Permit and Regulatory Drilling Requirements

Mining operations are required by law to provide a certain amount of geologic and hydrologic information. Specific regulatory requirements or guidelines for each state may differ and should be investigated.

Mine permits typically present information collected as part of the permit application process. Mine permits also specify what sampling and monitoring programs will be conducted both during and after mining. The extent of the program is set by regulation and negotiation. The current mine permit should be consulted for program specifics.

(1) Baseline Inventory

Regulations may require drilling to establish a premining baseline inventory of subsurface conditions.

(2) Overburden Suitability

A mining permit often requires that overburden suitability be established. The need for special handling of materials during backfill, if any, is established by drilling and sampling. Postmining backfill suitability and groundwater monitoring are also required to comply with mining regulations.

(3) Ground Water Monitoring

The ground water monitoring program is typically specified in the mine permit. Monitoring of both quality and quantity is the norm. Monitoring is conducted before, during, and after mining. Special drilling may be necessary in the development of monitoring wells to prevent inadvertent contamination of the well or samples. For example, sampling criteria for the collection of samples for selenium analysis can be restrictive and time consuming.

(4) Bureau of Land Management (BLM) Requirements

For lease coal, the BLM requires information regarding coal quantity and quality, and overburden thickness. Baseline information for economic and environmental evaluation is also needed.

d. Special Projects

Drilling is occasionally required to obtain data for structural design of foundations for new construction or for slope stability analysis. Drilled holes may also be required for installation or removal of ground wires for electrical substations.

Backhoe pits may be needed for various reasons, such as soil description. The same general requirements for reclamation that cover drilling operations will often apply to backhoe pits.

2. Identifying Logging and Sampling Requirements

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to outline any logging, sampling, analysis, or special equipment that may be required for a drilling program. These requirements will vary depending on the individual mine's needs for that year, as discussed in the subsection entitled "Identifying Drilling Needs".

Special Considerations

Once requirements for individual drilling programs have been identified, they should be specified in "Request for Quotation" and "Scope of Work" documents. More information on these documents can be found in the subsection entitled "Contracting the Drilling Program".

Techniques

a. Specify the Descriptive Requirements

More detail on logging can be found in the subsection entitled "Logging". However, the program administrator must decide if both lithologic and electric logs are needed for the project, or if lithologic logs alone will suffice.

(1) Lithologic Logs

Lithologic logs are prepared by the geologist, geotechnical consultant, and/or driller. They consist of descriptions of the materials encountered as drilling progresses. These logs note the depths at which soil/rock type changes or water is encountered, as well as depths and types of samples obtained.

(2) Electric (geophysical) Logs

Geophysical logs are made after completion of drilling by lowering electronic remote sensing equipment down the hole and recording digitally and/or on strip charts. Downhole logging of changes in density, moisture, resistivity, and caliper may be required for exploration holes. Geophysical logging is often performed by contractors.

b. Specify the Sampling Requirements

(1) Type of Samples Required

Chip sampling of coal and overburden is the most cost effective sampling method and may be used where practical. When continuous coring is required, three-inch diameter cores are standard, and have been found to provide adequate sample volume for analysis. If at least 90% of the coal and 75% of the overburden is not recovered in each run of the coring tool, that part of the profile must be re-cored.

If re-coring is unsuccessful, or, if in the judgment of the driller, recovery is highly unlikely because the material is too loose and soft to be retained in the core barrel, it is permissible to catch cuttings at the surface in a bucket placed near the discharge pipe of the drill. The cuttings are then bagged for each interval in which the unrecoverable material was drilled.

Special sample equipment may be required for geotechnical samples. The drilling contractor must know in advance any equipment he is to provide, potential materials to be encountered, and frequency of sampling that will be expected.

(2) Analysis Required

The analysis required to be performed on samples will govern the type of laboratory equipment and procedures necessary. Laboratories bidding to perform the work must have complete information on required analysis and time constraints for reporting of results. The mine permit will usually provide specific information on the analysis that must be performed on overburden and water samples.

Coal analysis requirements are usually dictated by the information necessary for the sale of coal. Normally, coal analysis can be broken down into the following groups: proximate, ultimate, ash mineral, fusion, and grindability. Federal regulations for coal analysis requirements of leased federal coal prior to the commencement of mining operations can be found in Section 43 CFR 3482.1 (c)(3)(i) of the Code of Federal Regulations (CFR, 1993). Meet with mine personnel to achieve consensus on the amount of data necessary for the purposes set forth.

(3) Special Equipment Required

If the need for specialized or unusual equipment is anticipated, extra lead time and expense should also be anticipated. For example, if undisturbed samples are required from unconsolidated backfill, a Pitcher sampler may provide better recovery than standard core samples. Special preparations may be required, however, to obtain the sampler and manage the samples.

(4) Sample Identification

Any special sample identification procedures that will be required must be identified and contractors advised before bidding.

3. Identifying Number, Size, Location, and Depth of Drill Holes

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to assist in planning the actual holes to be drilled in a mine's drilling program. These requirements will vary depending on the individual mine's needs for that year, as discussed in the subsection entitled "Identifying Drilling Needs".

Special Considerations

Once requirements for individual drilling programs have been identified, they must be specified in "Request for Quotation" and "Scope of Work" documents. More information on these documents can be found in the subsection entitled "Contracting the Drilling Program".

Techniques

a. Identify Grid Spacing and Number of Holes to be Drilled

The number and spacing of drill holes will depend on the purpose of the drilling. The mine permit requirements, and state guidelines, dictate the minimum number and spacing of drill holes.

Delineate coal and overburden quality sufficiently to prevent basing too large a portion of the near and intermediate term mine plan on interpolated data, especially if important parameters exhibit large variability over the areas sampled. Have a good picture for the next three to five years to allow flexibility of planning. Meet with mine personnel to verify hole spacing for the project.

Spacing and depth of geotechnical holes should be selected by the geotechnical consultant performing the analysis. When spacing drill holes for exploration, take into account the variability of data already in hand and the timeframe during which the area will be mined. Based on the grid spacing selected, and the area to be drilled, estimate the total number and size of holes to be drilled. Where possible, based on prior information, provide the total depth to which the holes will be drilled.

b. Choose the Drilling Method

Several factors affect the choice of drilling methods and the equipment required to perform the work. These factors include the type of material to be drilled, the water table, and possible monitoring.

(1) Anticipated Material to be Drilled

The types of materials anticipated to be drilled, and the water table levels expected, if known, can help predict the need to drill with air or with drilling mud, and whether or not surface casing must be provided to keep the hole open in saturated sands or gravels.

(a) Drilling with Air

Drilling with air is desirable to facilitate identification of materials drilled, and is preferable for collection of chip samples from specific sample intervals. Air drilling can also facilitate identification of water tables during drilling. Materials such as wet clays, however, will not clean well when drilled with air. If porous formations such as scoria (fused shale) are encountered, air circulation will be lost. Injection of water, and occasionally foam, while drilling with air prevents dust and facilitates cleaning the hole. Mine Safety and Health Administration (MSHA) requires that dust be controlled during drilling.

(b) Drilling with Mud

Drilling mud facilitates drilling in wet clays and scoria, but is time consuming and in some cases makes sampling and logging more difficult. Drilling with mud often has a greater environmental impact than air drilling. Drillers should be prepared to drill with air or mud as required.

(c) Using Surface Casing

When drilling near creeks or other locations where saturated sands and gravels may collapse into the hole, surface casing may be required to allow drilling and sampling. Anticipating these conditions can save time if the driller provides casing materials at the site before drilling begins.

(d) Drilling with Auger Rigs

Auger rigs with continuous flights and hollow stem augers are useful for sampling backfill and soils, or for shallow geotechnical sampling (usually less than 100 feet). Auger rigs are also employed to install shallow monitoring wells. These rigs are usually smaller, more maneuverable, and less expensive than rotary drilling rigs.

(2) Water Table if Known

Advance knowledge of water tables will allow drillers to anticipate possible drilling or sampling problems.

(3) Atmospheric or Soil Monitoring Required

Monitoring of gases such as hydrogen sulfide (H_2S) and methane (CH_4) that may be encountered while drilling may be required. The contractor's Scope of Work should specify what monitoring will be required, who will provide the equipment, who will perform the monitoring, and what records are to be kept. If hazardous materials are anticipated, the safety procedures and personal protective equipment to be employed should be specified, as well as any special waste disposal and decontamination measures required.

c. Name the Holes and Map the Hole Locations

There are many ways to name and identify holes. Typically a combination of letters and numbers are used. The letters generally designate the property or mine on which the drilling occurs, while the numbers give the hole a unique designation. For example, CB-0101 would designate Caballo hole number one hundred and one (101), where the holes are numbered sequentially over the life of the mine. Alternately, BT-9501 would designate Black Thunder, hole one (1), drilled in 1995. Or JRM-10-C-01 would designate Jacobs Ranch Mine's hole one (1) in coal in Section 10.Another way to identify holes is to use a six digit abbreviated form of the northing and easting, or other appropriate survey coordinate base, written in that order, and formed by extracting the fifth through third digits left of the decimal point rounded to the nearest one hundred feet. For example: If the location of a hole is given by northing 1,354,281.070 and easting 416,359.730, then the hole identification number on the hole marker would be 543164. Be aware that, when using this method, the hole name may change if its location changes during field operations. To avoid the confusion this would cause, proposed holes may be given a temporary numeric hole name at the outset of the program.

Hole identification conventions other than that suggested here may be developed which obviate renaming holes and which better suit the needs of the specific property. After naming the holes, place the proposed drill holes on a map. Show associated terrain features and access routes on the map.

4. Pre-field Permitting and Reclamation Planning

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

There are paperwork requirements that must be met before the actual drilling can begin in any drilling program. All paperwork should be documented in drilling correspondence files organized by year and hole type. Reclamation plans must also be made and outlined in the "Scope of Work" document.

Special Considerations

Regulatory requirements regarding permitting, reclamation, and bonding may differ from state to state. Planning should be done according to applicable regulations. Once these requirements have been identified, they must be specified in "Request for Quotation" and "Scope of Work" documents. More information on these documents can be found in the subsection entitled "Contracting the Drilling Program."

Techniques

a. Permitting and Notification for Drilling and Access

(1) Obtain Permission

Permission to perform any drilling in the permit area must be obtained from the state regulatory authority. If access to the drilling area requires crossing lands for which the mine has no control or existing right-of-way agreement, permission to cross must be negotiated.

(2) Obtain Permits

Written permits must be applied for in advance, allowing sufficient time for processing. The following figures give paperwork flow charts for BLM, Wyoming Department of Environmental Quality, Land Quality Division (WDEQ-LQD), and Wyoming State Engineer's Office (SEO) documentation and permitting requirements.

Federal regulatory requirements can be found in 30 CFR 772.11, 772.12, 772.15, 780.22(b)(2), 815.13; 43 CFR 3410, 3482, 3484.1(a)(4), and 3485.1(a),(b),(c) (CFR, 1993). There are significantly different requirements for drilling unleased, as opposed to leased, coal. Read applicable regulations carefully and contact the BLM. State regulatory requirements may differ from state to state and should be investigated.

(3) Give Public Notice when Required

Public notice may be required for some drilling activities. Be sure to retain records of the publication.

(4) Review Permits

Meet with mine personnel and property owners or other concerned parties to verify that all permitting and notification are complete. It may be appropriate to obtain legal advice, or consult with regulatory agencies, to confirm that all issues have been adequately addressed.

b. Reporting Requirements

Documentation and reporting of all drilling activities are required by Federal regulation. These regulations can be found in 30 CFR 772.11(b)(5); 43 CFR 3410.2-2(b), 3482.1(a)(3)(v), and 3485.1(b)(8) (CFR, 1993). These requirements are often addressed in the mine permit. In Wyoming, drill holes in which artesian water flow is encountered at the surface must be reported within 60 days to the Wyoming State Engineer's Office and the Administrator of the WDEQ-LQD. Regulations may differ for other states, and should be investigated. A drilling correspondence file should be developed to document all reporting activities.

c. Reclaiming and Abandoning Drill Holes

Reclamation and abandonment procedures are usually described in the mine permit. Federal regulations regarding these procedures can be found in 30 CFR 815.15, 816.13, 816.14, 816.15, 816.101, 816.102; 43 CFR 3484.1(a), and 3484.2(a) (CFR, 1993). State regulations should be investigated. In Wyoming, developmental drill holes to be mined through within one year should be made surface safe, but need not be permanently reclaimed.

The Scope of Work must specify what measures are to be employed and which holes are to be reclaimed. More detail on drill hole reclamation is provided in the subsection entitled "Drill Hole Reclamation".

d. *Bonding*

Where drilling is proposed off lease on federal coal, or on lease, a bond is required. Bonding for exploration and monitoring is set in the annual report in which the drilling for the year is forecast, and is based on the estimated cost to reclaim drill holes and sites.

FLOW CHART FOR BLM AND WDEQ-LQD PAPERWORK

Submit a letter to BLM requesting permission to drill. Copy letter to WDEQ-LQD.

↓

Receive the standard BLM stipulations for drilling.

↓

Sign and return the stipulations to BLM.

↓

Perform the drilling.

↓

Return the drilling completion form within 60 days of completion of the project. Notify WDEQ-LQD.

↓

Submit drill hole abandonment report and the required drilling data to the BLM.

↓

Notify WDEQ-LQD of well and drill hole abandonments in the annual report.

↓

Forecast the drilling needs for the upcoming year in the annual report to the WDEQ-LQD.

WYOMING STATE ENGINEER'S OFFICE PAPERWORK AND ACTIONS

Submit Application for Permit to Appropriate Ground Water (UW-5) forms to the SEO.

↓

Receive back copy of the UW-5 form and blank Completion Report (UW-6) with the permit number and the Notice of Commencement form. If drilling a production well, also receive back a Proof of Appropriation and Beneficial Use (UW-8) form.

↓

Submit the "Notice of Commencement" after drilling is begun.

↓

Drill the well.

↓

Submit completed UW-6 form within 30 days of project completion.

↓

Submit completed UW-8 form by end of calendar year.

↓

Upon abandonment of the well, submit a letter informing SEO of proper abandonment and referencing the permit number.

5. Contracting the Drilling Program

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection outlines the steps necessary for obtaining a contractor that will fill the needs of a specific drilling program. Requirements and responsibilities for all contractors must be clearly documented.

Special Considerations

The contractor requirements for a drilling program should be specified in "Request for Quotation" and "Scope of Work" documents. These needs will depend upon decisions already made regarding drilling, logging, and sampling requirements. Exact responsibilities of each contractor should be clearly specified. It is desirable to allow for some contractor flexibility in execution of the program, while clearly stating requirements that *must* be met.

Techniques

a. Prepare the Written Scope of Work

Include every aspect of the project as it pertains to the various contractors who may bid on all or part of the project. Use a checklist similar to the following for preparing a Scope of Work.

1. Determine the purpose of the drilling.
2. Gather all pertinent documents that control the type of drilling proposed.
3. If geotechnical or other consultants are required to participate, obtain their input on special requirements for drilling, sampling, or analysis.
4. Define the sampling program for the project.
5. Determine the number, location, and depth of drill holes and list what types of drilling and sampling equipment are to be provided by the drilling contractor. Identify who is responsible for any equipment, such as probes, that may be lost down drill holes.
6. Note anticipated materials that may be encountered during drilling, and any atmospheric or soil monitoring required.
7. Provide a map of the drill hole locations showing associated terrain features, access routes, any restricted areas, and pertinent geologic and hydrologic data that are available.
8. If appropriate, list the types of laboratory analysis required and the time frame in which the results will be needed. The analysis of the samples may be bid separately from the drilling.
9. List the type of logs that need to be prepared during drilling, and who will prepare them.
10. If wells are to be developed, list the materials to be used and provide a drawing of the completed well.
11. Determine what reclamation and abandonment procedures are applicable to the project and list specific materials to be used.
12. Determine who will provide well and/or reclamation materials.

13. Determine the time frame during which the project will be completed and any unusual working schedules necessary to meet the deadlines which may be set.
14. Prepare a "Scope of Work" or "Request for Quotation" for each contractor to include all of the foregoing information.

b. Identify Contractors

Prospective contractors bidding on the work should provide current statements of qualifications, current licenses, references from previous clients, and a history of work performed. The driller, the geologist, the logger, and the laboratory may be bid together as a package or separately.

(1) Driller

(a) Safety Record, MSHA Training

Investigate for any history of safety violations or accidents that may have occurred, and determine if remedial steps were taken. Determine if the contractor provides a safety training program for his employees, and whether or not MSHA training has been completed if required.

(b) Suitable Equipment

Determine if the prospective contractor's equipment is appropriate to the job and in good operating condition.

(c) Past Experience

If the prospective contractor has performed work for the mine previously, information may be available from records or personnel about the quality of work performance that can be expected.

(d) References

Obtain a list of references of previous clients from prospective contractors about whom additional information is desired. Consult these clients concerning past job performance.

(2) Geologist/Geotechnical Consultant

The geologist can be sub-contracted through the driller, requiring the driller to coordinate all applicable activities, or vice-versa. The same information regarding safety, equipment, experience, and references that are required for the driller should also be obtained for the geologist/geotechnical consultant.

(3) Laboratories (Chemical/Geotechnical)

The same information regarding equipment, experience, and references that are required for the driller should also be obtained for the laboratory. In addition to this, it is necessary to ascertain if prospective laboratories have met standards of government or industry sponsored certifying agencies for the types of analysis required.

Establish what timeframe is required to receive laboratory results and evaluate the prospective lab's ability to meet requirements with respect to equipment, personnel, and workload.

Laboratories must demonstrate that they can consistently achieve accurate analytical results. In some cases it may be desirable to submit duplicate samples or "spiked" samples to check lab performance. Selection of reputable, certified labs and submission of duplicate samples to different labs can help minimize variability of results caused by lab operations.

(4) Downhole Logger

The logger can be sub-contracted through the driller, requiring the driller to coordinate all applicable activities. The same information regarding safety, equipment, experience, and references that are required for the driller should also be obtained for the downhole logger.

Check equipment calibration records to verify timely regular performance checks of logging equipment. Identify the digital data capacity of the logger. In addition to strip charts or other visual representations of data, it may be desirable to have geophysical data provided in a digital form compatible with available computer systems.

c. Contact Prospective Bidders

Contact prospective contractors to determine their availability to perform the work during the proposed project timeframe.

d. Pre-bid Meeting

Meet with prospective contractors to discuss and clarify the Scope of Work prior to accepting bids.

e. Receive and Analyze Bids

Once bids have been received, prepare a master spreadsheet that allows a direct comparison of both line item and overall bid costs. Discuss this comparison with purchasing, accounting, and engineering personnel. Remember, the low bidder may not be the best buy. Finally, select the contractor.

f. Schedule the Contractors

Prepare contract documents which establish a timeframe for beginning and completing work and give contractors notice to proceed. If desired, establish the normal working hours expected.

6. Sample Storage

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

Planning for the handling and storage of drilling samples will expedite these activities when field work is actually being done. Storage facilities should be identified before they are needed.

Special Considerations

Capacity, accessibility, and necessary climate control must be considered in the choosing of a storage facility for drill samples.

Techniques

a. Capacity and Accessibility

The sample storage facility must be large enough to allow samples to be easily identified and sorted by hole number and depth interval. Use hole number, diameter, and depth to estimate the total storage volume required. Loading and unloading of samples should be as convenient as possible. Provide keys to the locked storage facility to authorized persons only.

b. Temperature and Humidity

Ensure that climate control in the storage facility is adequate to preclude extremes of temperature or humidity. Samples must not dry out, or lose volatile constituents during storage.

c. Time Constraints

Transfer samples expeditiously to the analytical laboratory in accordance with good practice for the types of analysis required. Determine how long it will be necessary to use the storage location before samples are shipped.

C. FIELD WORK

1. Field Activities

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to outline the steps needed for actual field work required in a drilling program, and to ensure that all elements of the program are addressed.

Special Considerations

In any drilling program, supervision will be required regarding location, access, and drilling of holes, as well as safety and environmental control considerations.

Techniques

a. Locate and Identify Drill Holes

(1) Select Accessible Drilling Sites and Drillable Hole Locations

Locations of holes may have to be adjusted to avoid obstacles to accessibility, such as swamps, ravines, steep slopes, and rock outcrops.

(2) Survey the Holes

Mark holes with a lath and flag or other suitable means. The following information may be helpful if placed on the lath:

(a) Northing and easting or UTM coordinates.

(b) Elevation at the surface.

(c) The estimated depth to coal, and coal thickness (optional).

(d) Type of hole (label the holes as monitoring, dewatering, exploration, etc. on the marker).

(e) If GPS (Global Positioning System, based on satellite transmissions) is available, this method may be used to locate drill holes.

b. Access the Drill Site

(1) Roadways

Special precautions may be necessary when permits or special permission have been obtained. If special permission has been received to cross lands not controlled by the mine, care must be taken to assure that all contractors are specifically advised of routes to be followed and restrictions to be observed.

Use existing roads and trails whenever possible. Limit vehicular traffic to drill sites to the minimum necessary. When wet conditions prevail, avoid areas where rutting and vegetation damage will cause undue reclamation effort.

(2) Hours

Drilling operations are normally scheduled during daylight hours for safety. If night drilling is anticipated, ensure that adequate lighting is provided.

(3) Restrictions

Drilling operations may involve movement of equipment in pit traffic areas, and, if so, may have to be restricted to certain times or routes. Drilling may have to be suspended and equipment moved during blasting operations.

c. Drill the Hole

(1) Special Sampling Considerations

Begin all drilling operations with clean equipment. Make sure any water, lubricants, pipe dope, or similar items used during drilling do not contain materials that will be analyzed in the samples, or that may interfere with analytical results. Obtain Material Safety Data Sheets (MSDS) to verify the contents. For example, if samples are to be analyzed for molybdenum, then drill pipe grease containing molybdenum should not be used while drilling and sampling.

(2) Environmental Considerations

(a) Safety (including monitoring for gases such as H_2S and CH_4)
Hydrogen sulfide and methane gases are routinely encountered when drilling in coal and overburden. Other toxic or flammable vapors may be found, especially when drilling in the vicinity of underground storage tanks. Have monitoring devices for hazardous gases available to ascertain if explosive, fire, or toxic exposure conditions exist. If toxic concentrations exceed the threshold limit value or flammable gas concentrations exceed 10% of the

lower explosive limit in the work area, mitigating procedures must be taken and personnel and equipment protected from hazards.

(b) Housekeeping

Require contractors to maintain a clean and orderly work place, and to contain and dispose of waste materials in an approved manner. Unused equipment, well supplies, and reclaiming materials should be stockpiled to avoid damage or loss, and to present no hazard to drilling or mine operations.

(c) Environmental Control

Excavate and backfill mud pits used to contain drilling fluid and cuttings in accordance with the mine permit. Take any precautions that may be necessary to protect people, livestock, and wildlife from open holes or other hazards.

Require contractors to prevent uncontrolled release of excess drilling fluids that may contaminate surface water or damage vegetation. Have the contractor provide MSDS for all material to be used during the drilling program.

d. Monitor Groundwater Levels

This is always done for geotechnical drilling, and may be appropriate for other types of holes. Instructions for monitoring are given in "Standard Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)" (ASTM, 1994).

2. Sample Collection

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

Sample collection is an important part of the drilling program. This subsection is intended to cover various aspects to be considered for all associated sampling. Sample requirements can be very site specific; the information provided herein is intended for use as a guide only.

Special Considerations

Methods used for collecting, bagging, and handling of samples will vary from mine to mine, depending on permit and regulatory requirements, as well as the information that is to be collected.

Techniques

a. Coal

There is usually no special cleaning required for coal sampling. Continuous coring through coal, with at least 90% recovery, is usually required. The structural tops and bottoms of the coal seams should coincide with sample interval starts and endings.

Sample collection can be made in a variety of ways. Composite coal samples can be taken and submitted for analysis for each seam encountered. Samples can be taken at two-foot intervals in the top and bottom six feet of coal, and at five to ten foot intervals between. The company representative in charge of geology should be consulted on sample intervals. Geophysical logs can be used to identify tops and bottoms of structures. If the parting is identified, sampling is optional, but if sampling is required, separate bagging for the parting is required.

b. Overburden

Holes are drilled and cored or chipped. The interval at which chip samples are collected is set by the program administrator, and may depend upon bench height.

Subtract the estimated topsoil break and do not include as part of the overburden sample. This may be as much as five feet. Cores can be bagged in two-foot intervals, then combined for eight-foot intervals. When placing cores in boxes, orient the interval marking with the actual orientation of the cores as they were removed from the ground. Select sampling intervals consistent with the mine permit.

Selenium sampling may require special cleaning of samplers and equipment. Some operators collect samples for selenium analysis in accordance with "Standard Operating Procedures for the Sampling and Analysis of Selenium in Soil and Overburden/Spoil Material" (Carroll, et al., 1994).

c. Backfill

Backfill monitoring and sampling requirements are usually specified in the mine permit. In general, backfill sampling is required to demonstrate compliance with the mine permit.

d. Geotechnical

Normally, no special cleaning is required for geotechnical sampling. Types and locations of samples to be taken are specified by the program administrator or a geotechnical consultant. General requirements are outlined in the "Standard Guide for Investigating and Sampling Soil and Rock" (ASTM, 1994).

Geotechnical samples are to be transported to laboratories in accordance with "Practices for Preserving and Transporting Soil Samples" (ASTM, 1994).

e. Special Considerations

Begin all drilling operations with clean equipment. The type of sample dictates the procedure required for cleaning equipment. For example, when sampling for selenium (if following Carroll, et al., 1994), samplers, drill pipe, etc., must be washed with Alconox and rinsed three times with distilled water between samples.

Make sure water, lubricants, pipe dope, and similar materials used during drilling operations do not contain materials that will be analyzed in samples or that will interfere with analytical results. Obtain MSDS to verify the contents. For example, if samples are to be analyzed for molybdenum content, then drill pipe grease containing molybdenum should not be used while drilling and sampling.

f. Handling

(1) Packaging

Core and chip samples should be placed in double plastic bags, to provide additional resistance to damage and extra moisture protection. Seal both bags separately with tape to assure no loss of moisture. 6-mil polyethylene bags are adequate. All samples may then be placed in water resistant boxes for transport. If core boxes are used, double bagging may not be necessary.

(2) Labeling

Color code or label clearly for coal, overburden, and backfill samples as necessary to prevent confusion when handling samples. Mark the hole number and sample interval on the outside of the bags, and also on a tag placed between the two sample bags. Do not place sample tags inside the sample bag, as they will become unreadable.

(3) Cataloging/inventory by Geologist or Driller

Any data collected that may eventually be computerized should be in a format that reflects that eventuality. A copy of the lithologic log, which lists samples by number and depth, may be included with samples submitted to the lab, and with a chain of custody sheet, which should also accompany the samples.

3. Well Drilling

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection outlines requirements that may be necessary in contracting the drilling of water wells.

Special Considerations

Physical requirements of each well will differ greatly. Specifications for casing size and depth, placing of well screens, and any other requirements must be clearly designated to the contractor. Overburden sampling when drilling dewatering wells may be desired to add to the overburden quality or coal database.

Techniques

Wells to be developed as production or monitoring wells do not need to have earthen samples collected, although they may have. These wells must be cased with screen placed at the water-bearing levels to be monitored or pumped.

All casing must be sealed to prevent contamination from surface or other undesired water sources. Excess drill cuttings must be spread to one-quarter inch thickness, or disposed of in the pit or other disposal area to prevent any chemical hazard. Wells can be protected from unauthorized access, and are preferably maintained under lock and key.

In addition to the casing required to facilitate drilling and sampling, casing must be provided for the development of monitoring or production wells. Specify the inside diameter of the casing, the schedule of pipe to be used, the screen opening width, where the screen is to be placed, and the type of any security device to be installed. Specify the particle size range of sand to be placed around the well screen in wells. Wells are to be sealed from surface contamination or from communication with aquifers that are not desired to be sampled or pumped. Identify any preferences regarding brand names or sources of materials.

4. Logging

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to give a brief summary of the various types of downhole logging that may be used in a drilling program.

Special Considerations

The readouts from these logs may be used by one or more parties. There is often only one print-out of each log, and it is difficult to copy. Obtain digital data in addition to hard copies when possible. Information obtained from each log will differ, and can be compared with other logs for confirmation of results.

Techniques

a. Electrical Logs

Caliper, resistivity, and nuclear logs are the electrical logs normally obtained. The logs are obtained by lowering a logging device down the hole. Data from electrical logging are recorded digitally, and can be printed immediately in the field. The data are also usually recorded as computer data files. To the extent drilling has been completed, logging should also be completed by the end of each day.

(1) Caliper

The caliper log measures the hole diameter, and can be used in conjunction with other logs to confirm readouts.

(2) Resistivity

The resistivity log measures changes in the resistance of materials to electric current, and is especially useful in identifying water levels, logging changes from overburden to coal, and indicating fresh versus saline water.

(3) Nuclear

(a) Natural Gamma

Natural gamma radiation is emitted from downhole materials used to delineate lithologies.

(b) Gamma (density)

Gamma radiation is attenuated in proportion to density of materials, and is used to log changes in density in the profile.

(c) Neutron (porosity)

High speed neutrons are scattered by hydrogen-bearing materials such as hydrocarbons or water, hence can be used to infer porosity in the profile.

b. Descriptive Logs

Descriptive logs include lithologic and core logs. These are prepared by the driller or the geologist as material is removed from the hole. Drill logs should be received and reviewed daily for completeness and accuracy.

(1) Lithologic Log

The lithologic log identifies depths and thicknesses of general geologic rock types. This log is completed, for both chip and core drilling, by the driller or geologist. Guidelines for lithologic logs are given in "Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock" (ASTM, 1994). Other logging formats can be used as determined by the operator.

(2) Core Log

The core log, which is generated by the geologist, is a description of specific lithologic and environmental characteristics of the core as it is removed from the hole.

D. Post-drilling Requirements

1. Drill Hole Reclamation

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

Proper reclamation and abandonment of all drill holes and disturbed areas are necessary as part of the drilling program. Procedures must be planned for and outlined in the "Scope of Work". More information on the Scope of Work document can be found in the subsection entitled "Contracting the Drilling Program".

Special Considerations

Permit requirements and appropriate regulations must be considered in planning proper abandonment and reclamation of drill holes.

Techniques

a. Documentation and Reporting

Documentation and reporting of all drilling activities are required. For more details on reporting requirements, see the subsection entitled "Pre-field Permitting and Reclamation Planning."

b. Reclamation Procedures

Reclamation and abandonment procedures are usually described in the mine permit. Federal regulations regarding these procedures are listed in part c. or the subsection entitled "Pre-field Permitting and Reclamation Planning". State regulations may differ from state to state and should be investigated. Monitoring wells must be reclaimed in accordance with appropriate regulations when the period of monitoring is complete.

Holes in the area to be mined in the next year should be made surface safe, but need not be permanently reclaimed. Exploratory holes that will not be mined in the next year must be permanently reclaimed. These holes are normally filled to the top of coal with bentonite and above the coal with a mixture of bentonite and overburden chips. If the top of the hole is within the projected topsoil stripping depth, do not cap it. If the top of the hole is not within this depth, cap it with concrete from two to seven feet. Cover the cap with topsoil after inspection.

Specify in the Scope of Work the reclamation practices that are to be followed, and the estimated quantities of materials such as bentonite chips, concrete, or sand to be used.

c. Disposal of Drill Cuttings

Drill cuttings, especially carbonaceous, should be replaced in the hole or hauled to the coal mine prior to completing hole reclamation. Because monitoring and production wells must remain open and free of debris, drill cuttings from these holes should be spread around the hole to one-quarter inch thickness, or disposed of so as to prevent any chemical hazard.

2. Post-drilling Responsibilities

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection outlines the post-field activities that accompany a drilling program. These activities must be identified and assigned to responsible parties.

Special Considerations

The responsibilities listed in this subsection can be efficiently carried out by more than one party. For example, some of the work listed as the geologist's responsibility may be given to the geotechnical consultant, at the discretion of the geologist or program administrator.

Techniques

a. Geologist's Responsibilities

(1) Transporting Samples

Packaging and labeling of samples, and preparation of a list of samples collected, are supervised in the field by the geologist or geotechnical consultant. Especially during exploratory drilling and coring, a large number of heavy samples may be obtained in a day's work. Specify in the Scope of Work who will provide a truck or trailer of sufficient capacity, and labor for transporting samples to the storage facility each day. More information on the Scope of Work document can be found in the subsection entitled "Contracting the Drilling Program."

(2) Storing Samples

Store samples in the designated facility, but prevent excessively high temperatures. Organize samples by drill hole in the storage facility. Use the inventory sheet developed in the field for confirmation and tracking of samples. Overburden, coal, and backfill samples may be separated for ease of handling.

(3) Completion of Activities Report

Require the geologist to complete a form summarizing all drilling data needed to meet regulatory reporting requirements. Figure 1 gives a good example of a form that may be used.

(4) Processing Samples

(a) Sample Handling

Submit samples for analysis to an appropriate lab promptly. Minimize delays and environmental extremes in storage or transit. Geotechnical samples must always be protected from excessive temperatures or drying out, as their properties can be altered significantly by these processes. Ordinary air temperatures are usually not detrimental to coal and overburden samples, but direct sunlight may increase sample temperatures excessively.

Samples for chemical analysis are often sensitive to changes in temperature, humidity, or contact with the air or other substances. Time restrictions may apply, especially when analysis is to be performed for chemical properties which vary significantly with biological activity in the sample or which exhibit high volatility. Consult with the laboratory performing the analysis to determine if special handling or field procedures are required to assure valid results.

(b) Specifying Tests Required

Verify that all necessary testing has been included in the Scope of Work for the laboratory, and communicate with laboratory representatives for clarification.

Drilling Project Report Summarization

HOLE TYPE	HOLE NUMBER	LITHOLOGIC LOG	ELECTRIC LOG	DRILLERS LOG	COAL ANALYSIS	OVERBURDEN ANALYSIS	WATER ANALYSIS	RECLAMATION REPORT	COMPLETION REPORT	COMMENTS
BACKFILL										
DEWATERING										
EXPLORATION										
GEOTECHNICAL										
MONITORING										
PRODUCTION										

(c) Interpreting Results

Review the data and compare with previous data, noting significant changes in values or variability. Note values which appear anomalous, and evaluate possible causes.

b. Laboratory Responsibilities

In addition to hard copy, laboratories may also be able to provide data in digital format for ease of assimilation into computer programs currently used for statistical analysis, plotting, or drafting.

c. Program Administrator's Responsibilities

(1) Chain of Custody Forms

Review chain of custody forms that accompany samples to the lab, and document changes in custody as samples change hands during the process of analysis or transport. Look for completeness of the documentation and note discrepancies. Maintain a file of these forms for reference should problems be encountered.

(2) Processing the Data

Analyze the data, reducing it to a form appropriate for the context in which it is intended for use at the mine or by regulatory agencies.

(3) Presenting the Data in Usable Form

Computerize the data in a spreadsheet format such as Lotus. Data in this format can be sorted by hole number, location, depth, date drilled, hole type, etc. Disseminate this data to the users by appropriate means.

3. Reporting, Inspection, and Recordkeeping Requirements

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Applicability

Reporting and recordkeeping practices are vital to any successful drilling program. These needs must be identified and assigned to responsible parties.

Special Considerations

Some of the activities listed in this subsection may be efficiently carried out by more than one party and may be assigned at the discretion of the program administrator.

Techniques

a. Reporting

Reports, as described in the flowcharts in Figures 1 and 2 of the subsection entitled "Pre-field Permitting and Reclamation Planning", must be completed and documented. Drilling correspondence files should be developed and maintained by year and hole type to document all reporting activities. Include all items given in this flow chart in the documentation.

Documentation and reporting to the BLM should include geophysical and lithology reports, coal quality reports, and completion/abandonment forms. State Land Quality annual reports should include information on holes drilled, reclamation of drill holes, and bonding. In Wyoming, remember to report to the State Engineer's Office any artesian well encountered during drilling.

b. Inspection

All holes should be inspected by the program administrator after drilling, installation (in the case of wells) and reclamation activities have been completed. A standard form may be useful in documenting that the holes are left in an acceptable condition. Reclaimed holes may be inspected by State or Federal regulatory authorities, at their discretion. It is best to conduct your inspection before such an inspection is conducted by an outside party.

c. Recordkeeping

Maintenance of drilling files usually falls to the person responsible for maintaining the geologic database. These files typically include computer files, hard copy files, and the all important correspondence file.

(1) Computer Files

Maintaining computer data files is an important part of the drilling program. Sample analysis data files should be kept together where they can be easily located. Backup diskettes may also be kept on file.

(2) Hard Copies

Hard copies of drilling information can be filed numerically by hole number. Each hard file should contain all information pertaining to that hole, including lithologic and geophysical logs, depth to water, and laboratory sample analysis data. It may be desirable to color code holes by type.

(3) Correspondence Notebook

Annual notebooks, subdivided by hole type, may be used to file copies of all correspondence.

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