

CHAPTER 21

BACKFILLING AND GRADING





CHAPTER 21

INDEX

	<u>Page</u>
Introduction	1
Historical Grading Summary	1
Postmining Topography	1
Backfilling and Grading Procedures	5
Graded Spoil Stability	9
Affected Lands	10
Future PMT Design Techniques	10
PMT Design Using Geomorphic Principles	12
Small Depressions	13
In-channel Pools	14
Literature Cited	16

LIST OF TABLES

	<u>Page</u>
Table 1 Postmining Land Form Mass Balance	4

LIST OF ATTACHMENTS

Attachment A - Swell Factor Study





## BACKFILLING AND GRADING

Introduction

The final postmining landform achieved in the field through backfilling and grading activities is a result of careful planning and implementation by the reclamation, engineering, and operations departments. This chapter, in conjunction with the Surface Stabilization Program described in Chapter 26, will quantitatively describe the magnitude and rate of grading, the planning and methodology employed to estimate the configuration of the final postmining landform, and the backfilling and grading to be performed within the framework of the estimated postmining topography. In addition, Chapter 26 describes a plan for establishing drainage systems and stabilizing the reclaimed surfaces. Finally, this chapter and Chapter 26 will demonstrate that the postmining surface configuration resembles the general premining surface configuration, blends into the surrounding terrain, compliments the surrounding drainage patterns, provides for graded spoil material stability, prepares for a stable reclaimed surface, and supports the postmining land use.

Historical Grading Summary

The first mining operations on the Black Mesa leases began in 1970 at the J-3 pit, Black Mesa Mine. Since that time, the J-27, J-1/N-6, and J-7 pits have been opened. The J-3, J-7, and J-27 pits have been completely mined and reclaimed. At Kayenta Mine, the N-1 pit was the first to be mined with operations beginning in 1973. Subsequently, the N-2, N-7/8, N-10, N-14, J-16, J-21, J-19, N-11, N-9, and N-11 Extension (N-99) pits were or will be opened. Currently, operations are being conducted in the N-9, J-19, and J-21 pits. The N-1, N-2, N-7/8, N-11, N-14, and J-16 pits have been completely mined, and the N-10 pit has been temporarily closed. Reclamation will be completed in accordance with the projected reclamation schedules in Chapter 20. Reclamation has been completed at the N-1, N-2, N-7/N-8, N-10, N-14, and J-16 pits.

Postmining Topography

The design of postmining topography utilizes information presently available and is at best an estimate or prediction. An appropriate design methodology and form of presentation must be developed to best utilize the available information and produce a best estimate product that is not unnecessarily overdesigned and adequate for estimating

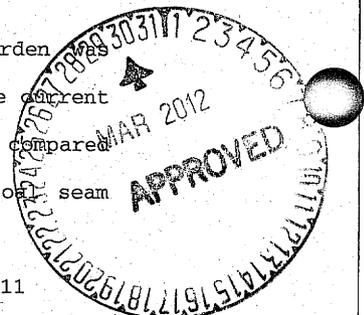
material utilization, general slope configurations, watershed boundaries, macro-drainage networks, landform similarity, and extent of disturbances that may occur. Although exactness cannot be produced, the presented estimated topography can provide the framework for discussing backfilling and grading operations and surface stabilization plans (Chapter 26) for the various situations that may occur. In accordance with the discussion in Chapter 26 and numerous OSM/PWCC meetings, PWCC utilizes the Surface Stabilization Plan as the iterative process, (see Chapter 26, Figure 1) to develop the final postmining topography, utilizing the backfilling and grading guidelines discussed in this chapter and the regulations. The Annual Surface Stabilization Report will provide the regulatory authority the current status of the backfilling and grading in each reclamation area, and the proposed and existing drainage plans.

Postmining topography is presented on 1" = 400', plan scale, at a 10-foot contour interval. (Drawing No. 85352, 1" = 400' scale).

The postmining topography was developed for the current life of mine plan for each active pit area and proposed N-11 south extension. The 1" = 400' scale maps were developed from the latest aerial mapping. In addition, in subsequent years, the final postmining topography will be reevaluated during the implementation of the Surface Stabilization Program described in Chapter 26. The following discussion explains how the postmining topography was developed for the current and future mining areas.

The first step in developing the postmining topography was to develop range diagrams perpendicular to the existing and planned pits on approximately 1000-foot centers or less. Range diagrams are cross-sections illustrating how the overburden will be moved and the configuration of the final surface after mining is complete. The range diagrams were engineered utilizing software developed in-house from the PWCC geological model. A regraded surface was then developed for each range diagram assuming a cut/fill balance. Elevations were determined for points along the regraded surface. AutoDesk (LDD) then transferred these points back into the plan view using Land Development Desktop or similar engineering software. Using LDD and the elevation points from the range diagram, a primary postmining surface was developed. This surface was then adjusted by hand for regrading of ramps, to ensure all areas drained, and to tie the postmining topography into existing topography. The completed postmining surface is on Drawing No. 85352.

To ensure that all overburden is accounted for the total volume of overburden calculated and compared to the total overburden volume mined as determined by the current life of mine model. The total overburden volume was determined using LDD which compared the final postmining surface for each mining area with the lowest mineable coal seam



bottom surface and calculated the volume within each mining area. The lowest mineable coal seam bottom surface was developed using the current mine plan and the lowest mineable coal seam bottom-of-coal structure maps. The life of mine overburden volume for each mining area was calculated from the area mine model. The bank cubic yards (bcy) calculated from the mine model was swelled by 25% and then compared to the total overburden volume. This swell factor has been typically used by mining operations personnel for field planning and by the Mine Planning Department for various material calculations with no appreciable discrepancies discernable when material are actually handled. A study of the J-7 resource area determined an average swell factor approximately equal to 21.6 percent. A discussion of this study is presented in Attachment A.

The material balance results are shown on Table 1. As shown on Table 1, all volume comparisons are within  $\pm 5\%$ .

Topographic manipulation includes recontouring or reshaping of the spoil after coal removal in a manner that minimizes the potential for soil erosion and facilitates the establishment of a stable landform. Utilizing the methods described in the "Postmining Topography" section, an estimated postmining topography has been developed that is similar to the original landform (see Drawing No. 85352). Since implementation of the Surface Stabilization Program in 1990, PWCC utilizes the guidelines outlined for backfilling and grading in this chapter, Drawing No. 85352, the procedures outlined in Chapter 26, Figure 1, and the approved Surface Stabilization Program to develop the postmining landform. As a result of creating this landform, the postmining drainage network will also develop characteristics similar to the premining drainage system (see Chapters 15 through 19). The premining drainage network at the Kayenta Complex typically produces many deeply-incised channels, which develop supercritical flows during large precipitation events. In order to minimize these deeply-incised channels within the postmining drainage network, generally PWCC will utilize grass-lined swales in flatter graded interior spoil reclaimed areas, gradient terraces and swales, reclaimed downdrains, and reclaimed ephemeral and intermittent channels in steeper outslope, ramp, and final pit reclaimed areas to intercept surface runoff and convey runoff away from the reclaimed areas and to develop an adequate postmining drainage system.

The topographic manipulation process begins as the overburden is placed in the piles and the coal has been removed (see Chapter 26, Figure 1). The type of mining operation, the direction of overburden removal, and the final spoil pile configuration will begin to dictate grading operations and the development of drainage patterns in the reclaimed watershed. Once the spoil is placed in its final resting place, but before

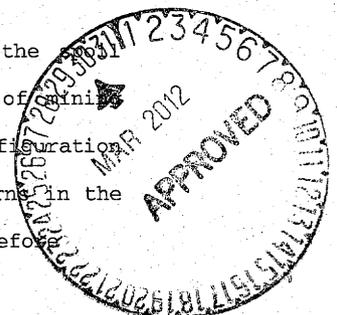
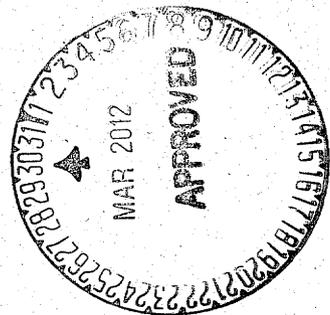


TABLE 1  
Postmining Landform Mass Balance

Item	N-7	N-6	N-16	N-12	N-21	N-9	N-10	N-11	N-11 EXTENSION	N-14
Total Overburden Mined (BCY) (1)	54,796,000	221,690,000	NA(4)	404,033,000	400,363,000	208,314,000	NA	116,727,000	250,279,900	NA
Total Overburden Mined (LCY) (2)	68,495,000	277,113,000	NA	505,042,000	500,454,000	260,393,000	NA	145,909,000	312,849,900	NA
Total Overburden (LCY)	67,325,000	281,665,718	NA	516,662,000	519,793,000	247,590,000	NA	141,078,000	343,600,000	NA
± Difference	1.7	5	NA	2.2	3.7	5.2	NA	3.4	9	NA
Notes:										
(1) BCY - Bank Cubic Yards										
(2) LCY - Loose Cubic Yards										
(3) TBD - To be Determined										
(4) NA - Not Applicable										



Revised 04/24/07

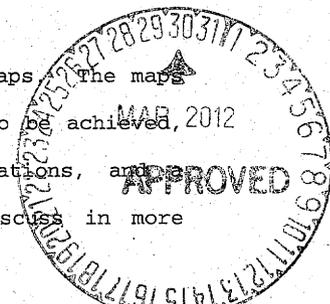
rough grading of the spoil peaks, the engineer will begin the preliminary design of conveyances as outlined in Chapter 26, Figure 1. This preliminary design will provide the preliminary watershed drainage plan, which will be used by the field reclamation crew for guidance in rough grading the spoil around and in the conveyance structure locations (i.e., reclamation channels and downdrains). This watershed drainage plan will be based on the engineer's estimate of the reclaimed watershed size, time of concentration, conveyance geometry, and other appropriate site-specific watershed characteristics. The preliminary watershed drainage plan will conform to the backfilling and grading requirements discussed in this chapter. This plan will guide the field reclamation crew during the rough grading operation, including general direction of dirt movement.

Once the rough grading has been initiated, the engineer will develop the final design of all conveyances including main reclaimed channels and main downdrains based on the preliminary drainage conveyance plan and the basic design data collected from the site. Before the topsoil is spread on the graded spoil, and after the graded spoil has been field checked for suitability criteria, the engineer will determine the watershed size and final location for all conveyances including gradient terraces, swales, and downdrains. Conveyance structure size, slope, and lining type will be designed based on updated topography data (see Chapter 26, Figures 1).

The majority of the area within each reclaimed resource area consists of graded interior spoil. These areas are relatively flat compared to other areas in the reclamation. Observations of surface mechanical manipulation and revegetation measures implemented to date appear adequate to control rill and gully formation in these areas. Revegetated swales are utilized in conjunction with the surface mechanical manipulation measures to control runoff and velocities. In other areas where slopes are steeper or where ephemeral drainages are designed to occur, including reclaimed outslopes, reclaimed highwalls, major reclamation channels, reclaimed ramps, and facilities areas, PWCC will use a combination of gradient terraces, reclaimed downdrains, or reclaimed ephemeral and intermittent channels to minimize erosion while still approximating the original landform.

#### Backfilling and Grading Procedures

The previous section described the development of postmining topographic maps. The maps generally depict the life-of-mine estimated approximate original contour to be achieved, all highwalls and spoil piles being eliminated, stable slope configurations, and a landform that supports the postmining land use. This section will discuss in more



detail, within the framework of the estimated postmining topography maps, the backfilling and grading activities to be performed during the surface mining and reclamation operations to achieve the landform configuration. The following section will describe the procedures to be utilized to establish a stable landform in the field. In addition, a detailed discussion of and design methodology for a surface stabilization plan is presented in Chapter 26.

The surface mining operation at the Kayenta Complex is a conventional form of strip mining, called area mining, wherein the overburden above the coal is removed in parallel strips across the coal field until the entire area is mined. Draglines excavate the overburden by creating wide trenches or cuts and piling the spoil along the side of the cut. When mining in a coalfield begins, the first cut is called a box cut and the dirt and rock material from the cut is called box cut spoil. This spoil differs from other spoil in that it is placed outside and adjacent to the cut being mined onto lands that have not been mined. The other spoil, internal spoil, results from cuts created after the initial box cut and is backfilled directly into the adjacent, previously mined cut.

Reclamation grading activities commence after the lowest mineable coal seam has been extracted and a sufficient amount of spoil material is available for grading. It has been Peabody Western Coal Company's experience that grading three or more spoils simultaneously produces more desirable reclamation results than grading one spoil at a time. This is more desirable because the creation of graded slopes consistent with the estimated postmining landform is primarily dependent upon the ability to perform "area grading" versus grading one or two spoil rows. Because of many variables encountered in the overburden removal process, it is very difficult to predict the exact, final configuration of the spoil. Thus, the final planning for reclamation grading must be performed after the spoil is created in order to grade the disturbed areas in a diverse manner such that surface irregularities are created to minimize erosion, improve range and wildlife habitat, increase topographic diversity, and increase infiltration and soil moisture holding characteristics for the revegetation process.

Although more than three spoil ridges may occasionally exist along irregular box cuts, certain inside and outside curves, and where haulage ramps exist in the pit, they will be relatively limited in extent. The Surface Stabilization Plan, Chapter 26, allows PWCC to maintain more than four spoil ridges when needed to develop the approved PMT. Once the pit configuration becomes regular and progresses into the field, rough grading will generally be accomplished when three spoil ridges exist. Creating an acceptable postmining landform is the primary consideration that determines the number of spoil ridges that may exist in the field. Once the spoil piles are reduced to the point that



equipment can be safely operated across the slope of the rough graded area, final grading is performed.

Box cut spoil is placed onto unmined land as described in Chapter 5, and shown on the Estimated Postmining Topographic Map, (Drawing No. 85352). Suitable topsoil, vegetation, and organic material are removed from the area where box cut spoil is excavated, placed, and graded.

Once sufficient spoil material is available, rough grading is performed with bulldozers, scrapers, maintainers, loaders/end-dump trucks, and occasionally, draglines. Typically, the process of grading begins with bulldozers building roadways into the ungraded spoil. Once access into the spoil is provided, dozers and/or scrapers move the spoil material in the direction required to achieve the desired landform and surface stabilization, begin establishment of reclaimed drainage networks, prepare for surface stabilization activities, and blend the material into the surrounding terrain. Planning for the box cut and internal spoil grading must necessarily consider factors including the mine plan, depths of seams to be mined, mining equipment, coal transportation networks, landform to be achieved, surrounding terrain, natural surrounding drainage networks, and reclaimed drainage networks. At the Kayenta Complex, the box cuts are usually at a lower surface elevation relative to the remainder of the cuts in the coal resource area. Being at a lower elevation, the reclaimed drainage network will usually exit the reclaimed lands through a box cut area and the in-pit coal transportation ramps will typically originate from the box cut area. It is therefore logical that, where practicable, reclaimed drainages can generally be located at and exit from the reclaimed areas through these haulage ramps.

During the mining operations, spoil is placed to accommodate haulage ramps. When reclamation grading begins on the spoil in ramp areas, the material is typically used to create reclaimed drainages and to facilitate the construction of other surface stabilizing controls. All box cut outslopes are graded to as shallow a slope as practicable but not steeper than 4(H):1(V). Postmine hillslope gradients will be measured and averaged from the crest to toe. Short segments may be steeper to accommodate landform blending by native areas and reconstructed drainages. It is also anticipated that some box cut spoil grading will create a separation between an undisturbed receiving drainage and the reclaimed drainage in order to control the reclaimed drainage slope and/or exit location. This is evident when reviewing the estimated postmining topography of the J-19 resource area (Drawing 85352).



Box cut spoil may also be placed and graded onto natural uphill slopes. The reclaimed lands are configured to accept drainage in a stable manner and allow water to flow through or along the reclaimed area. It is important to realize that sufficient spoil material is necessary in order to provide the flexibility needed to adequately configure drainage into, through, along, and out of the reclaimed areas. Since box cut spoil material is configured to blend with the natural topography, create drainage networks, and achieve the postmining land use, surface stabilization measures such as contouring, swales, and terraces may be employed in addition to limiting the steepness and length of slopes, creating concave slopes, and providing a roughened surface for placement of suitable plant growth media.

As the mining and reclamation activities progress through the box cut area into the coal field, the internal spoil material becomes relatively regular, varying as the original topography varies. The grading operations are conducted to continue the established drainage networks and other topographic manipulations and to achieve the estimated postmining landform. The internal slopes are relatively flat but complimentary of the drainage networks.

When a resource area has been completely mined, one of two final cut types will exist. One type, a double final cut, does not result in a final highwall and the other, a single final cut will create a final highwall. The J-19 West, N-6, N-11, and N-14 coal resource areas conclude with double final cuts. The J-7, J-19, J-21, N-9, and N-11 Extension (N-99) coal resource areas will conclude with single final cuts. The remaining coal resource areas, J-16 and N-10, are the only two areas that would conclude with a final highwall at a recovery or cropline.

Final pit grading depends on the type of final cut. Double final cut grading will backfill the cut with spoil material. Slopes into the primary drainages will be in a concave configuration and the postmining primary drainage network will be constructed to be stable in order to ensure that the postmining land use will be achieved. Single final cuts will be backfilled with spoil material and, if necessary, material from the final highwall. Blasting a portion of the highwall and/or ripping the material with dozers and hauling or dozing it into the final cut will ensure stable contours, adequate backfill material is obtained, and an adequate drainage network are achieved. Appropriate measures will be taken to conserve suitable plant growth media. Final slope grading will produce slopes as flat as practicable but no steeper than 3(H): 1(V) to create large wide swales where complete backfilling is not practicable. Postmine hillslope gradients will be measured and averaged from the crest to toe. Short segments may be steeper to accommodate landform blending by native areas and reconstructed drainages. It is



anticipated that intensive planning and grading activities as described in Chapter 26 will be necessary to reclaim the final cut and highwall to provide stable flow through drainage, blend any inflow from undisturbed drainages into the reclaimed area, and to minimize erosion.

Waste materials are not used for fill. Mining waste materials, in the form of rider seams, carbonaceous shale, materials with high sodium adsorption ratio (SAR), and high sulfur materials, when encountered, are buried under a minimum of four feet of noncombustible material (see Chapter 22).

Coal waste generated at the coal handling facilities is essentially nonexistent since rejected coal is recycled through the crushers or processed through a screening system and secondary crusher until proper size specifications are achieved. Non-coal waste consisting principally of rock is estimated to amount to less than 0.025 percent of the total material processed at the coal handling facilities. This rock material is returned to an active pit and covered with spoil material.

Until it was closed in 1997, Peabody operated an OSM approved solid, non-coal waste landfill in the mined-out J-3 coal resource area. The type of materials excluded from the J-3 Landfill prior to Closure and the operations plan for the landfill can be found in Appendix C, Volume 12. PWCC has contracted with a solid waste vendor to pickup and haul the solid waste material off-site to a regulated landfill, (see the Solid Waste Disposal section in Chapter 6, Volume 1).

#### Graded Spoil Stability

Several studies have been performed to investigate the stability of graded spoil on Black Mesa. In the fall of 1981, Water, Waste and Land, Inc. of Fort Collins, Colorado investigated the stability of spoil for use in the creation of internal impoundments. Graded spoil heights of 100 feet and 3:1 slopes were investigated. The investigators concluded that the wet zone caused by the infiltration of water downward from a ponding area would not be expected to create a phreatic surface within the slope of the spoil. No ground-water mound would be expected to develop to a height that would affect the stability of the graded spoil slopes. The case where an embankment was to be placed across a drainage with seepage through the foundation was also investigated. Test pits were developed in spoil in the J-3 and N-6 mining areas. Using conservative data safety factors of 1.9 for static loading and 1.35 for earthquake loading conditions were computed (Volume 27, Appendix D).



In June, 1984, Sergent, Hauskins & Beckwith, consulting geotechnical engineers performed slope stability analyses for graded slopes on the exterior of the southwest portion of N-14. Analyses were performed for existing conditions and also assuming a maximum spoil height of 200 feet and a 3:1 slope. Static safety factors of 3.09 and 4.20 were determined for two existing slopes. Using the maximum height and slope assumptions given above, a safety factor of 2.25 was calculated. The ground-water table could rise from no saturation (existing situation) to saturation within 40 feet of the crest before the safety factor would be reduced to 1.5 (Sergent, Hauskins & Beckwith, 1984).

Given that the material in J-3, N-6, and N-14 as examined in these analyses is generally representative of the range of spoil characteristics experienced on the Mesa, maximum slopes are 3:1, and no phreatic surface would be expected to develop except in the immediate vicinity of internal impoundments, no spoil stability problems would be expected to develop.

Based on the above and past experience at Black Mesa, the probability of slides occurring is low; however, at any time should a slide occur which results from mine-related activities and which may have a potential adverse effect on public property, health, safety, or the environment, Peabody Western Coal Company will notify OSM of the occurrence of the slide and the remedial measure proposed to be undertaken.

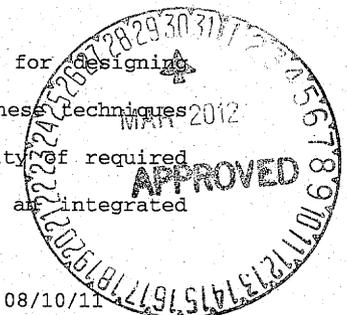
#### Affected Lands

A total of 64,858 acres of land have been leased to Peabody on Black Mesa for the purpose of mining. The Black Mesa Complex proposed life-of-mine permit area contains approximately 62,930 acres of land, (see Chapter 3, Attachment 6). Estimated disturbances for each mining area may be found in Chapter 20.

The major disturbances due to the mining operation include the area actually mined and the area upon which spoil is deposited and graded. The approximate areas of major disturbance are shown on the Jurisdictional Permit and Affected Lands Map, Drawing No. 85360.

#### Future PMT Design Techniques

PWCC will evaluate and implement where feasible geomorphic principles for designing postmine topography (PMT) at the N-11 extension (N-99) and N-9 areas. These techniques may allow a more stable surface to be designed that minimizes the quantity of required terraces and maintenance. The resulting postmine topography will be an integrated



combination of geomorphic principles, drainages, engineered structures, and BTCA practices.

Using these principles, PMTs are developed as follows:

- Final spoil and high wall topography is created using PWCC range diagram cross-sections. Final ramps and high walls were also located in the spoil topography.
- Cross-sections were taken through the spoil topography at intervals of approximately 500' usually at 90-degree from the final pit. Additional sections were added for ramps, drainages, and existing ridgeline continuation.
- During the cross-section design phase, slopes on the final high wall are 3.0:1 or flatter and internal slopes are 4.0:1 or flatter. Cut/fill balance was maintained with each cross-section. Some cross-sections had drainages influencing the amount of material available to fill in the pit. An example is the final high wall on the lower eastside of N-9; the drainage channel would be routed through the final pit and through the N-C Pond drainage channel. The drainage slope was maintained at 0.5%-1.0% so fill material was also restricted.
- A preliminary PMT topography was generated for review. Modifications are made to the topography for routing out drainages and mass balancing. This process is repeated until all drainage is routed off the PMT and Mass Balance is within 5%.
- Drainages using meandering was utilized in certain areas, but with a 10-ft contour interval; meanders are sometimes not clearly shown. The larger meanders are shown in the final pit areas.

Following is a presentation of the comparison of the N-9 Pre- and Post-Mining slopes, (see Table below). With PWCC's proposed PMT Maps, about 436 acres are shifted from slopes steeper than 25% to the 0%-25% categories with over 60 percent shifted to the 0%-13% slope categories. These flatter slopes will allow more of the reclaimed land to be used by livestock and local residents.



KAYENTA MINE

N-9 MINING AREA

SLOPE EVALUATION:

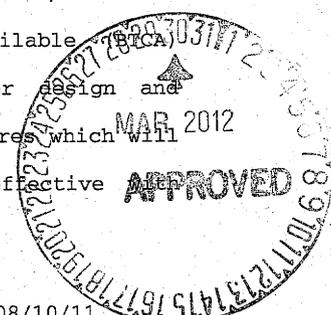
SLOPE %	(ACRES)		POST vs. PRE (ACRES)
	PRE-MINING	POSTMINING	Difference
0 to 9%	364	457	93
9% to 13%	235	411	176
13% to 18%	271	385	114
18% to 25%	282	335	53
25% to 33%	194	0	-194
Greater than 33%	242	0	-242
TOTAL AREA:	1588	1588	0

PWCC's PMT maps have historically been produced on a 10 ft. contour interval and a 1"=400' map scale. In the N-9 mining area, PWCC commits to reclaim the postmining drainage areas to a similar drainage density as the premining drainage areas. PWCC will fine-tune the drainage network as required prior to bond release approval.

PWCC will minimize using terraces when designing and implementing the postmine drainage network. On March 4, 2002, the Surface Stabilization Plan was evaluated, modified, and approved reducing the terrace density (by 20 to 50 percent) required for postmine lands. This reduction was justified based on site-specific soil and vegetation monitoring data. PWCC will continue to evaluate vegetation success related to stability, slope erosion, and terrace spacing in an attempt to reduce terrace installation whenever feasible and practical. Drawing No. 85352, Sheet Nos. K-6 and K-7 shows the N-9 PMT slopes as refined will be stable, erosion will be minimized, and the approved postmine land use will be met.

PMT Design Using Geomorphic Principles

Chapter 26, Surface Stabilization Plan (Plan) presents PWCC's detailed program for establishing a reclaimed landscape that will be effective in providing long term erosion control. As described in Chapter 26, it takes into account site parameters, material properties, reclamation procedures, and Best Technology Currently Available practices that are most applicable; it provides detailed criteria for design and implementation of the various stabilization measures; and it provides measures which will insure the implemented stabilization program remains functional and effective with minimal maintenance.



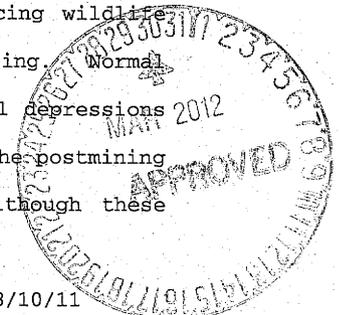
Attachment A to Chapter 26, Reclamation Scale Geomorphology, presents supporting information related to the Plan including sediment transport observations based on monitoring and modeling data, geomorphic characteristics of an adjacent un-mined watershed, and ranges of select geomorphic characteristics proposed to be used as sideboards for designing and constructing reclaimed watersheds in mined coal resource areas (CRAs) within permanent program areas at the Kayenta Complex. Geomorphic characteristics with sideboards include hillslope lengths and gradients, channel gradient, sinuosity, drainage density, and terrace lengths and gradients.

Using steps one through five as outlined in the previous section of this Chapter (Future PMT Design Techniques) and Chapter 26, Surface Stabilization Plan, a preliminary PMT will be developed. Modifications to the PMT will then be made for establishing preliminary drainage networks and mass balancing that ensure select geomorphic characteristics are within the sideboard values provided in Table 1 of Attachment A to Chapter 26. This process is repeated keeping the select geomorphic characteristics within sideboard values until the Mass Balance is within five percent.

PMTs that are developed to achieve Mass Balance criteria within five percent and exhibit geomorphic characteristics within the sideboard values will result in preliminary drainage networks that will be used as templates for developing grading plans and creating drainage patterns and hillslope configurations for reclaimed watersheds during the rough grading phase (see Chapter 26, Surface Stabilization Plan).

#### Small Depressions

During the process of final grading, small depressions may be established within reclaimed landscapes on an opportunistic basis pursuant to 30 CFR 816.102(h). These features will enhance postmining topographic diversity, promote landscape stability, and act as seasonal opportunistic surface water collection sites that retain water for short periods of time. Small depressions will serve as wildlife enhancement features and micro-topographic niches for establishment of unique plant species. The small depressions will also provide seasonal, opportunistic, short-term livestock water sources aiding in grazing distribution. These small depressions will be beneficial for minimizing erosion, conserving and retaining moisture, creating and enhancing wildlife habitat, increasing species diversity, and assisting revegetation and grazing. access throughout the postmine landscape will not be restricted by the small depressions nor will they constitute a hazard. Small depressions may occur throughout the postmining landscape where they are compatible with the stability of the fill. Although these



depressions will not have specific design criteria, they will be small enough that they will occur within the limits of the approved AOC. These small depressions will also meet the following specific criteria:

- Each depression or combination of directly adjacent depressions will be less than one acre foot total capacity,
- No depression will be deeper than 10 feet,
- All small depressions will be incised (below ground level),
- The in-ponding area slopes for the small depressions will be 5:1 or flatter, and
- At bond release, small depression areas will be subject to vegetation sampling similar to any area within the bond release parcel.

#### In-channel Pools

During the process of establishing final drainages in the reclaimed landscape, in-channel pools may be developed as opportunities occur. These features will be unique and are not considered to be permanent impoundments. Similar to small depressions, in-channel pools will enhance postmining topographic diversity, promote reclaimed stream channel stability, provide additional sediment control, attenuate flows, and act as seasonal opportunistic surface water collection sites that retain water for short periods of time. In-channel pools will serve as wildlife enhancement features and provide unique site conditions for establishing species and communities adapted to more mesic site conditions. The in-channel pools will also provide seasonal, opportunistic, short-term livestock and wildlife water sources aiding in grazing distribution and meeting critical habitat needs. These in-channel pools will be beneficial for minimizing sediment loss, conserving and retaining moisture, creating and enhancing wildlife habitat features, increasing species and community diversity, and enhancing revegetation and grazing management. Normal access throughout the postmine landscape will not be restricted by the in-channel pools nor will they constitute a hazard. The in-channel pools may occur in all but the uppermost reaches of drainages throughout the postmining landscape where they are compatible with the stability of the fill. The in-channel pools will be incised with no structure and the pooling area will be confined to the incised in-channel pool area. Although these in-channel pools will not have specific design criteria, they will be small enough so as to occur within the limits of the approved AOC. These in-channel pools will also meet the following specific criteria:

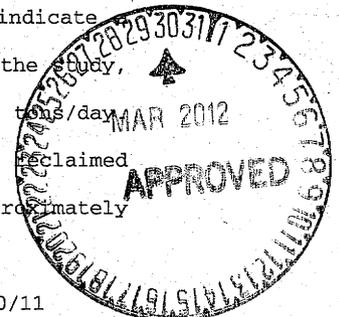
- Each in-channel pool will be less than 1.5 acre feet total capacity,
- No in-channel pool will be constructed within 50 feet up- or down-stream of an adjacent in-channel pool,



- No in-channel pool will be deeper than 5 feet,
- All in-channel pools will be incised (below ground level),
- The maximum percentage of a given total channel reach length where in-channel pools will be constructed will not exceed 25 percent,
- The in-channel pools widths will be no wider than the designed channel top width,
- The side slopes for the in-channel pools will be 10:1 or flatter in the direction of flow and 4:1 or flatter for slopes perpendicular to the channel, and
- At bond release, in-channel pool areas will be subject to vegetation sampling similar to any area within the bond release parcel.

Average annual sediment yields have been calculated for more than 4,000 acres of reclaimed mined lands at the Kayenta Complex using a watershed model (EASI). The model was developed based on a nine-year study of small watersheds on Black Mesa between 1984 and 1992. An average annual sediment yield of 3.2 tons/acre was predicted for reclaimed watersheds in the N1 and N2 areas, and this value takes into account both hill slope and channel erosion. An average annual sediment yield of 0.78 tons/acre was calculated for reclaimed hill slopes in the N7/N8 mining area, and represents hill slope erosion only. Based on recent measurements of representative in-channel pools found in the J16 reclaimed mining area, one of the largest measured featured a volume of 10,350 cubic feet. The contributing drainage area is about 160 acres. Annual sediment yield representative of both hill slope and channel erosion (3.2 tons/acre) would generate about 11,600 cubic feet of sediment and could completely fill this in-channel pool during one year of average precipitation. Annual sediment yield that only represents hill slope erosion controlled by terraces (0.78 tons/acre) would generate about 2,700 cubic feet of sediment, and could fill this in-channel pool in less than 4 years. Considering average annual sediment yields predicted for more than 4,000 acres of reclaimed areas on Black Mesa, typical in-channel pools may fill in within one year if active channel erosion processes prevail above each pool, and may persist as long as four years if only hill slope erosion is the predominate contribution of sediment to the in-channel pools.

Measurements of stream flow sediment concentrations have been collected during a range of runoff events at stream monitoring sites located in both reclaimed and undisturbed watersheds on Black Mesa as part of the small watershed study. Sediment rating curves, which depict the relationship between stream discharge (cfs) and sediment discharge (tons/day), have been developed using this information. The rating curves indicate discharge of 10 cfs is representative of the higher discharges measured during the study, and the corresponding sediment discharge for this large event is about 1000 tons/day. Based on the sediment rating curves developed from data collected in reclaimed watersheds, a large runoff event of 10 cfs or greater would generate approximately



22,700 cubic feet of sediment that could be deposited in the in-channel pools. This is more than double the size of the large in-channel pool found in the J16 reclamation mentioned above, and suggests one very large runoff event in a reclaimed area at the Kayenta Complex could generate enough sediment to completely fill in several of the larger in-channel pools constructed.

Regardless, the life of in-channel pools constructed in reclaimed stream channels at the Kayenta Complex will depend on the magnitude, duration, and frequency of runoff events, sediment delivery characteristics and sediment yields. Channel erosion is a dynamic process, and can cause stream channel beds to aggrade or degrade depending on local channel geometry and gradient, and the amount of sediment transported. The capacity of a stream channel to transport sediment and the amount of sediment available to transport both govern whether sediment deposition occurs or whether the stream channel bed scours. Hill slope erosion processes will likely dominate in the post-mining landscape as opposed to channel erosion processes, as channel design and construction methods will result in relatively stable stream channels in comparison with the sand-bed channels that have been formed in the surrounding natural landscape on Black Mesa. In-channel pools constructed in stable reclaimed stream channels should persist for several years until sediment contributions from upland hill slopes and to a lesser extent the upstream channel beds and banks eventually fill these in. Once the in-channel pools fill in, the stream channels will continue to adjust according to the variability of runoff events and the sediment transported during each runoff event.

Literature Cited

Sergent, Hauskins & Beckwith, Consulting Geotechnical Engineers. Geotechnical Investigation Report. SHB Job No. E84-100. June, 1984.

