Chapter 8

Technical Issues in Western Surface Mine Permitting and Reclamation

Contents

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CHAPTER OVERVIEW

OTA'S assessment of Western surface mine permitting and reclamation highlighted several technical issues that have significant implications for the long-term success of Western reclamation. These issues encompass the technologies, data, and analytical methods for identifying acid-forming overburden; techniques for controlling sediment in runoff; soil handling methods that could improve revegetation; achieving revegetation of woody plants; defining and maintaining the postmining land use; and designing the postmining landscape.

Some of these issues address areas in which OTA'S analysis of surface mine permitting and reclamation indicated additional research or reclamation experience is necessary to resolve uncertainties about the long-term success of reclamation. For example, baseline studies indicate that some Western mine spoils may contain material with a potential for acid-formation, which could be detrimental to revegetation. The magnitude of possible impacts cannot be estimated reliably, however, because available techniques for predicting the acid-base potential of spoils were developed for Eastern mining conditions, and their reliability when applied to the very different climate, hydrology, and other conditions in the West has not been demonstrated. Ongoing research is making progress at developing a more reliable technique, but in the meantime, estimates of acid-forming potential in the West may be overly conservative, increasing the cost of reclamation.

Meeting uniform high woody plant density standards is a major concern throughout the study region. While the technology of shrub reestablishment has advanced substantially in recent years, operators in many areas still find it difficult to establish more than one or two species. At the same time, high woody plant density has long been a source of aggravation to ranchers, who have undertaken large-scale rangeland management programs to thin or kill woody species, frequently with financial or technical support from Federal land management agencies. Additional research and reclamation experience are needed on the relative values of different densities and groupings of woody plants for the postmining land uses of rangeland and wildlife habitat.

A second set of issues discussed in this chapter highlights reclamation techniques that are accepted practice or are required by law or regulations, but which may themselves cause adverse environmental impacts. **Sedimentation ponds are considered the best technology currently available to control the discharges of total suspended solids that result from accelerated erosion caused by mining and reclamation activities. But sediment control ponds increase the land that must be disturbed during mining and reclamation, can cause reduced streamflows and channel degradation downstream, and are expensive to build and maintain.** Additional data are needed on sediment yields and on the effectiveness of alternative means of control before the continuing need for sedimentation ponds can be evaluated fully.

A third set of issues highlights emerging practices that OTA found to improve the quality of reclamation. **Innovation in soil handling methods has significantly improved the prospects for the long-term success of revegetation. Furthermore, optimization of soil handling can reduce the costs of reclamation.** Yet, in some casees, operational and regulatory considerations constrain the widespread adoption of such techniques.

OTA also examined **the concept of "landscape diversity, " which recognizes the mosaic nature of Western landscapes resulting from localized**

differences in the physical environment, plant communities, wildlife populations, and land uses. While no general requirements related to landscape diversity currently exist, requirements for specific mines have been established on a case-by-case basis, primarily in relation to vegetative communities.

Finally, **OTA found a general lack of attention to the detailed quantitative characterization of pre- and postmining land uses that is required by the Surface Mining Control and Reclamation Act (SMCRA) for the permit application package.** Lack of specificity and quantification in these characterizations can adversely affect postmining vegetative (and landscape) diversity, the implementation of surface owners' or management agencies' land use recommendations, and the difficulty and cost of reclamation. Moreover, at mines where reclaimability is an issue during permitting, a much more vigorous approach to characterizing premining land uses and to predicting the capability and productivity of the reclaimed surface is necessary.

ACID POTENTIAL IN WESTERN MINE SPOILS[1]

One objective of methods used to design the replacement of overburden is to identify strata that could be detrimental to revegetation, including potentially acid-forming materials within the premine overburden, in order to devise a strategy by which the deleterious potential of these materials will be neutralized. The principal means of accomplishing this are selective placement in the post-mine spoils to prevent saturation with surface or groundwater, and/or burial with sufficient depth of cover to block infiltration of surface water and prevent the deleterious material from migrating upward to the root zone.

Regardless of the specific setting or the mining technique, mining rearranges the natural sequence of coals and associated rock strata and places them in contact, at least temporarily, with atmospheric conditions. In that new environment, a host of interrelated factors, including oxygen, humidity, and iron bacteria, combine to accelerate the rock-weathering processes which, in turn, may cause radical changes in the chemistry of water contacting the weathering strata. In some cases, mineralogy is such that the rock remains inert and neither acid nor alkaline conditions are produced.

Acid drainage from mining is a common prob lem in the East, where groundwater systems generally are more active than in the West, and recharge rates much greater. The overburden from Eastern coal mines contains significant amounts of sulfur as inorganic iron pyrite (FeS_2). In an oxidizing environment, much of the sulfur in the pyrite will combine with water and oxygen to form sulfuric acid (H_2SO_4). The humid climate in the East accelerates the oxidation of sulfur compounds by ensuring there is a constant supply of water to saturate the spoils and thus a constant supply of hydrogen ions to form sulfuric acid. The pH of surface or groundwater supplies in contact with the pyrite-bearing strata will be lowered unless the surrounding materials have a large buffering capacity. As the pH is lowered the water becomes an acidic solution with a high content of sulfate and iron that is unsuitable for all domestic and agricultural uses. Moreover, the volubility of other mineral constituents of the soil or rock will be affected by a lowered pH and potentially toxic materials (e.g., arsenic, barium, cadmium, chromium, lead, mercury, selenium) can go into solution, further contaminating the water supply and rendering it harmful to vegetation or to animal and human populations.

The potential for acid formation in the West is different for several reasons. First, the climate is generally arid or semiarid, which limits the amount of water available for oxidation of sulfur compounds. Below *the water tab/e,* the oxidation process is not very active because the availability of oxygen in the geological material there is severely restricted by the very low volubility limit for oxygen in water. However, the time

[1] Unless otherwise noted, the material in this section is adapted from references 2, 4, and 6.

scale associated with the evolution of this hydrogeochemical process may vary over years, decades, or possibly centuries and cannot be predicted with much confidence with existing knowledge. If pyritic materials are inadvertently placed *above the water table,* oxidation can be very active and rapid provided that the pore spaces in the material receive oxygen, because the subsequent infiltration of rainfall or snowmelt causes the oxidation products and associated weathering products to go into solution. They are then able to move downward where they become part of the dissolved solids in the groundwater systems.

Second, while the sulfur in Western overburden occurs in organic compounds as well as in inorganic iron pyrites, **Western overburden typically has a high buffering capacity.** Calcite and dolomite, common overburden constituents, are solublee in an acidic solution and the carbonates combine with available hydrogen to form bicarbonates that raise the pH and neutralize the acidity. From an environmental viewpoint, alkaline drainages originating from calcium-magnesium carbonate systems are normal in the West, and thus do not harm the hydrologic regime. A rising water table that inundates pyrite-rich zones in the spoils is another mechanism by which pyrite oxidation is inhibited. A fluctuating water table can promote weathering in the zone of fluctuation, but if no replenishment of oxygen from the atmosphere occurs, severe degradation of groundwater quality is unlikely.

The following must be determined to predict the potential for acid formation:

- the organic content of the pre- and postmining soil;
- the porosity and permeability of the recontoured spoils, to aid in predicting available oxygen for oxidation;
- the predicted level of the postmine water table and in what general time frame recharge will occur (1, 10, 50, 100, 500 years);
- the percentage of pyrite in the overburden, to give a gross indication of the potential for acid formation; and
- the buffering capacity of the overburden, to allow a gross indication of the potential for neutralizing acid.

A test has been devised that uses these data and analyses from Eastern overburden materials to predict their acid-forming potential. This procedure leaches overburden samples with hydrogen peroxide to extract sulfur forms; it assumes that all sulfur forms will be oxidized completely. In the West, however, a large fraction of the sulfur is in less reactive organic forms, and the assumption that all sulfur forms will go from a reduced to a completely oxidized state is not valid. These lab methods and the overburden suitability criteria derived from them have been proven reliable for predicting the potential for acid production in Eastern mine spoils through years of application.

Applicability of the same methods and unsuitability limits has not been proven in the West. The chemical and physical conditions that contribute to the potential for acid formation are sufficiently different in Western coal regions to invalidate the lab results and, therefore, the interpretations from which suitability limits are established. The issue is one of understanding the geochemistry of Western overburden and the range of conditions that exist in the various coal fields, and of devising a laboratory method that yields reliable results from which valid overburden suitability criteria can be established.

Baseline studies similar to those listed above have demonstrated that there are conditions under which acid formation could occur in New Mexico and in the Wyoming portion of the Powder River basin.[2] The Wyoming Department of Environmental Quality (DEQ) has acknowledged the potential for acid production in mine spoils since 1978. DEQ requires sample testing for determination of the acid-base potential (ABP) of overburden using a furnace-induction method that allows isolation of the reactive inorganic sulfur compounds. The calculation of acid potential still is based on the assumption that all reactions go to completion, however. In New Mexico, the soils and overburden are strongly alkaline, the climate desert-like, and sulfates appear primarily as gypsum in weathered strata.

[2] It is unclear why the unknown potential for acid formation is not considered a problem in the Montana portion of the Powder River coal region.

Acid-forming strata have been documented at one mine, and ABP determinations are required for strata low in lime.

The potential for acid-forming material is low in the Fort Union coal region of North Dakota and Montana where soils are deep and more likely to be sodic. No ABP analysis is required in these areas. [n Colorado, no special analysis or interpretation would be required unless there were a reason to suspect a problem (e.g., acid formation at nearby mines, or high concentrations of pyritic sulfur in the lab data).

While both the regulatory authorities and the operators acknowledge that the available techniques for estimating ABP may not produce reliable results when applied to Western overburden materials, the lab techniques will continue to be used until better methods are devised. As a result, the operators believe that some overburden material is being erroneously classified as unsuitable and that, as a result, they are being required to special handle the material needlessly (see box 8-A) and/or bury it more deeply than would ordinarily be the case. The regulatory authorities, while recognizing this possibility, believe that an overly conservative estimate of acid potential is better than failing to special handle deleterious material, with potentially much greater costs for reconstruction if revegetation problems arise.

Research currently being funded by the Western mine operators, both jointly and individually, is making progress in resolving this problem. The regulatory authority in at least one State, Wyoming, is prepared to rewrite State guidelines to reflect any changes in analytical techniques or overburden suitability criteria that may result from this research.

Box 8-A.—Special Handling of Potentially Acid-Forming Spoil[1]

The initial baseline overburden characterization at a large mine in the Eastern Powder River basin of Wyoming indicated that most of the overburden strata at this site have no deleterious qualities. The controversial ABP analysis suggested a few of the strata were potentially acid-forming; other overburden strata, in the vicinity of surface draws, were found to be saline. The overburden handling plan consists of a premining drilling program ("developmental drilling", see ch. 5), special handling if indicated, the use of suitable near-surface material as the last 4-foot spoil lift, a recontoured spoil sampling program, and an additional 4 feet of suitable cover where necessary. The top bench of overburden is sampled on 500-foot centers prior to mining.

The data gathered in this drilling program are used to delineate unsuitable overburden, but also are used for other operational considerations. If these data identify unsuitable material comprising more than 20 percent of the bench, the material will be placed in backfill areas of heavy clay or silty shale to prevent further contact with air, surface water, reconstructed aquifers, topsoil, or vegetation. Coal partings and carbonaceous shales have been identified as potential sources of acid production under oxidizing conditions, so these materials will be buried below the projected backfill water table, where they will be quickly covered by compacted overburden and where, eventually, the void spaces will fill with water. The recontoured surface is backfilled to within 4 feet of the final level with run-of-mine spoil, then covered with the final 4 feet of near-surface, coarse-textured, oxidized, suitable spoil. This recontoured spoil surface is then sampled to assure suitability (see chs. 5 and 7). This general method of overburden characterization and special handling has been adapted for use at all of the truck and shovel mines in the Powder River basin of Wyoming, promoting a tendency for uniformity of approved procedures.

[1]See case study E in reference 4.

SEDIMENT CONTROL[3]

Surface coal mining and reclamation operations in the Western United States can result in discharges of sediments to surface streams as a result of accelerated erosion caused by removal of the vegetative cover; topsoil stripping; and construction of stockpiles, roads, and other facilities. Discharges of total suspended solids (TSS) are regulated under SMCRA and the Clean Water Act.

The Clean Water Act requires the States to establish water quality standards to be achieved through effluent limitations on discharges from point sources, These standards and limitations are established and enforced through permits issued for point source discharges under the National Pollutant Discharge Elimination System (N PDES; see ch. 4). Effluent limitations for surface coal mines regulate discharges of TSS as well as iron, manganese, and pH. SMCRA also established a performance standard that requires a mine operator to prevent, to the extent possible using the best technology currently available, additional contributions of suspended solids to streamflow or to runoff outside the permit area.[4] Until 1982, the Federal regulations specified that the best currently available technology for the control of sediment is a properly designed and constructed sedimentation pond, as governed by both design and performance standards adopted by each State (see ch. 4).

In 1982, the Environmental Protection Agency (EPA) Changed the Federal effluent limitation for sediment in discharges from sedimentation ponds (point sources) from 70 mg/l to a far less stringent settleable solids effluent standard of 0.5 ml/1 to be used during precipitation events and for reclaimed areas. The original TSS standard of 70 mg/l still applies to all discharges when no precipitation is occurring and to pit water discharges.

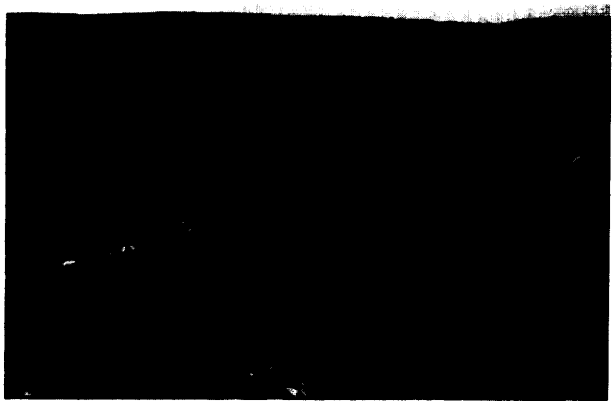
The 1982 EPA revisions also eliminated specific design and construction standards for sedimentation ponds. In 1983, the Office of Surface Mining (OSM) revised its TSS performance standard to be consistent with the new EPA rules. While most State regulatory programs still adhere to the more stringent suspended solids standard of 70 mg/1 for point source discharges, the States eventually may revise their programs to incorporate the new settleable solids standard.

Sedimentation ponds historically have been the accepted technology for sediment control in all of the Western States studied except New Mexico, which is just beginning to develop a policy on the design and construction of runoff and sediment control structures. Previously, New Mexico had no design standards for sediment control structures, and New Mexico mines generally would construct a berm around the limit of disturbance to contain the estimated runoff from a 10-year 24-hour event. There is no discharge from the mines for runoff events less than the 1 ()-year 24-hour event. In other States, the use of alternative sediment control measures (see below) has been permitted through case-by-case exemptions. For example, a mine in a plains area of southern Wyoming, where peak flows occur primarily from rainstorm runoff and all drainages are ephemeral, received a permit in June 1982 for a combination of sedimentation ponds and "other sediment control techniques. " Contour berms and retention ditches were proposed and implemented as alternative sediment control measures to intercept surface runoff and trap sediment from disturbed areas.

Alternative means of maintaining sediment production at or below the level produced from undisturbed terrain include preventive measures and remedial designs. Preventive measures generally retard the velocity and reduce the quantity of runoff, thus reducing erosion rates. The primary preventive measure is topographic design of reclaimed slopes and drainage basins to reduce erosion rates, and thus sediment production. Complex slopes with upper convexities, middle straight reaches, and lower concave reaches have long been associated with the lowest erosion

[3] Unless otherwise noted, the material in this section is based on reference 6.

[4] In this context, "best technology currently available" is defined in the Federal regulations as "equipment, devices, systems, methods, or techniques which will prevent, to the extent possible, additional contributions of suspended solids to stream flows or runoff outside the permit area, but in no event result in contributions or suspended solids in excess of requirements set by applicable State or Federal laws''(10).



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rates. Such slopes, in concert with drainage basin design that provides adequate drainage density and shorter slopes, will minimize long-term sediment production from reclaimed lands. Other preventive measures include revegetation, mulching, contour plowing, and use of rocky topsoil. Revegetation adds soil strength and surface roughness, retarding the velocity of overland runoff. Mulch retains surface water, enhances infiltration, and adds surface roughness. Contour plowing also adds surface roughness and enhances infiltration. Rocky topsoil produces an armor when it erodes, thus impeding further erosion, but is not allowed under the regulatory programs because rocks are considered to "contaminate" soil.

Remedial designs for actively disturbed and temporarily unstable lands can be constructed, where needed, at low cost and with minimal added impact. These techniques reduce erosion either by avoiding sensitive areas or by decreasing the amount of sediment in runoff. They include small diversion channels, porous rock or straw bale check dams, interceptor ditches, vegetative buffers, and diversion of runoff into the pit. Small channels divert runoff away from sensitive areas. Rock check dams and straw bale dikes act as temporary, permeable barriers to decrease streamflow velocity and cause sediment to deposit. interceptor ditches are small, level trenches running across hillsides that slow surface runoff and promote sediment deposition. Strips of undisturbed native vegetation adjacent to disturbed land enhance sediment deposition and inhibit further erosion. Ditches placed around the toes of all topsoil and overburden stockpiles capture sediment as close to the source as possible.

The requirements for sedimentation control ponds are controversial in the Western United States because the ponds are expensive to build and maintain, because they increase the amount of land that must be disturbed during mining and reclamation, because most Western streams already have naturally high sediment levels, and because the cumulative effect of water storage in ponds at several mines can be a significant loss of water—the West's most scarce resource —to downstream users. Moreover, historically, the alternative sediment control techniques described above are considered proven technology and have been implemented successfully in agriculture, highway construction, and other land-disturbing activities.

Most of the streams in the semiarid West are ephemeral (flow only during runoff events). They originate in fine-grained sedimentary materials, derive all of their flow from surface runoff, and average 50 percent solids by weight. TSS concentrations as high as 1 million mg/1 have been documented during runoff events. Runoff from mines or mine-water discharges into ephemeral streams can have adverse impacts on water uses that are especially sensitive to sediment loads. Also, if the sediment load is increased to the point that the sediment transport capacity of the stream is exceeded and its basic deposition processes fundamentally altered, the changes in the stream system can extend offsite. A significant decrease in sediment loads (e.g., when relatively clear water is released from ponds) also can have adverse impacts on ephemeral streams, because the unnaturally clear discharged water is erosive, and can result in channel incision or degradation downstream.

Perennial streams, on the other hand, originate in mountainous areas, receive discharge from groundwater, and derive their runoff chiefly from snowmelt. These streams, such as the Tongue, Yampa, and Missouri Rivers and their major tributaries, have naturally high-quality water. They typically support sport fisheries, municipal and domestic water uses, and large amounts of irrigation–all uses that would be affected adversely by an increase in sediment loads.

The cumulative effect of multiple sedimentation control ponds at several mines within a drainage basin can be a reduction in streamflows in both ephemeral and perennial streams. For example, the Wyoming DEQ's cumulative hydrologic impact assessment of mines north of Gillette, Wyoming, concluded that "the greatest cumulative impact to the surface-water system will be the reduction in streamflows resulting from the impoundment of runoff in sedimentation ponds and mine pits.''(7) The greatest effect on the Little Powder River, as determined by DEQ from mine plan maps submitted by the permit applicants, will occur at its confluence with Rawhide Creek. Above this point, the flow of the Little Powder River could be reduced as much as 17 percent.

Such streamflow reductions could cause conflicts between mines and downstream irrigators who depend on flood flows to irrigate hay meadows. These potential conflicts have led DEQ to encourage the use of "alternative sediment control measures" such as straw dikes and porous check dams, which trap sediment but allow water to pass downstream, in lieu of conventional sedimentation ponds (8). This recommendation is made only where the receiving streams are ephemeral or intermittent, and therefore naturally high in TSS during runoff events. Perennial streams, which could be adversely affected by discharges high in TSS, still must be protected with sedimentation ponds. Therefore, it is unclear how these alternative measures would mitigate the streamflow reductions in perennial streams.

The advantages of alternative sediment control practices for discharges to ephemeral streams are highlighted in the Wyoming DEQ decision document on the proposed use of such practices at a mine in the southwestern part of the State. The decision document included a determination as to whether the alternative sediment control practices would encourage advances in mining and reclamation technology—one of the bases for permitting an experimental practice under SMCRA (see ch. 4):

> sediment ponds are considered to be the best technology currently available to control sedimentation and protect receiving water quality. The coal mining industry as well as professional hydrologists and geomorphologists are often of the opinion that although sediment ponds may very well be the best technology currently available to protect perennial stream water quality in the Eastern United States, they are not the best, or most practical technology currently available to protect ephemeral stream water quality in semi-arid regions of the Western United States.
>
> The potential benefits of using alternate sediment control techniques instead of sediment ponds to protect the quality of receiving streams are as follows:
>
> 1. The lack of sediment ponds will lead to less land and wildlife habitat disturbance.
> 2. Alternate sediment control techniques will keep topsoil and subsoil on site where it is most useful for revegetation efforts.
> 3. Several alternate sediment control techniques result in less runoff which may lead to greater soil moisture, providing for more successful revegetation.
> 4. Alternate sediment control techniques may be more cost effective than sediment ponds.
> 5. The consequences of sediment pond dam failure and associated environmental degradation are eliminated.
> 6. Channel incision below sediment ponds, resulting from TSS concentrations well below ambient conditions, is eliminated.
> 7. Alternate sediment control techniques minimize the retention of runoff from undisturbed areas thereby providing more water to downstream water users (6).

Two sets of data are needed before the regulatory authorities will consider changing the strict requirement for technological sediment control on ephemeral streams to more flexible performance standards: empirical data on sediment yields (the total amount of eroded material that reaches a control point), and on the effectiveness of alternative means of control. The data on sediment yields from surface mining and reclamation can be obtained from premining baseline studies and from monitoring. Whether designing sediment ponds or planning alternative sediment control measures, it is necessary to estimate the amount of sediment that will erode from a watershed and be subject to transport downstream during a precipitation event. This can be accomplished through premining erosion pin studies or with other methods (see chs. 5 and 6). Small watershed studies currently are underway at a number of mines that also could provide empirical data on sediment yields during mining and reclamation.

Two mines in Wyoming currently are collecting data from experimental practices designed to demonstrate that alternative sediment control measures are as effective as sedimentation ponds in protecting water quality in ephemeral streams. One of these was approved for southwestern Wyoming in 1983 (see box 8-B) and one in the southern portion of the Powder River basin in 1985. As stated in the Wyoming DEQ decision document on the mine illustrated in box 8-B:

> To date, little, if any, meaningful suspended sediment data has been collected in areas being affected by coal mining activities in semi-arid areas of the Western United States. Therefore, this experimental practice will not only determine the adequacy of the alternate sediment control techniques proposed but will also adequately quantify ambient water quality conditions and streamflow conditions in ephemeral streams. This information, coupled with precipitation data, will greatly further the understanding of ambient and mining disturbed runoff conditions. [In turn this can be used to adjust analytic techniques used by the mining industry and regulatory authorities in the development of mine drainage plans etc.
>
> Additionally, data collected as a result of this proposal will also be able to be used for the development and calibration of various hydrologic and sedimentation models . . . (6).

Box 8-B illustrates both innovative sediment control practices and state-of-the-art sediment and runoff monitoring techniques for ephemeral streams. The mine in this case study may benefit substantially from alternative sediment control because the high drainage density of the permit area would have required construction of over 200 ponds. Not all mines are faced with this situation, and for other mines the monitoring, reporting, and inspection requirements that accompany a formal experimental practice may outweigh any economic benefits of alternative sediment control.

As regulatory authorities **become more comfortable with the use of state-of-the-art sediment and runoff monitoring techniques and with alternative sediment control measures, and as the needed data become available, more mines may be able to use alternative sediment control practices without the extensive requirements for an experimental practice. As the result, water quality in ephemeral streams will be protected while creating smaller impacts on the availability of water for downstream users—a critical consideration in the arid and semiarid West.**

A continuing uncertainty is how the effectiveness of alternative sediment controls will be evaluated. The SMCRA and Clean Water Act effluent limitations are technology-based standards dependent on the designation of any control structure as a point source. For example, if the alternative controls implemented at the mine discussed in box 8-B are considered point sources, they must meet the TSS limitation of 70 mg/l; otherwise they could have TSS concentrations measured in the tens of thousands and be in compliance with Wyoming regulatory program standards so long as the receiving water quality is not degraded.

in approving the experimental practice illustrated in box 8-B, OSM indicated that the effectiveness of the alternative controls will be evaluated in terms of whether they are at least as effective as sediment ponds. If this means achieving point-source effluent standards, obviously alternative practices will not be as effective as ponds. The operator's evaluation program for this experimental practice is designed, with State concurrence, to measure effectiveness in terms of nondegradation of water quality —i.e., whether the alternative controls will prevent additions to naturally occurring TSS concentrations. The alternative sediment control practices also will be evaluated in terms of minimizing land disturbance

Box 8-B.—An Experimental Practice for Alternative Sediment Control[1]

A surface coal mine in southwestern Wyoming requested an exemption to the use of sediment control ponds because the mine's large area and high drainage density would have required the construction of about 200 ponds, and because the region% ephemeral streams have naturally high sediment loads. The sedimentation ponds would be classified as point sources of the Clean Water Act. Therefore, they would be subject to stringent effluent pH, suspended solids, total iron, and total manganese. The natural sediment concentrations in the area range from 400 to 1 million mg/l—far in excess of the point source effluent standard of 70 mg/l.

Under the Wyoming regulatory program, anfofmsthelusee ntation ponds can be granted if alternative sediment control' ameasures aremine drainage from degrading receiving waters. Although theprempiningdata andanalyses that such degradation would not occur, and DEQ granted the exemption, OSM required that the alternative sediment control measures be permitted as a formal experimental practice under SMCRA.

The objectives of the alternative sediment control plan at this mine are to protect water quality, conserve soil, and reduce mining costs. Other environmental advantages eked by the operator are the elimination of channel degradation below dams (from the discharge of unnaturally clear and therefore erosive water); reduction in land disturbance that would have been required for the construction of sediment ponds (estimated at over 400 acres); and mitigation of water quantity impacts on natural streamflows through elimination of impoundment storage, seepage, and evaporation.

In-stream flow criteria were established to provide a clear definition of stream water quality degradation. Though this plan deals with nonpoint source runoff exclusively, the operator used the NPDES point source parameters for iron, manganese, pH, and TSS a guide from which to select nonpoint source water quality parameters. Baseline surface water quality data showed that TSS was the only parameter in *natural* streamflow that consistently violated NPDES criteria. Therefore, the operator used TSS concentrations as the design parameter for the alternative sediment control program. After consultation with the regulatory authority, the operator designated the largest ephemeral stream in the area (to which all streams within the permit area are tributary) as the receiving stream. The receiving stream is not currently truncated by the pit, and changes in through-flowing water quality therefore can be observed at sites above and below the disturbed area. Alternative sediment control techniques will be used in all areas draining to these sites.

In order to apply the alternative control techniques in a rigorous manner to the disturbed areas, the operator developed a design method based on a standard computer simulation model (SEDIMOT II; see ch. 6) to simulate runoff from an area prior to the need for sediment control and with different sediment control techniques. The sizes and locations of the controls were evaluated to determine how best to reduce the sediment discharge to levels below the receiving stream water quality. Successive computer iterations were conducted and additional sediment controls added as necessary until the design TSS concentration (30,000 mg/l) was achieved. Control structures were added in the following order: rock check dams, contour interceptor ditches, contour berms, vegetative buffer strips, toe ditches, temporary barriers, and benches on stockpile For the nine areas modeled, four required no control measures to limit TSS concentrations to values less than or below the design value of 30,000 mg/l. Two watersheds required contour ditches and/or contour disking to meet target TSS concentrations.

In consultation with DEQ and OSM, f& operator designed an extensive monitoring program to obtain site-specific and areawide hydrologic and sedimentologic data. These data will enable the operator to evaluate the effectiveness of the alternative techniques and to quantify the impacts of mine area drainage on water quality in the primary receiving stream. Data are collected on the receiving stream upstream of the disturbed area, on the drainage from the disturbed area, and on an undisturbed drainage that serves as a control watershed+ In the event that runoff data show degradation of receiving water quality during a runoff event, the alternative sediment control program will be temporarily out-of-compliance, (The possibility of temporary noncompliance also exists for a sediment pond if the dam were to wash out, or if set-

[illegible]

and changes to natural streamflow rates. If these additional criteria are applied to the performance of the control measures, then they may be more effective than sediment ponds in some cases. If this is demonstrated, the definition of best practicable control technology may have to be changed to recognize factors other than contributions of suspended solids.

SOIL HANDLING AND REVEGETATION[5]

The early State reclamation laws, followed by SMCRA and the Federal regulatory program, instituted requirements for topsoiling in the reclamation of surface mined lands. Soil handling and redressing ought to be an optimization process—too little soil or soil of poor quality and revegetation will be unsatisfactory; too much soil and money is wasted.

The results of long-term studies of the effects of different methods of soil handling on revegetation have indicated that stockpiling can adversely affect the success of revegetation efforts. Studies that compare revegetation with stored soil versus directly hauled soil indicate that storing soil for more than about 2 years at many sites significantly decreases the viability of seeds and microbiota. The direct haul or "live" soil-handling technique (see ch. 3) preserves the biologically active component of the soil and tends to encourage faster reestablishment of nutrient cycles, improving the establishment of planted and volunteer species and producing superior lifeform and species diversity within a relatively short time. The most recent monitoring data at one mine where the conditions for revegetation are among the most favorable in the study area indicate that the combination of biologically active direct haul soil plus other innovative soil handling techniques can produce revegetation on some areas that meets the SMCRA performance standards even without direct seeding or planting (see box 8-C, below). The efficacy of direct haul soil handling varies among regions and sites within regions, however.

The importance of maintaining a biologically active soil is not surprising when one considers that temperate-zone grassland and shrub-steppe ecosystems—those common in the study area—have substantially more biomass (i.e., living tissue) below ground than above ground. Furthermore, a good portion of the central ecosystem

[5] Unless otherwise noted, the material in this section is adapted from references 4 and 5.

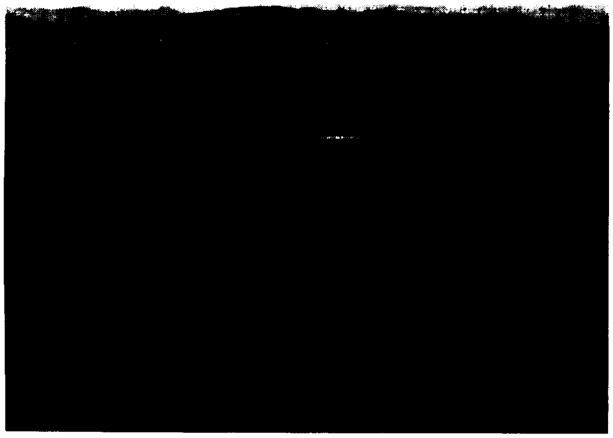

Photo credit: Jenifer Rob/son, OTA staff

The foreground shows a portion of a mine in northwestern Colorado that was revegetated 4 years previously with volunteer growth (no seeding or planting) using two-lift direct-haul soil handling and supplementing the topsoil with mulch produced onsite by shredding the premining vegetation.

processes (nutrient and energy cycling) are located below ground.

Because the direct haul technique eliminates the middle step in the process of stripping, stockpiling, and respreading soil, it can be less expensive, depending on haul distances, equipment, and other operational considerations. Direct haul also is advantageous for small mines that do not have room for topsoil stockpiles. The fortuitous coincidence of economic and biologic advantage has caused direct haul to be adopted to some degree by most Western surface coal mines that are beyond the first box cuts, and that were able to incorporate it in their operational mine planning. At some mines, the area ultimately treated by direct haul will be well over sO percent. In other cases, however, mine logistics can prevent the use of direct haul over much of the disturbed area (e.g., in deep or multiple seam operations). In North Dakota, the ability to direct haul soil also is limited by the regulatory requirement to return soils to the original landowner. Where direct haul soil handling is not feasible, supplemental top-dressing–application of a thin layer of freshly salvaged topsoil—could enhance volunteer growth and diversity and serve as a source of desirable microbiota.

A second soil handling method that recognizes the importance of reestablishing the natural horizon order within soil profiles, and also helps to maintain biological soil components in an active state, is the handling and replacement of the biologically most active surface soil layers, without dilution by underlying subsoil–''two lifts.'' Two lifts require that surface materials are kept seg-

BOX 8-C: Innovative Soil Handling and Revegetation Techniques[1]

In northwestern Colorado, conditions for revegetation are probably favorable than anywhere else in the five-State study region, and the development of vegetation cover and production on reclaimed land has been very rapid. Seeded areas 3 to 7 years old at one mine in this area have about 60 to 85 percent cover, compared to 43 to 82 percent cover on baseline (undisturbed) areas. Similarly, herbaceous production levels are about 660 to 8,900 lb/acre, compared to 890 to 8,900 lb/acre in baseline vegetation types. Because of the favorable environmental conditions for revegetation, one operator experimented with volunteer growth from a combination of two-lift direct-haul soil handling supplemented with mulch produced onsite by shredding preexisting vegetation. The soils are salvaged to 18 inches. If the 18 inches is all organic-rich horizon, the entire 18 inches is handled in one lift. If subsoil occurs within the 18-inch salvage depth, however, separate handling results in 10 inches of subsoil being covered with 8 inches of topsoil. A trial area using this combination was allowed to revegetate naturally (i.e., without seeding or planting); it supports about 75 percent cover and about 2,140 lb/acre herbaceous production after 4 years. Based on 3 years of monitoring data for this trial, the operator petitioned the regulatory authority to have the seeding requirement waived on areas receiving direct haul soil with live mulch, arguing that the presence of viable seeds and potentially regenerative roots in the soil leads to the establishment of plants better adapted to the site than are available in mixes of commercially available seed. The proposed practice will be approved as a field trial.

[1]See case study CO-1 and related text in reference 5; case study J in reference 4.

regated from subsurface materials during stockpiling or direct haul operations, and redressed with topsoils over subsoils (see ch. 3). The surface soil, including the A horizon along with the upper B horizon, is the zone of maximum organic matter accumulation and macrobiotic activity. The subsoil, consisting of the lower B horizon (if present) and the C horizon, contains far less organic matter, and can have a layer of calcium carbonate accumulation that reduces its value as a plant growth medium.

Two-lift soil handling is an especially important consideration in deep soils. As a result, it has been practiced and/or required in Montana and North Dakota for years, and is standard practice at many other Western mines with deep soils. When a soil suitable to depths as great as 60 inches is salvaged in a single lift, the relatively thin surface layer of maximum biological activity is buried or mixed with relatively sterile, albeit chemically and physically "suitable" subsoil. Roots, seeds, and beneficial microbiota, as well as the organic-rich surface material, are diluted or lost by burial. Surficial organic matter that could increase soil moisture capacity and gas exchange and decrease erodibility is diluted. Seeds and roots are distributed throughout a large soil volume, many buried too deeply to aid revegetation.

The combination of two lifts with direct hauling is especially advantageous for the reestablishment of rangeland diversity, and maybe enhanced even further in some instances by the use of other soil treatments such as mulch derived from shredding native vegetation (see box 8-C). There are no formal research projects directly comparing two-lift direct-haul soil handling with other methods, but monitoring data from the mines in the study area that are using this combination should be available within a few years for comparison with those from mines in the same areas using other methods.

The results of recent research and innovation on soil handling and revegetation raise questions about whether soil handling is optimized under the current regulatory framework. SMCRA, as implemented in the Federal regulations, requires that topsoil, defined as A and E horizons (originally the A horizon), be redressed over spoil, and that subsoils be used only if the regulatory authority determines it to be necessary (1 1). The State programs in the study area (with the exception of Colorado), however, require the salvage of all "suitable" soil, including A, E, B, and C horizons. In some cases this requires salvage of soil down to depths of 60 inches or more. "Suitable" is defined by physical and chemical criteria (pH, salinity, sodium adsorption ratio, texture, and other parameters such as coarse fragments, lime, boron, and selenium). This salvage requirement aims at providing the most favorable medium for seed germination and plant growth–a medium similar to that in which the native plants grew originally. **Salvage of all suitable soil is appropriate in many situations; e.g., when undetected deleterious materials may occur in the spoil, where erosion is a concern, or where the moisture-holding capacity of the spoil is limited. But it is not appropriate in every case.**

First, as discussed above, the experiments with direct haul, two lifts, and other techniques (e.g., mulch produced onsite from native vegetation) all indicate that the biological and organic parameters of soil are at least as important in determining soil quality for revegetation —if not more important-than physical and chemical criteria. **Greater attention needs to be paid to the biological quality of soil in planning and implementing soil handling and revegetation.**

An additional consideration is soil depth. There has been very little research on the optimum depth of soil as a function of soil quality. Much of the work has been on the soil depth needed over problem spoils. Where such spoils are not a concern, one rationale for requiring the salvage of all suitable soil is that in arid and semiarid regions, where soil moisture is assumed to be the primary limiting plant growth factor, the moisture-holding capacity of the reclaimed soil will be maximized by maximizing soil thickness. Thus, if none of the physical or chemical criteria is limiting in soil handling, depth to bedrock is the usual limiting factor. Yet the surface layers of soils generally have better structure, aeration, lower resistance to root penetration, and infiltration capacity than subsoils, These favorable characteristics will be diluted by salvaging all suitable soil (including B and C horizons) in one lift, Organic matter is primarily responsible for the development and maintenance of soil structure. An organically rich, thin soil layer with well-developed structure at the surface will have better infiltration than a thicker soil with less organic matter, and the moisture-holding capacity of a soil low in organic matter may not be better than the spoil. Because organic matter typically decreases with depth, salvaging subsoil will dilute the organic matter content of the reconstructed soil unless two-lift handling is practiced. Where surface soils are low in organic matter and the soil nutrient content does not greatly exceed that of the spoils, a minimal thickness may be as effective as a thicker one. Because present baseline analyses **in permit applications do not evaluate characteristics such as organic matter or moisture-holding capacity of either the reclaimed soils or recontoured spoils, current soil thickness requirements do not consider the optimum reclamation needs (see** box 8-D).

Direct-haul soil handling could conceivably outweigh considerations of soil quality or thickness, but existing regulations can discourage direct haul. For example, in some cases the regulatory requirement for approximate uniform topsoil thickness actually promotes stockpiling. With a direct haul system, redressed thickness would vary as the mine moved through areas in which the premining thickness varies naturally. Stockpiling, however, allows a uniform thickness to be replaced over a landscape that had variable soil thicknesses before mining. Regulations that require the salvage of all suitable soil undermine the effectiveness of the direct haul method (without two lifts) because the biologic component of the topsoil that produces many of the beneficial effects of direct haul is compromised under the requirement to salvage all suitable horizons.

SMCRA itself is sufficiently flexible to accommodate all of these considerations related to soil handling and revegetation, but the regulations in most States are not. Several of the regulatory authorities do allow nonuniform thickness on a case-by-case basis, however. **In future revisions of the regulatory programs, special attention should be paid to relating requirements for soil quality and depth to the proposed mining and reclamation methods and the supporting baseline analysis.**

Box 8-D.—Challenging the Requirement for 100 Percent Soil Salvage[1]

The permit application for a case study mine in Wyoming stated:

. . . [although] topsoil salvage depth is often emphasized as the most important criterion in providing suitable and sufficient plant-growth material to meet the proposed postmining land use . . . two better criteria are suitable plant growth material and quality replacement depth.

The applicant conducted a laboratory and short-term greenhouse study to show that the optimal salvage plan for several of the deep soils of the site would be to salvage the A, B, and upper C horizons and leave the lower C horizons. The applicant maintained that the lower C was no different from the overburden and, in some subsoi with high lime, the overburden was better. The operator proposed to salvage A, B, and upper C materials to be redressed over the 48 inches of suitable top bench cover material. The regulatory authority felt the results of the applicants research were inconclusive, and rejected this approach, stating:

. . . [it] does not meet the requirements of all applicable rules and regulations. Although the C topsoil material in some of the soils is not as fertile as the A and B horizons, it is felt that the stripping of those suitable C materials will not appreciably reduce the quality of the replaced topsoil.

[1]See case study E in reference 4.

REVEGETATION OF WOODY PLANTS[6]

Woody plants–trees, shrubs, and subshrubs[7]–occur in a variety of plant communities in the Western United States, including the woody draws of North Dakota, the shrub-steppe communities of Montana and Wyoming, the mountain shrub communities at higher elevations in most States, and the pi non pine-juniper and salt desert shrub types of the Southwest.[8] Woody plants are ecologically important **in the West as forage and cover for livestock and wildlife as** well **as for improving soil moisture and for protecting leafy herbaceous plant species from heavy grazing.**

"Cover" includes a number of habitat features, such as thermal cover (shade) on hot days; hiding cover for solitude and protection from predators; shelter from wind; and nesting, perching, and feeding sites for birds and many small mammals. The food value of shrubs includes the actual leaf, stem, and fruit tissues of the shrubs for herbivores, as well as the variety of insects they support that serve as prey for songbirds and small mammals, which in turn are prey for raptors and carnivores. In areas where the shrub overstory is relatively open and varied, the herbaceous understory usually is diverse and forage plentiful, but where dense stands of shrubs with little diversity are present (as in severely overgrazed areas), the understory usually is sparse and forage more limited. Shrubs are particularly valuable during winter because they are more nutritious than the above-ground portions of dormant herbaceous species and more available because they protrude above snow cover.

Cattle, and to a lesser extent sheep, prefer herbaceous vegetation to shrubs. Cattle are heavily oriented toward grazing, although they do consume the current year's growth on smaller shrubs (and especially subshrubs) during fall and spring. Sheep also are grazers, but they tend to prefer forbs (nongrass herbs) rather than grasses, and they make greater use of shrubs than cattle, especially during the fall and winter. This enables sheep to be kept on rangeland throughout the winter even at northern latitudes, and to forage successfully (along with goats) in herb-poor desert shrublands in the Southwest. Even so, the quality of sheep range, like that of cattle range, is more apt to be limited by a scarcity of palatable herbaceous species than by the lack of shrubs.

Although shrubs in high densities may decrease the range value for cattle and sheep, their presence improves habitat quality for a variety of wildlife species. The food value of big sagebrush is particularly important for pronghorn antelope and sage grouse, which are species of special concern in the West because of their recreational and economic value. These species utilize sagebrush throughout the year, but especially in winter when other food materials either are buried under the snow, or offer low nutritional value, palatability, or digestibility. During severe winters, these animals may be almost totally dependent on sagebrush. Sagebrush also is essential to all other aspects of the life history of sage grouse. Open areas surrounded by sagebrush serve as strutting grounds, and most nesting and brood rearing occurs under sagebrush (3). In mountain areas, sagebrush openings near aspen stands can be important for elk calf-rearing. Other shrubs of value to wildlife include four-wing saltbush, Gardner saltbush, bitter brush, shadscale, winterfat, chokecherry, service berry, and mountain mahogany.

Besides their value for forage and cover, woody plants are important for improving soil moisture and for protecting herbaceous species subject to heavy grazing. Soil moisture in shrubby communities is enhanced because the woody plants accumulate snow within their crowns and in their lees, especially in windy prairie habitats. Woody plants also reduce wind velocities and hence desiccation at the ground surface. Moreover, the shading effect during summer may lower ground temperatures, and thus evaporation rates from the ground surface, sufficiently to offset the moisture loss from evapotranspiration though the

[6]Unless otherwise noted, **the material in this section is adapted from references 1 and 5.**

[7]Subshrubs **are perennial plants that are woody at the base and are either of small stature or die back nearly to ground level (i.e., intermediate between a shrub and a** forb) **(5).**

[8]For descriptions of these plant communities and their importance for wildlife and livestock, see references 1 and 5 in vol. 2.

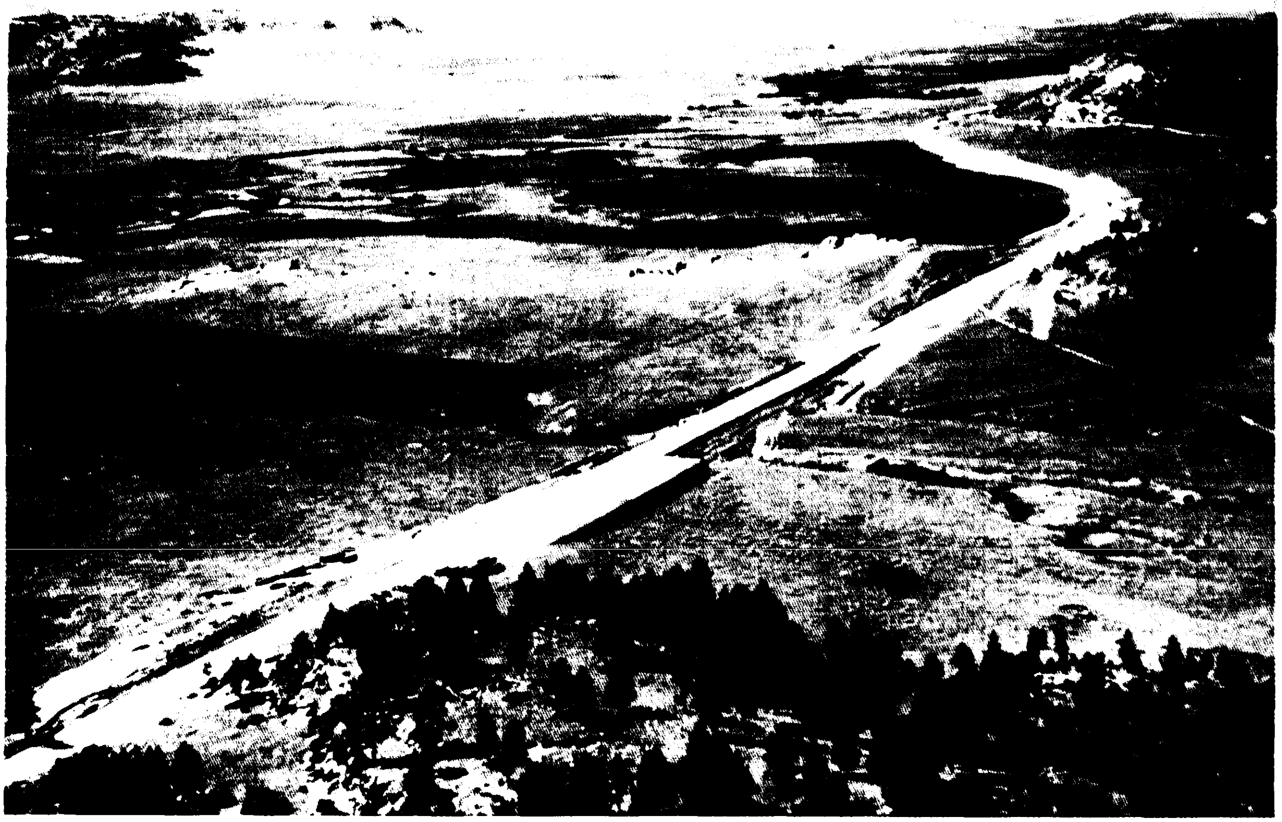

Photo credit: Office of Surface Mining

Lands in the northern portion of the study region typically include tame pastureland interspersed with sagebrush and other shrubs, with trees at higher elevations.

leaves. Groups of herbaceous plants are protected from grazing animals because the animals are unable to reach grasses or forbs growing around the base of a shrub. The protected plants serve as an important seed source, particularly in situations where heavy grazing virtually eliminates seed sources in open areas between shrubs. in some combinations of slope and substrate, woody plants also may improve slope stability because their more massive root systems can anchor a greater volume of material than many herbaceous species.

Because of the ecological importance of woody plants in the West, the revegetation requirements in SMCRA are tied to the reestablishment of native woody plant species as well as other lifeforms (forbs and grasses) by land use category (see ch. 7, table 7-2).[9] In States without specific woody plant standards for particular land uses, shrub density standards usually are negotiated on a case-by-case basis, based on the premining density, the postmining land use, and/or practicality (see box 8-E, below). For the desert shrub communities of New Mexico, the negotiated figure for shrubs generally is 190 stems/acre, while in northwestern Colorado (where the conditions for revegetation are among the most favorable in the study region) it normally is 1,000 stems/acre. In North Dakota, woody plant density standards only address wooded draws because of the paucity of shrubs or trees in upland sites. Guidelines and success standards for replacement of woody

[9]The SMCRA performance standards and standards for revegetation success are discussed in chs. 4 and 7.

Photo credit: Utah International Inc.

Pinon-juniper woodlands occur in the surface coal mining regions of the desert Southwest.

draw habitat currently are being developed based on research at one mine (see ch. 3, box 3-N). Pinon-juniper habitats in New Mexico also are relatively scarce, but regulatory personnel there are uncertain whether the technology exists to replace pinon-juniper after the rocky substrata supporting these species have been altered.

Wyoming is the only State so far to propose a formal woody plant density standard that is not tied directly to the baseline premining density. The Wyoming proposal states that 10 percent of the reclaimed surface should have shrub densities of at least one stem per square meter (4,050 stems/acre), and the remaining 90 percent of the area should have shrubs included in the seed mix, but no shrub density performance standards must be met. This proposed standard was under review by OSM at the time of this writing (see ch. 7, box 7-B).

The requirements for reestablishing woody plants raise two issues. First, in all States except Wyoming, the standards call for uniform postmining densities based on premining values. In areas where the premining density is relatively high (primarily Wyoming, Colorado, and New Mexico), however, there is little field evidence that high densities can be reestablished over an entire reclamation site during the lo-year liability period even with the most advanced shrub establishment technology (see below). Second, in many areas the requirement to restore sagebrush in its premining density directly conflicts with ranchers' and surface management agencies' postmining range management practices.

Achieving woody plant density performance standards has been an area of concern throughout the study region, and the technology of shrub reestablishment has been a major focus of research and innovation. In the first few years after SMCRA was passed, operators found it extremely difficult to establish woody plants from seeds, and emphasis was placed on live plants from containerized stock (tubelings), bareroot

Box 8-E.—Innovative Techniques for Enhancing Reestablishment of Woody Plants[1]

A mine in northwestern Colorado has instituted a variety of innovative revegetation techniques to enhance woody plant density and diversity in this mountainous region where shrubs are especially important to wildlife. The mine-site includes four major premining vegetation types: aspen, mountain shrub, sagebrush, and meadow. The pre- and postmining land uses are primarily livestock grazing and wildlife habitat. Mature native shrub clumps are transplanted on 1,300 foot centers using specially modified front-end loaders or scrapers. Antelope bitterbrush and true mountain mahogany are seeded between the transplanted clumps. In some areas, hard-to-establish shrubs are drill-seeded at an angle to more aggressive species. In addition, sites with woody plant cover were treated before topsoil removal with a tractor-mounted shredder that leaves a residue of finely chopped woody biomass on the soil surface. This native-vegetation mulch is incorporated into the topsoil before the soil is direct-hauled to a reclamation site, creating an additional source of woody plant material. Big game predation on young shrub growth in reclaimed areas is diverted to adjacent undisturbed areas where mature low-productivity shrub growth is crushed to stimulate sprouting of new growth attractive to browsers (see ch. 3). Monitoring data for this mine show a range of shrub density from 0.28 to 0.86 stems/m^2 on 3-year old seedings and as high as 1.02 stems/m^2 on 1-year old seedings (the negotiated shrub density standard is 0.25 stems/m^2).

[1]See case study mine CO-1 in reference 5.

Photo *credit: Jenifer Robison, OTA* staff

Shrub clumps transplanted directly to reclaimed areas with a specially modified front-end loader can establish islands of native shrubs and other species from which volunteers may radiate later in the liability period.

stock, and direct transplants from native stands in the mine area. However, trials in mines in New Mexico, Colorado, and Wyoming with containerized and bareroot stock have shown low survival rates and very high costs per surviving stem. Bareroot stock also is only available for a limited number of suitable species. Direct transplanting of shrub clumps at some mines (see box 8-E) can establish islands of native shrubs, soils, and accompanying herbaceous species from which volunteers may radiate, vegetatively or from seed, later in the liability period, This method is very expensive, however, and it probably is not capable of establishing required stem densities over an entire reclamation site.

Because of the availability of seed and the cost advantages of direct seeding, recent shrub establishment technology essentially has come full circle, and this method is now accepted as the major means of achieving the required woody plant density effectively and economically. improvements in the success of direct seeding resulted from recognition of the ecological fact that most shrubs cannot tolerate vigorous herbaceous competition during their first few years. Successful shrub establishment usually requires the use of techniques that reduce interspecies competition, such as separation in space or time from the aggressive cool season grasses that are planted to control erosion and to support grazing (see ch. 3).

Other techniques that may help improve shrub establishment include direct-haul soil handling (see separate discussion of Soil Handling and *Revegetation),* wildlife control, using locally adapted seeds, and applying mulch produced by shredding of woody vegetation (see ch. 3). The latter has been used successfully at a mine in northwestern Colorado (see box 8-E; see also ch. 3, box 3-L). Areas treated by this wood residue technique have shown substantial woody plant regeneration by root sprouting, resulting in far greater densities than had been achieved previously by seeding. Moreover, this method allows more complete topsoil salvage (due to the soil that normally adheres to uprooted shrubs and is disposed of with them in the absence of this method), and after topsoil removal and replacement on the reclaimed surface, sufficient organic debris remains on the surface to function as a mulch, The technique is now being tried at a mine in northwestern New Mexico where the vegetation is sagebrush shrubland and pi non-juniper forest, but results of that trial were not available at the time of this writing.

The results at the mine depicted in box 8-E suggest that shrub densities of one stem per square meter (4,050 stems/acre) can be realized at some mines in very favorable revegetation environments within the early part of the liability period using direct seeding and one of the various methods for reducing competition (see ch. 3). Monitoring data available from mines in less favorable environments for shrub reestablishment and using other technologies (e.g., live transplants) have resulted in lower shrub densities than those at the mine in box 8-E—in the range of 0.05 to 0.15 stems/square meter.

Fewer data are available concerning shrub establishment in the sagebrush-steppe ecosystems of the northern part of the study area. In the past, operators have found it difficult to establish shrubs other than fourwing saltbush in the Powder River basin of Wyoming, with a big sagebrush being especially difficult. The most recent data suggest that the prospects for shrub establishment may be improving as operators invest more effort in special measures. However, the ability to meet Wyoming's proposed standard of one stem per square meter on 10 percent of the area may depend on whether fringed sage and Gardener saltbush are counted as shrubs for density purposes.

The abundance of woody plants on Western rangeland has long been a source of aggravation to ranchers, who would prefer that postmining landscapes have fewer woody plants than before to improve grazing for cattle and sheep. As a result, ranchers have undertaken large-scale programs to thin or kill woody species–primarily sagebrush, but also Gambel's oak, and pinon pine and juniper–on rangelands, frequently with financial or physical support under rangeland management programs conducted by the Bureau of Land Management (BLM). Rangeland management may be accomplished by chemical means (spraying with a broadleaf herbicide), mechanical means (root-plowing or chaining), or burning. Such management generally reduces the wildlife habitat value of the land, can reduce the soil's ability to retain moisture, and can exacerbate the effects of overgrazing because the shrubs are no longer available to protect herbaceous species.

The issue of postmining versus premining sagebrush densities is further complicated by the widespread belief that present premining densities are greater than "natural" levels because of historical grazing pressure. Thus, range managers and ranchers often feel that mine reclamation programs should reemphasize sagebrush because high densities decrease the value of the land for livestock and are not "natural" for the region. While it is true that very high sagebrush densities may result from overgrazing (through selective removal of the forbs and grasses with which sagebrush seedlings must compete for moisture, nutrients, light, and space), their presence or even dominance in certain regions and on certain sites is sometimes related to other factors.

While mine operators and regulatory personnel recognize the ecological importance of woody plants, they consider it senseless that so much effort and expense is put into the reestablishment of premining sagebrush density when the postmining landowner or surface manager may negate those efforts through range management programs. This conflict is exacerbated because, while big sagebrush is the single most widespread shrub in the study area, it also is among the most difficult to reestablish.

For the most part, this conflict can be traced to the lack of specificity in designation of the postmining land use (see separate discussion in this chapter), and to inadequate coordination among Federal and State regulatory authorities and land management agencies. The options discussed in the next section for defining postmining land uses more carefully also could help mitigate the conflict between surface mine revegetation and rangeland management.

In addition, many State regulatory and mining industry personnel feel that lower woody plant densities, if accomplished as groupings based on premining habitat mapping, provide wildlife habitat as valuable overall as high uniform premining levels. In this context, rangeland management programs also can benefit wildlife if done selectively. For example, thinning big sagebrush to increase herbaceous production can improve the forage for pronghorn antelope as long as shrubs remain available in critical winter browse areas and are not totally removed from summer range. Similarly, thinning dense oakbrush can greatly improve the forage value for elk, which primarily are grazers, by increasing herbaceous production. Although deer mainly are browsers and are heavily dependent on shrubs throughout much of the year, thinning oakbrush and pinon-juniper also can be beneficial for deer because it stimulates tender young shoots that are more nutritious, palatable, and easily reached. For both deer and elk, however, thinning must be done in relatively small blocks so that adequate densities of tall brush and trees remain nearby for the requisite thermal and hiding cover.

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POSTMINING LAND USE

The postmining land use is defined during permitting of a surface coal mining operation. Under the Federal regulations, "land use" means specific uses or management-related activities, rather than the vegetation or cover of the land. Multiple land uses may be identified when joint or seasonal uses occur. Native rangeland is the most extensive premining land use in the study area (see ch. 3). The regulations define "native rangeland" as land on which the natural potential (climax) vegetation is principally native grasses, forbs, and shrubs valuable for forage. This includes natural grasslands and savannahs, as well as juniper savannahs and other brush lands. Except for thinning shrubs (see discussion of Woody *Plant Revegetation,* above), management of native rangeland primarily involves regulating the intensity of grazing and season of use (1 O).

Other common land uses in the study area (as defined in the Federal regulations) are:

- **Cropland:** land used for the production of adapted crops for harvest, alone or in rotation with grasses and legumes, including row crops, small grain crops, hay crops, nursery crops, orchard crops, and other similar crops.
- **pastureland or land occasionally cut for hay:** land used primarily for the long-term production of adapted domesticated forage plants to be grazed by livestock or occasionally cut and cured for livestock feed.
- **Grazingland: land used for grasslands and**

forest lands where the indigenous vegetation is actively managed for grazing, browsing, or occasional hay production.

- Fish and wildlife habitat: land dedicated wholly or partially to the production, protection, or management of fish or wildlife species (10).

In the West, the postmining land uses usually are the same as the premining uses, although some changes can occur. Where the surface is privately owned, for example, the postmining land use generally is consistent with the surface owner's preference. Thus, at a mine in North Dakota, the postmining land use will convert most of the existing rangeland to cropland at the stated request of the surface owners (see box **8-G,** below).[10]

OTA identified three issues related to the designation and implementation of postmining land uses: the lack of specificity in describing postmining land uses, implementation and management of the postmining land use after bond release, and the effects of the postmining land use designation on the difficulty of reclamation.

Designating the Postmining Land Use

As discussed in chapter **4, SMCRA requires** that surface mined land be restored to a condition capable of supporting the uses which it was capable of supporting prior to any mining, or higher or better uses of which there is reasonable likelihood (1 3). SMCRA and the regulatory programs require detailed characterizations of the premining and postmining land uses in the permit application and reclamation plan. The permit application package must contain a statement of the condition, capability,[11] and productivity[12] of the land within the proposed permit area, including: 1) a map and supporting narrative of the uses of the land at the time of the filing of the application and, if the premining use was changed within 5 years before the anticipated date of beginning mining, the historic use; and 2) a narrative of land capability and productivity, which analyzes the land use description relative to other required environmental resources information (climatological, vegetation, fish and wildlife resources, soil resources), as well as to the land's premining capability and productivity (1 **5).** The reclamation plan also must describe the use that is proposed to be made of the land following reclamation, how that use is to be achieved, and the necessary support activities that may be needed to achieve it. Where the postmining land use is rangeland or grazing, the operator must provide details on the management plans to be implemented (16).

Some of the State regulatory programs require an even greater degree of specificity in describing pre- or postmining land uses. In Wyoming, for example, the regulations require a permit applicant to describe and rank the previous uses of affected lands on an individual basis according to the overall economic or social value of the land use to the area or local community (9).

Despite the requirements for detailed descriptions of the pre- and postmining land uses, and quantification of land capability and productivity, the characterization of these uses is extremely perfunctory. A number of the surface mining permits and reclamation plans reviewed for this **assessment contained land use discussions with little more information than the state ment, "The premining land use is grazing and the postmining land use is grazing."** In some cases, this lack of specificity can be attributed to inadequate baseline characterization by the permit applicant. In others, it is the fault of the Federal surface management agency, which is required to determine, or at least consent to, the postmining land use on Federal lands (1 7).

This lack of specificity and quantification can adversely affect postmining vegetative and landscape diversity (see separate discussions in this chapter), the implementation of surface owners' or management agencies' land use recommen-

[10] See case study mine A in reference 4.

[11] For the purposes of BLM land management, "capability" means the ability or potential of a unit of land to produce resources, supply goods and services, or allow resource uses under a set of management practices at a given level of management intensity without permanently impairing the resource involved. Capability depends on a fixed set of conditions that are relatively stable over time, including but not limited to, climate, slope, landform, soils, and geology (14).

[12] Productivity is determined by yield data or estimates for similar sites based on current data from the U.S. Department of Agriculture, State agricultural universities, or appropriate State natural resource or agricultural agencies (1 5).

dations, and the difficulty and cost of reclamation. Moreover, at mines where reclaimability is an issue during permitting, much more rigorous approaches to characterizing premining land uses, and to predicting the capability and productivity of the reclaimed surface, are necessary to demonstrate reclaimability (4).

The principal option for resolving this problem is for the regulatory authorities to enforce more strictly the permit application and reclamation plan requirements for pre- and postmining land use characterization. For privately owned lands, the land use description and the quantification of capability and productivity must remain the responsibility of the permit applicant, with the cooperation and concurrence of the landowner. The U.S. Forest Service (USFS) has developed a system for predicting potential land capability classes on reclaimed surfaces, which could be used for such quantification. The acres of land in each capability class in the premine condition could be compared to the predicted acres in the postmining condition to determine if the land capability would be maintained (4).

On public lands, the applicable land use and activity plans prepared by the surface management agency should provide the basis for quantitative characterizations of pre- and postmining land uses.[13] The surface management agency prepares a resource management plan or other land use planning document as the first step in analyzing Federal lands for their suitability for a variety of uses, including coal resource development. This document is then supplemented by BLM during activity planning for a coal lease sale with detailed site-specific analyses for each proposed lease tract. The information in these plans and analyses should be sufficiently detailed to meet the requirements in SMCRA and the regulatory programs for the quantitative characterization of pre- and postmining land uses, capability, and productivity.

BLM and USFS currently are in the process of preparing land use plans that meet the requirements of the Federal Land Policy and Management Act of 1976. Until these documents are completed, **Federal surface management agencies should ensure, during interagency review of permit applications and reclamation plans, that careful attention is paid to the quantitative characterization of pre- and postmining land uses, productivity, and capabilities.**

Implementation and Management of the Postmining Land Use

Implementation and management of the postmining land use after bond release raises issues about changes in land use, conflicts among land uses, and the long-term success of reclamation. If the proposed postmining land use is different from the premining or historical land use, the regulatory authority must formally approve a “change to an alternative land use” (1 O). After consultation with the landowner or the surface management agency, the regulatory authority may approve a higher or better use as the alternative if the proposed use meets the following criteria: 1) there is a reasonable likelihood for achievement of the use; 2) the use does not present any actual or probable hazard to public health or safety or threat of water diminution or pollution; and 3) the use will not be impractical or unreasonable, be inconsistent with applicable land use policies or plans, involve unreasonable delay in implementation, or cause or contribute to any violation of Federal, State, or local law.

Changes to alternative land uses can be beneficial for the capability and productivity of the land. At a surface mine in the Colorado portion of the San Juan River Region, for example, the operator will attempt to change part of the permit area to a higher or better use. At this mine, the premining land uses were rangeland, wildlife habitat, and some privately owned dryland pasture. About 20 acres of rangeland will be reclaimed to pasture to increase the ability of the land to support livestock husbandry.[14] However, such changes also can make reclamation more difficult and costly (see below).

At other mines, conflicts arise between land uses—particularly between agricultural uses and wild life habitat. In these situations, restoration of

[13] See the discussion of the Federal coal leasing program in ch. 4.

[14] See case study mine K in reference 4.

wildlife habitat features is often in conflict with the management objectives of the landowners, who usually are farmers or ranchers who desire all land returned to cropland, pastureland, or grazingland. This conflict is most evident where reclamation standards for wildlife habitat (e.g., woody plant density standards and overall vegetative diversity) are more difficult to meet than those for other land uses, such as pastureland. It is especially a concern in areas such as North Dakota, where natural habitat is very limited in areal extent and is "shrinking" each year due to water developments, urban expansion, and agricultural expansion. At a mine in North Dakota that is converting most of the premining rangeland to cropland at the request of the surface owners, this conflict is being resolved by the replacement of premining wildlife habitat on an acre-for-acre basis after mining.[15]

There are no regulatory mechanisms to ensure that the surface owner will not convert lands reclaimed for one use (e.g., wildlife habitat) to other uses after bond release. As with the conflict over sagebrush reestablishment discussed in the previous section, operators consider it senseless to restore wildlife habitat and native rangeland at great expense when the surface owner will convert the land to tame pasture or other uses after bond release.

Similarly, **although the use itself may not change, even the best reclamation can be negated quickly by postmining land management decisions or techniques.** For example, much of the land in the West is used for grazing and, historically, there have been problems with overgrazing adversely affecting vegetative density and diversity. While many reclaimed surface mine lands are required to graze for a specified period of time prior to bond release, the operator can control the number and type of livestock in such grazing tests. After bond release, however, grazing pressures on reclaimed lands can increase significantly. Similarly, the mix of woody plant species for revegetation may be selected to favor particular wildlife species, but postmining management practices to enhance pastureland uses can reduce the number of shrubs beneficial to those species and the overall vegetational diversity.

One solution to conflicting land uses, postmining land use conversion, or improper management is careful design for the return of land uses that minimize post-reclamation conflicts (see box 8-F, and the discussion of landscape diversity, below). Greater specificity in describing the postmining land use (e.g., number and type of livestock that will be grazed after bond release) would aid in this effort.

Effects on Reclamation

Specification and implementation of the postmining land use are extremely important for the reclamation plan and for the evaluation of the success of reclamation. Many of the reclamation plan requirements, performance standards, and bond release criteria in SMCRA and the regulatory programs are tied directly to the postmining land use. Two of the general objectives of the performance standards are the prompt reclama-

Box 8-F.—Designing Reclamation To Minimize Postmining Land Use Conflicts[1]

At a surface mine in Northwest Colorado, the mine personnel believe that the postmining land use governs how and where reclamation practices are to be implemented. Accordingly, they are implementing an optimal land use design in which premining land uses are reestablished on the postmining topography according to slope and elevation such that the best management practices can be applied for each land use. Lower elevational land with less than 12-percent slopes will be returned to the premining use of agriculture. Land with greater than 12-p[illegible] slopes that is not suitable for agriculture [illegible] reclaimed to grazingland. Land at high[illegible] tions, as well as rough breaks and drain[illegible] be reclaimed to wildlife habitat. No a[illegible] made to reestablish uses in the areal [illegible] tion in which they existed prior to d[illegible] This differs from more typical approa[illegible] land unit for land unit is returned to [illegible] ing use.

[1]See case study mine F in reference 1.

[15]See case study mine A in reference 1

tion of all affected areas to conditions that are capable of supporting the premining land uses or higher or better uses, and revegetation that achieves a prompt vegetative cover and recovery of productivity levels compatible with approved land uses (1 8). The specific performance standards for backfilling and grading, topsoil and subsoil redistribution, revegetation, protection of the hydrologic balance, and protection of fish and wild life also are tied to support of or consistency with the approved postmining land use (1 **9-23).** Furthermore, the regulatory standards for determining the success of revegetation vary according to land use category (grazingland, pastureland, cropland, wildlife habitat, rangeland), and specify that revegetation shall be judged on its effectiveness for the approved postmining land use (1 6).

This variability in the regulatory standards directly affects the difficulty and cost of reclamation because there are more stringent reclamation requirements for some land use categories. Except in North Dakota, postmining land uses generally are designated as native rangeland and wildlife habitat rather than improved grazingland or tame pastureland. As a result, these lands are subject to the full requirements for the establishment of native species; vegetative diversity, permanence, cover, seasonality, and self-regeneration; and woody plant density and diversity. For land reclaimed to cropland, there are no requirements in the study area States for vegetative diversity, permanence, cover, seasonality, and self-regeneration, but the soil reconstruction requirements may be more stringent (see box 8-G) (5).

More careful attention to description of postmining land uses, and to considerations related to landscape diversity, could, in the long term, reduce the difficulty and cost of reclamation in that the stricter requirements for particular uses would be limited to specified areas rather than applied to an entire reclamation site. While mine operators and reclamation specialists may experience initial difficulties and costs i n adjusting their planning for and implementation of such an approach, the long-term benefits for the ease and success of reclamation could be great.

Box 8-G.—The Effects of Postmitiing Land Use on the Cost of Reclamation

At a mine in North Dakota, the premining land use was mostly for dryland wheat production, with about 10 percent of the permit area being used as rangeland. Although areas in rangeland have some limiting soil factors (typically shallow depth) that inhibit their use as cropland, the postmining land use characterization indicates that most of these rangelands will be converted to cropland at the stated request of the surface owners. As a result, the operator will be subject to the more stringent cropland vegetative productivity standards, which can be more costly to achieve than the rangeland standards if the soils are not suited to growing crops.[1]

At a mine in the Eastern Powder River basin in Wyoming, the premining land uses were 76 percent native grazinglands and improved pasture, 16 percent haylands, and 7 percent croplands. The premine croplands were used for wheat, oats, and barley, The permit application stated that "low crop yields and high operating costs make tillage agriculture a break-even or net loss operation in most years." Therefore, land uses at the site were ranked in value (as required in Wyoming) as: 1) hayland (improved pasture), 2) grazingland, 3) cropland, 4) water resources, and 5) wildlife habitat. Despite these rankings, most of the site will be reclaimed to grazingland based on the premining survey of surface owner preferences. Croplands will be reclaimed despite the marginal yields, and the operator will have to meet the yield standards for bond release. Some grasslands will be reclaimed to shrublands to maximize wildlife habitat, and will be subject to the woody plant density and diversity standards. Haylands will not be restored.[2]

[1]See case study mine A in reference 4.
[2]See case study mine E in reference 4.

LANDSCAPE DIVERSITY

In surface mine reclamation, the term "diversity" traditionally has been used in the context of vegetative diversity in lifeforms, species, or seasonality. The most recent reclamation and related research indicates, however, that a broader meaning of "diversity," one that encompasses the entire landscape, may be important to the quality of reclamation. **This concept, known as landscape or ecosystem diversity, recognizes the mosaic nature of Western landscapes that results from localized differences in the physical environment, plant communities, wildlife populations, and land uses.** The five-State study area has a wide range of localized environments, including native prairie, badlands, wetlands, woody draws, broadleaf tree and shrub communities, shrub-steppe communities, ponderosa pine woodlands, rimrock or escarpments, riparian areas, mountain shrub communities, meadow communities, aspen woodlands, pinon-juniper communities, and desert.[16] Even some abandoned mined lands in the West have become prime wildlife habitats because of their diverse landscape relative to the surrounding area. In North Dakota, some orphan mines are protected State wildlife areas.

Localized environments on mine sites are altered or lost during mining, but with special attention to landscape diversity in planning reclamation, many of these features could be restored. This subject has received little attention, however, at either the State or Federal level, although requirements for specific mines have been established on a case-by-case basis, primarily in relation to reestablished plant communities. The restoration of ponderosa pine woodlands in Montana, woody draws in Montana and North Dakota, and wetlands in North Dakota are examples of reclamation that attempts to preserve landscape diversity. The proposed woody plant diversity requirement in Wyoming for dense shrub patches on 10 percent of the mined area clearly addresses this issue (see separate discussion in this chapter). Informal approaches to woody plant density standards in Colorado also have begun to include mosaic plantings of shrubs to enhance community diversity (5).

The importance of physical and vegetational diversity of an area has been recognized for some time in relation to the number of wildlife and livestock species and individuals that it can support. A well-established diverse community of cool and warm season grasses, forbs, and shrubs on a varied physical landscape provides vastly more feeding and nesting sites, thermal and hiding cover, and food items than a monoculture. Additionally, different food items become available throughout the seasons of activity so that there is less of a "feast or famine" effect. Lifeform and species diversity in vegetation also may enhance long-term survival of a plant community, because the various plant species are able to tolerate slightly different combinations of environmental factors. The various reproductive strategies and delicate competitive balance within a diverse plant community would enable some species to quickly fill any void created by the decline or demise of other species. As a result, the soil and wildlife resources would be buffered from an environmental stress such as overgrazing or drought (5).

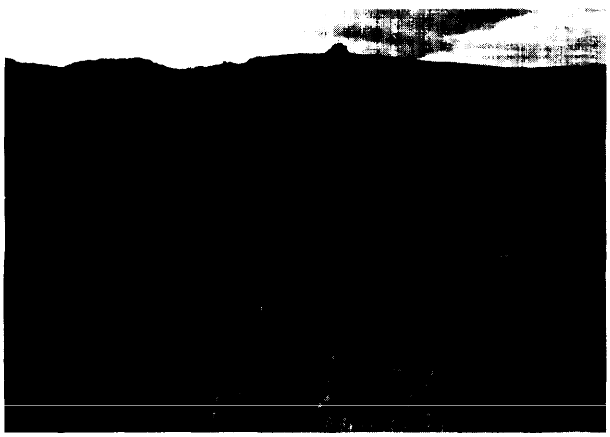
As reclamation experience is gained in the West, an understanding of the complex interrelationships among all of the physical aspects of the environment is leading to an interdisciplinary approach to reclamation that recognizes the importance of diversity in more than the vegetation. The shift to such an approach has encompassed the design of everything from the overburden in its relation to water quality, to restored surface drainage systems, to the physical and vegetative features of the postmining landscape:

- The term "engineered cast overburden" was coined by researchers in North Dakota to refer to an approach to control of postmining groundwater chemistry that combines geologic and soil mapping, geochemical and geohydrological studies, and development of a three-dimensional materials framework, with a thorough understanding of the form and internal structure of material deposited by various types of mining equipment and

[16] These localized environments and their ecological importance are described in detail in the technical reports in vol. 2.

techniques, to determine how best to obtain optimum physical and chemical characteristics at desired locations within the cast overburden (see ch. **6,** box 6-H) (6).

- The design of restored surface drainage systems is beginning to combine the concepts of quantitative geomorphology, rainfall-runoff hydrology, and detailed hydraulic analyses with appropriate revegetation to enhance both erosional stability and the wildlife value of riparian areas (6).
- Other research in North Dakota suggests that reconstructing sites with topography that catches and retains moisture is very important in cropland productivity and in reestablishing deciduous shrub and tree communities. At one mine in that State, a small field of prime farmland was placed on a concave landscape position in the design of the postmining surface to maximize water runon and snow accumulation (4).
- Many wildlife habitat requirements relate to the physical features of an area in addition to its vegetational components. Topographic diversity provided by rock outcrops, minor variations in slope/aspect, and the juxtaposition of different plant species and types create a variety of ecological niches important to many species of wildlife (1).



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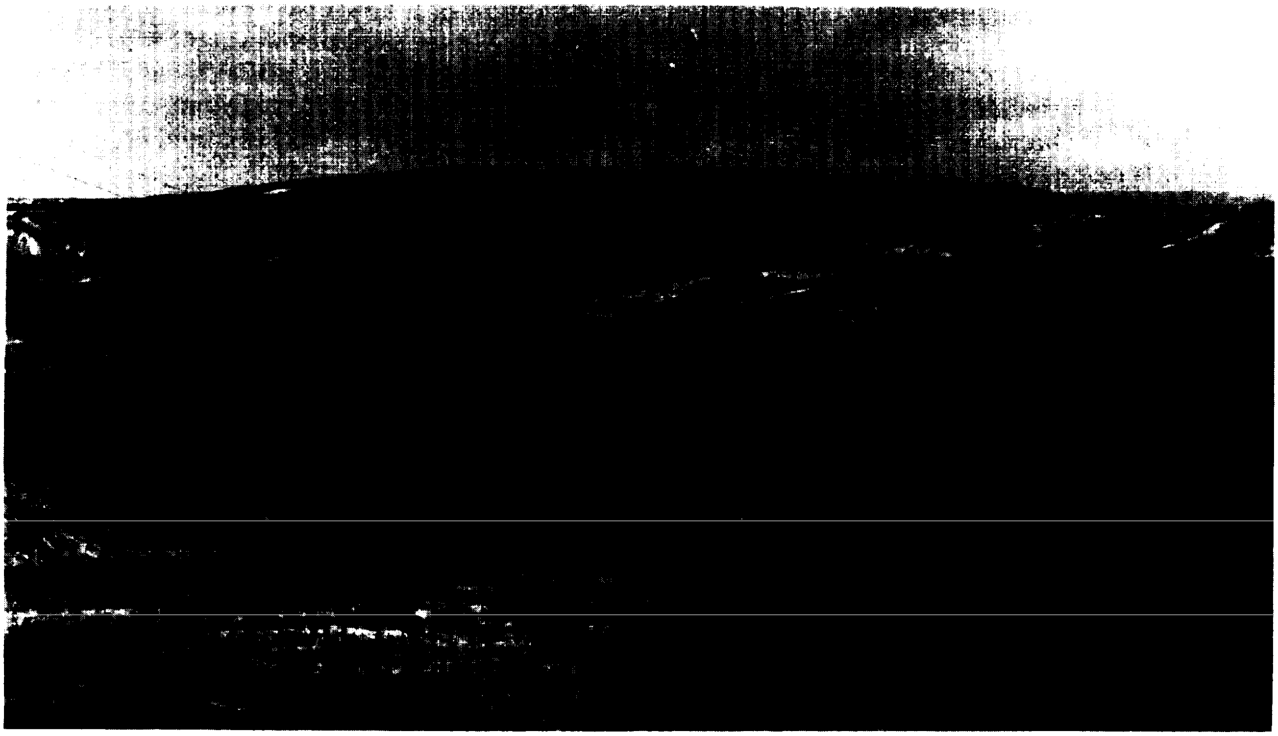
Adoption of a landscape diversity approach to surface mine reclamation involves trade-offs between the cost and/or difficulty of achieving diversity versus the potential long-term benefits for the quality of reclamation. Moreover, some regulatory requirements (e.g., highwall reduction, uniform topsoil thickness) may actually discourage innovative approaches to diversity. These requirements are directed at pre-SMCRA abuses, but do not incorporate the more recent reclamation experience on the benefits of diversity. Permit applicants will have to include the cost of obtaining a site-specific variance from such requirements in their overall assessment of the costs and benefits of achieving diversity.

Reclamation design at some mines has been kept as simple as possible to minimize costs and conflicts with conventional mining methods. Promoting an interdisciplinary approach to design and implementation of landscape diversity would require some additional effort, and thus cost, in premining baseline studies, in specification and design of the postmining land use, in implementing the reclamation design, and in developing criteria for evaluating the success of reclamation. Moreover, obtaining a permit for a design that conflicts with regulatory program requirements may require approval of a site-specific variance or an alternative reclamation technique. These are expensive and time-consuming to obtain, especially given the risk of disapproval and subsequent redesign and resubmission of the permit application package. On the other hand, once approaches to landscape diversity become accepted, they could provide cost savings (e.g., in soil handling, seeding, and grading), as well as benefits for the quality, and perhaps the long-term success, of reclamation.

The legislative and regulatory requirements that are most often cited as deterrents to reclamation designs that incorporate diverse landscape features are those related to restoration of approximate original contour (AOC) and uniform topsoil depth. **The requirement for full restoration of AOC was intended to prevent large discrepancies between premining and postmining topography, but, in the West, typically has resulted in gently undulating land with little topographic variety. This has substantially lim-**



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ited the potential for vegetative and wildlife diversity.** A full consideration of geomorphology in reclamation design would emphasize not only restoration of AOC, but also the postmining topography's consistency with the hydrologic characteristics of the reconstructed soils, the revegetation communities, the reconstructed drainage systems, and the proposed postmining land use, as well as its compatibility with the geomorphology of the contiguous areas (4),

There are some landforms that always will be impossible to restore to their premining condition. For example, hogback ridges are supported by resistant strata that would be removed during mining, precluding their reestablishment on the reclaimed surface. Similarly, badlands—bare outcrops of vari-colored shales that compose highly dissected mesas, buttes, pillars, and rock tables with high drainage density and little soil—cannot be re-created because mining removes the thin resistant strata of sandstone and siltstone that act as ledge- and pedestal-formers and on which the badland topography has formed by erosion (4). Where these features are ecologically unique, they could be preserved through measures such as unsuitability designations (see ch. 4).

In other cases, however, the postmining topography can be designed to mimic premining features such as rimrock and "microsites." Rimrock or escarpments are physical habitat features that can occur in a variety of vegetation communities, and serve as nesting or denning sites for many species of mammals, birds, and reptiles. Golden eagles, red-tailed hawks, great-horned owls, and prairie falcons commonly nest on ledges or in cavities in rim rock and, in many areas of the West, suitable cliff-nesting habitat is a limiting factor to these raptor populations. Rimrock also serves as protective cover for a wide range of animal species during winter storms, and it col-

Photo credit: Jenifer Robison, OTA staff

In this post-SMCRA mined area, the highwall was reduced (background), leaving gently-undulating land with little topographic variety.

lects moisture that promotes a greater variety of shrubs or trees than are found in adjacent communities (l).

Attempts have been made at many mines to mimic rimrock in the postmining landscape with rock piles, but these usually bear little physical resemblance to the original features, and do not provide as much topographic, vegetative, or habitat diversity as the rim rock or escarpments that were removed during mining. Alternatively, portions of highwalls with appropriate aspect and ledges or cavities could be left after reclamation to restore valuable nesting habitat that otherwise would be lost because of mining and reclamation. However, the AOC provisions of

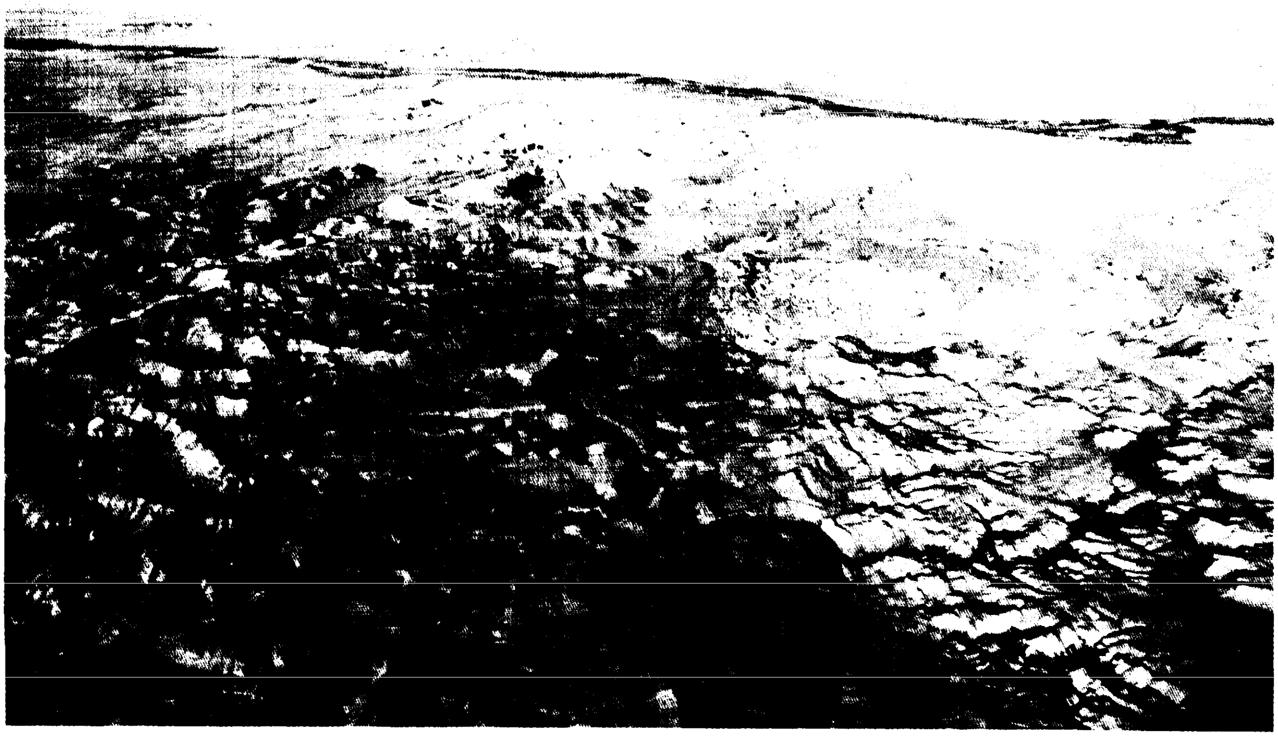

Photo credit Utah International Inc

Badlands cannot be re-created because mining removes the siltstone and sandstone strata on which the badland topography formed through erosion.

SMCRA require that all highwalls be eliminated. While leaving an unreduced highwall portion clearly would provide cost savings in reclamation, the cost and difficulty of obtaining regulatory approval for an experimental practice or alternative reclamation technique for highwall retention generally is a serious deterrent. This deterrent has been overcome in a few instances in order to create artificial cliffs or bluff extensions that come closer to simulating the original features than rockpiles and that aid in the retention of additional surface moisture near the highwall base (box 8-H; see also ch. 3, box 3-O; and ch. 9, box 9-A).

Small premining surface features (or "microsites") are another aspect of landscape diversity that may be foreclosed by a lack of understanding about their importance, or by the difficulty and cost of their design, permitting, and restoration. Minor depressions, drainages, and hummocks that ex hi bit different slope/aspect combi - nations and are dependent on varying topsoil depths and soil structure characteristics not only provide topographic diversity, but also encourage vegetative diversity vital for the reestablishment of a variety of wildlife. SMCRA and the Federal regulatory program allow small depressions on the postmining landscape if they are needed in order to retain moisture, create and enhance wildlife habitat, or assist revegetation. Some forms of microsites are difficult to re-create, however, because they are dependent on particular hydrologic, soil, and overburden characteristics that are very expensive to duplicate with available mining and reclamation equipment.

An internal drainage including a playa has been approved for one mine in Wyoming. '[17] The heavy clay soils typical of such features will be special-handled and returned to the playa. This will necessitate precise timing to catch the limited range of appropriate soil moisture content to avoid massive clod or block development and subsequent difficulty in developing a suitable seedbed.[18]

[17] Aplayais the flat. floored bottom of an undrained desert basin that becomes at times a shallow lake.

[18] See Case Study Mine WY-6 in reference 5.

Box 8-H.—Retaining a Highwall Portion To Simulate a Bluff Removed by Mining[1]

The permit application for this surface mine in the Montana portion of the Eastern Powder River basin contains an innovative postmining topography that raises questions of AOC, erosion control, uniform topsoil thickness, maximization of the coal resource, alternative reclamation, and experimental practices. It is referred to as the "bluff extension alternative."

The coal being mined extends under some large bluffs, which are capped by a massive and thick (greater than 100 feet) sandstone bed that has eroded into irregular cliffs. Mining into the bluffs and subsequently reducing the highwalls to a maximum 5:1 slope would require 1.5 million cubic yards of overburden to be cut back from the previously undisturbed bluff tops, essentially removing the original topography. This alternative was not considered economically viable by the applicant. On the other hand, not mining into the bluffs would mean the additional coal would not have been recovered. Therefore, the operator proposed to extend the mine pits into the deeper overburden on the footslopes of the bluffs, but to retain 50 to 100 feet of the final pit highwalls adjoining existing undisturbed competent sandstone. Below these highwalls, the final pit will be backfilled to the flattest practical slope. The final highwall blast will be designed to maintain competence, but also to maximize the roughness of the highwall for wildlife habitat. Rock rubble will be placed at the base of the highwall to improve wildlife habitat.

The plan was accepted by the Montana regulatory authority as an alternative reclamation plan because "it optimizes use of the coal resource and achieves AOC, although it varies from the requirements to reduce all highwalls and redress topsoil. The plan minimizes erosion becaui&j%* steep, short highwalls are capped by the resistant sandstone and the slopes at the bottom of the highwalls as possible. Reducing the highwalls to 5:1 would produce long slopes that would be much more erodible.

[1] See Case Study Mine C in reference 4. '

Similarly, in North Dakota, it is common for the premine surface to lack a well-integrated drainage system, and to have many closed depressions (prairie potholes) typical of glaciated topography. The potholes are wetlands that are important to wildlife, and one mine is undertaking an extensive research project to determine whether prairie potholes can be reconstructed and reclaimed (see ch. **3,** box 3-G).

At a mine in Montana, restoration of a coulee bottom is being undertaken in response to a permit stipulation.[19] The moderately steep, concave sides with north to east aspects will be protected with a heavy straw mulch (5 to 7 ton/acre) applied after topsoil application and deep ripping of the side slopes, and then planted with woody species.[20]

Requirements for uniform topsoil depth over the regraded surface further homogenize site conditions and limit the potential for vegetative community diversity. Federal regulations require that topsoil be redressed in a uniform thickness consistent with the postmining land use. The Montana legislation has a provision for special reconstruction of soils using nonuniform depths, but the other States routinely require uniform thickness on each reclaimed area unless specifically exempted due to site-specific conditions (4). This requirement does not recognize the naturally occurring variation in soil depth that contributes to landscape diversity and strongly influences long-term plant community structure. At some sites, variations in topsoil depth, even to the point of no topsoil in areas intended for reestablishment of some types of woody plant species, may be more appropriate (see box 8-l). Moreover, because of the natural variability in soil depth, restoring uniform thicknesses can increase haul distances and thus costs, and can interfere with the ability to direct haul topsoil.

There are several other arguments against uniform thickness related to erosion control and the moisture-holding capacity of soils. One operator suggested thicker soils on ridges and thinner soils in swales in relatively high precipitation areas of the West; the landscape would be designed to forestall the effects of soil erosion on ridges. Another suggested the opposite in desert areas, where topsoil is at a premium and premine vegetation density is extremely low. In the desert, putting a very thin layer of topsoil on uplands and using most of the soil in the swales would produce deep soil profiles capable of storing moisture from runon and supporting better vegetation cover, while a uniform thickness would result in soils unnecessarily deep on the uplands and too thin in the swales. Research in North Dakota suggests that, to produce an optimum landscape position for dryland wheat production, thinner soils ought to be placed in concave positions, which support higher production regardless of soil thickness, with thicker soils redressed on convex surfaces to maximize moisture-holding capacity (4).

[19] A coulee is a steep-sided drainageway that normally is dry by late summer,

[20] See Case Study Mine MT-1 in reference 5.

Box 8-L-Reestablishing Sandstone Strata[1]

This small surface mine in southwestern Colorado is mining coal under a surface originally covered by massive sandstone vegetated by pinon pine, juniper, tall shrubs, and scattered patches of warm season grasses located in crevices **and on small terraces. After the coal is removed, the exposed surface will be another massive sandstone stratum. The reclamation plan calls for blasting shelves into this sandstone, placing fine material on these shelves and planting to trees, shrubs, and grasses.**

[1] See case study mine CO-4 in reference S.

A number of mines are redressing nonuniform topsoil thicknesses to replicate premining conditions, facilitate direct haul of topsoil, and promote vegetative diversity:

- New **Mexico:** At this mine, topsoil and subsoil will be redressed either in two 4-inch lifts to a depth of **8** inches over coarse-textured, benign spoil (sodium adsorption ratio–SAR– of less than 20 and a clay content of less than **28** percent), or to a depth of 18 inches in two lifts of **4** and 14 inches respectively over less favorable spoils (most of the mine), where SARS average 53 (4).
- **Wyoming:** The thickness of topsoil redress-

ing at this operation will range from 2.4 to 5.1 feet, depending on premining thickness, because of the long haulage distances that would be necessary to even out differences that occur naturally over the site (4).

- **Wyoming:** The topsoil handling plan for this mine calls for uniform distribution by mining block, but nonuniform distribution across the permit area. Redressed topsoil depth will range from 1 to 23 inches (4).
- **Wyoming:** This operator proposes to put 6 inches on the ridges and 36 inches in the swales to recreate the premining soil configuration. The operator contends that the requirement for uniform topsoil replacement is hindering the ability to achieve vegetative diversity (4).

Attention to landscape diversity needs to begin with baseline data collection for the reclamation plan and permit application. What is needed is an interdisciplinary ecological characterization of the proposed mine area that can be used in the design of a diverse postmining landscape, in addition to a set of numbers to be used to set performance standards. For example, baseline wildlife habitat descriptions should include measurements of physical features such as the size, distribution, and frequency of rock outcrops or the overall variety in topographic relief. This effort would be aided greatly by more exact specification of the postmining land use (see above). in addition, **research is needed to identify and describe quantitatively the physical features that are most important to the local ecology and to develop practical design criteria for use in reestablishing these features during reclamation.** Finally, better information exchange is needed among operators and regulatory authorities on the potential costs and benefits of reclamation designs that promote landscape diversity.

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