SECTION 34

POST-RECLAMATION TOPOGRAPHY

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SECTION 34

POST-RECLAMATION TOPOGRAPHY

LIST OF REVISIONS DURING PERMIT TERM

REV. NUMBER	REVISION DESCRIPTION	DATE APPROVED

SECTION 34 POST-RECLAMATION TOPOGRAPHY

34.1 Post-Reclamation Final Surface Configuration

Through the mining process the original or pre-mine surface configuration and surface contours are altered. Reclamation plans are based on grading the mined areas to meet specific criteria outlined in this section. In order to ensure that these criteria will be met and the material balance maintained, the designs of a new topographical surface are created based on current mine plans and features for a given operating area. This replacement surface is defined as the final surface configuration (FSC) or approximate original contours (AOC); the terms can be used interchangeably within this permit application package. Refer to Exhibit 34.1-1 for FSC designs for Pinabete ~~Mine Plan permit~~ Permit area (permit area). Reclamation plans are based specifically around meeting the drainage requirements of this FSC surface. Because this FSC surface is created from a modeled post-mine surface, the actual contour configuration of the reclaimed topography may deviate from the design FSC. The locations, configurations, and sequence of mining operations and features may vary slightly from preliminary plans (e.g., ramp centerline locations, dragline plug locations). However, these deviations will not be significant. The actual reclaimed surface will closely approximate the approved FSC and this surface will ensure current FSC drainage designs are maintained, meet the requirements this section, and ensure a material balance.

BHP Navajo Coal Company (BNCC) will utilize both traditional and fluvial geomorphic reclamation approaches to develop the FSC for the ~~Pinabete P~~permit area. These reclamation approaches are discussed further in Section 38 (Post-Reclamation Surface Stabilization and Sediment Control). The combination of these approaches enables BNCC to meet the objectives of the FSC as described below:

1. Achieve mass balance while maximizing contemporaneous regrade acreage between ramps,
2. Achieve positive drainage, except for the small depressions mentioned below, from all areas including pits and ramps,
3. Develop an adequate drainage density,
4. Allow development of stable drainage channels,
5. Support the approved post-mining land use.

The fluvial geomorphic reclamation approach utilizes site-specific fluvial geomorphic data, including but not limited to drainage density, tributary lengths and associated areas, sinuosity, width to depth ratios, and length between channels, to develop a reclamation surface model that generally mimics the natural landscape. The ~~field reconnaissance activities and technical evaluation used to develop the~~ fluvial geomorphic design input values that are used in the Pinabete FSC design ~~for Area 4~~ are included in Appendix 34.A.

The slope analysis for the post-reclamation final surface~~ in Area 4 North and Area 4 South~~ is provided in Table 34.1-1. A comparison between the pre-mine slopes, described in Section 13 (Topography) and post-reclamation slopes is provided in Figure 34.1-1.

Field Code Changed

34.1.1 AOC Exemption for Thin Overburden

BNCC is not requesting an AOC exemption for thin overburden. Therefore, this section is not applicable to the permit area.

34.1.2 AOC Exemption for Thick Overburden

BNCC is not requesting an AOC exemption for thick overburden. Therefore, this section is not applicable to the permit area.

34.1.3 Highwall Elimination Exemption for Operations on Previously Mined Areas

BNCC is not requesting a highwall elimination exemption on previously mined areas, as there are no previously mined areas that contain preexisting highwalls within the permit area. Therefore, this section is not applicable to the permit area.

34.1.4 AOC Variance for Mountaintop Removal Operations

BNCC is not requesting an AOC variance for mountaintop removal, as this is not a mountaintop removal operation. Therefore, this section is not applicable to the permit area.

34.1.5 AOC Variance for Steep Slope Mining Operations

BNCC is not requesting an AOC variance for steep slope mining, as this is not a steep slope mining operation. Therefore, this section is not applicable to the permit area.

34.2 Backfilling and Grading Plan

Overburden and parting materials are removed by a dragline and cast into the adjacent mined-out cuts. Such placements create spoil ridges (rows) or peaks, which need to be backfilled and/or graded. ~~BNCC contracted Norwest Corporation (Norwest) to develop a~~A post-mining ~~topography~~ configuration (PMC~~T~~) (Exhibit 34.2-1) was created, based on a computer simulation of mining in ~~Area 4 North and Area 4 South~~the ~~Pinabete~~ permit area. The computer simulation models the mining methods and dragline operation to create simulated PMC~~T~~. The PMC~~T~~ was then used to optimize the mass balance of the FSC design (Exhibit 34.1-1).

By combining the PMC~~T~~ and FSC designs, BNCC is able to develop mass-balanced logical reclamation blocks (Exhibit 34.2-2) for the mining area. Unbalanced surplus material will be redistributed within the reclamation blocks, and is not expected to significantly affect the overall FSC design. Backfilling and

grading will be completed in these logical reclamation blocks, which follow the stripping sequence~~, and allow for large areas to be regraded at one time~~.

These reclamation blocks will provide for a ~~more~~ consistent topography between regraded areas. In most cases, these logical reclamation blocks become available every 1 to 3 years in each mining area. The scheduling of these backfilling and grading blocks will result in a distance between the previous regraded area and the active pit; however, this distance will be operationally advantageous and improve the reclamation process as it will allow for larger areas to be reclaimed at one time. Less area will need to be re-disturbed to tie into existing reclaimed areas. Larger portions of the post-mine watersheds can be constructed at a single time, thereby reducing the number of temporary drainage and sediment control structures. Topdressing, revegetation, and irrigation operations will be operationally easier and more efficient at larger scales than in small irregular blocks. The areas around active ramps and final pits will remain ungraded until all mining activities are complete in order to preserve the material required to fill in these features.

Backfilling and grading operations of each logical block are divided into primary and secondary operations.

Primary regrading utilizes track dozers to level off the spoil ridges. Primary regrading will be accomplished as necessary to accommodate the FSC and the ~~regrading~~ backfilling and grading schedule (Table 51.1-1) in Section 51 (~~refer to Table 51.1-1~~ Reclamation Schedule). Some pits and ramps might not have sufficient backfill material readily available for track dozers to adequately regrade the area. In these instances, supplemental equipment may be used to facilitate primary regrading activities. This equipment includes, but is not limited to, scrapers, draglines, and end-dump trucks working with a large front-end loader.

Several areas may require delays in reclamation in order to facilitate reaching the desired post-mining topography. Changes or fluctuations in the dragline stripping sequence may cause variations in spoil placement, resulting in localized peaks or valleys that may require regrading equipment and cause primary regrading delays. Unregraded spoil areas of the mine are subject to applicable effluent standards and fugitive dust emissions. Refer to Section 25 (Sediment Control Plan), Section 26 (Drainage Control Plan) and Section 40.8 (Fugitive Dust Control Plan) for details discussion of the control measures associated with these plans.

Secondary regrading may, if needed, follow primary grading for additional contouring of the land surface to accommodate topdressing replacement. At this time, any special water control or wildlife habitat features will be constructed.

During the process of secondary grading, small depressions may be established on an opportunistic basis. These features will enhance post-mining topographic diversity and act as seasonal surface water collection sites. Small area depressions are discussed in Section 34.2.3.

Highwalls and ramps will be backfilled and graded per FSC maps shown in Exhibit 34.1-1. Portions of highwalls may remain in the FSC surface to replace natural escarpment features for wildlife habitat. Natural escarpment features and other wildlife habitat features are discussed in Section 38 (Post-Reclamation Surface Stabilization and Sediment Control) and Section 39 (Fish and Wildlife Enhancement).

BNCC will strive to reclaim the lands disturbed by mining activities through the implementation of established fluvial geomorphic principles (Dunne and Leopold 1978; Rosgen 1996); however, in some instances this approach might not be feasible or applicable. In these instances, BNCC will implement a traditional reclamation approach based on "hard-engineered" structures. Geomorphically appropriate slopes do not have the same design constraints as traditional reclamation approach slopes. Geomorphically appropriate slopes are dependent on their position within the landscape. Areas higher in the watershed may have steeper slopes, while areas lower in the watershed will have shallower, or flatter, slopes. Post mining FSC slopes within ~~Area 4 North and Area 4 South Pinabete~~ permit area are presented in Table 34.1-1 and compared with pre-mining slopes in Figure 34.1-1. Interior slopes constructed using the traditional reclamation approach will have grades equal to or less than 6.5 horizontal to 1 vertical (6.5h:1v). Outslopes constructed using the traditional reclamation approach will have grades less than or equal to 4h:1v. The overall slope for both the fluvial geomorphic and traditional reclamation approaches will be measured from the crest to the toe of the slope. Post-reclamation drainages and reclamation approaches are discussed in further detail in the Hydrologic Reclamation Plan (Section 35) and in the Post-Reclamation Surface Stabilization and Sediment Control Plan (Section 38).

Field Code Changed

Regraded lands are blended into the surrounding topography to establish drainage patterns, and the post-mining land use of range livestock grazing will be unimpaired following topdressing distribution and revegetation.

The mining operations, described in Section 20 (Mining Operations), will not generate any coal mine waste or coal processing waste as defined by 30 CFR 701.5.

The plans to minimize erosion and water pollution during backfilling and grading, and descriptions of the post-reclamation drainage and permanent impoundments is described in Section 38 (Post-Reclamation Surface Stabilization and Sediment Control) and Section 35 (Hydrologic Reclamation Plan).

34.2.1 Covering Acid-Forming and Toxic-Forming Materials and Combustibles

BNCC may encounter strata that contain limited quantities of potentially acid- and toxic-forming materials (PATFM). Based on the geologic description and overburden characterization in Section 17 (Geologic Information), the quantity of PATFM will be minimal and thus does not require special handling and disposal procedures.

BNCC will not generate coal mine waste or coal processing wastes. Small quantities of spilled coal and coal materials that do not meet quality standards (e.g., low BTU) will be hauled to mined-out areas and free dumped along the bottom of the pit or placed in an alternate location where the materials will not adversely affect reclamation operations. This coal material represents a low combustion risk; however, BNCC will follow the procedures discussed in the combustibles and coal mine waste fire control plan in Section 20 (Mining Operations) in the event that the material does combust.

The small quantity of PATFM and coal materials placed in mined-out areas will be handled in a manner that protects the environmental resources and will not impact surface drainages or the FSC. The handling and disposal procedures for these materials are presented in Section 20 (Mining Operations).

34.2.2 Post-Reclamation Slope Stability

The FSC surfaces for ~~Area 4 North and Area 4 South~~~~Pinabete~~ the permit area have been designed using a combination of fluvial geomorphic and traditional reclamation approaches. Areas designed with the fluvial geomorphic reclamation approach will contain geomorphically appropriate slopes, drainage densities, and channel profiles to mimic the pre-mine topography. Areas designed with traditional reclamation approaches will have interior slopes graded to less than or equal to 6.5h:1v overall and outslopes graded to less than or equal to 4h:1v overall. The designed slopes contained in the FSC surfaces have been designed to eliminate slopes at angle of repose and minimize the risk of slides. ~~Slopes of the FSCs for both Areas 4 North and Area 4 South are presented in~~ Table 34.1-1~~.~~

BNCC may include natural escarpment replacement features (e.g., thin exposed areas of end walls or final pits) into the final FSC. These features will enhance the wildlife habitat of the post-reclamation topography. The natural escarpment replacement features will typically be less than 15 feet in height and less than 500 feet in length and have a safety factor of 1.3 or greater. The criteria for designing natural escarpment replacement features are described in Section 38 (Post-Reclamation Surface Stabilization and Sediment Control).

34.2.3 Small Depressions and Final Surface Preparation

Small depressions may be established on an opportunistic basis during secondary regrading. These features will enhance post-mining topographic diversity and act as seasonal surface water collection sites. Small

depressions will serve as wildlife enhancement features and microtopographic niches for establishment of mesic and/or hydric plant species. Although these depressions will not have specific design criteria, they will be small enough that they will occur within the limits of the approved FSC. These small depressions will also meet the following specific criteria:

- Each depression or combination of directly adjacent depressions will be less than 1 acre foot total capacity;
- No depression will be deeper than 10 feet
- All small depressions will be incised (below ground level);
- The maximum inslope for the small depression will be 6h:1v;
- At bond release, small depression areas will be subject to vegetation sampling similar to any area within the bond release parcel.

Small depressions meeting the design criteria listed above will not require design approval prior to construction from the Office of Surface Mining Reclamation and Enforcement (OSM). However, OSM must authorize the retention of small depressions prior to final bond release.

34.3 Post-Reclamation Topography Collection and Analysis

~~Norwest developed t~~The initial PMC~~T~~ surface model was developed using QUICKSURF™ software and dragline spoil modeling techniques that jointly operate in an AutoCAD environment. ~~Their surface model was based on inputs provided by BNCC.~~ The~~se~~ PMC model inputs included, but are not limited to, the operational mine plan, material swell factors and geologic modeling. This final PMC~~T~~ was used ~~by Norwest~~ to design the FSC, develop the cut/fill contours, reclamation blocks, and perform volumetric calculations for ~~Area 4 North and Area 4 South~~ the ~~Pinabete~~permit area.

Along with the final PMC~~T~~ surface, ~~Norwest utilized~~ site-specific field measurements and Carlson Natural Regrade with GeoFluv™ were used to develop the FSC surface. Appendix 34.A ~~describes in~~includes further details of the ~~field investigations~~model inputs~~,~~ and FSC design criteria~~, and FSC surface~~.

BNCC performed the post-~~mining~~ reclamation slope analysis of the FSC using ArcGIS™ geographical information system software with the Spatial Analyst™ and 3D Analyst™ software extensions. Utilizing a combination of triangular irregular network (TIN) surfaces and raster datasets, BNCC was able to calculate the percent slopes and determine percentage of permit area for each slope class in 3% slope increments. For a more detailed discussion on the slope analysis, see the pre-mine slope analysis discussion in Section 13 (Topography).

34.4 Certification of Designs and Exhibits

All certified exhibits for this section of the permit application package are available for review upon request at the mine office or OSM, Western Region, technical office in Denver, Colorado. Certified as-built drawings will be kept on file at the mine site and made available upon request.

Personnel

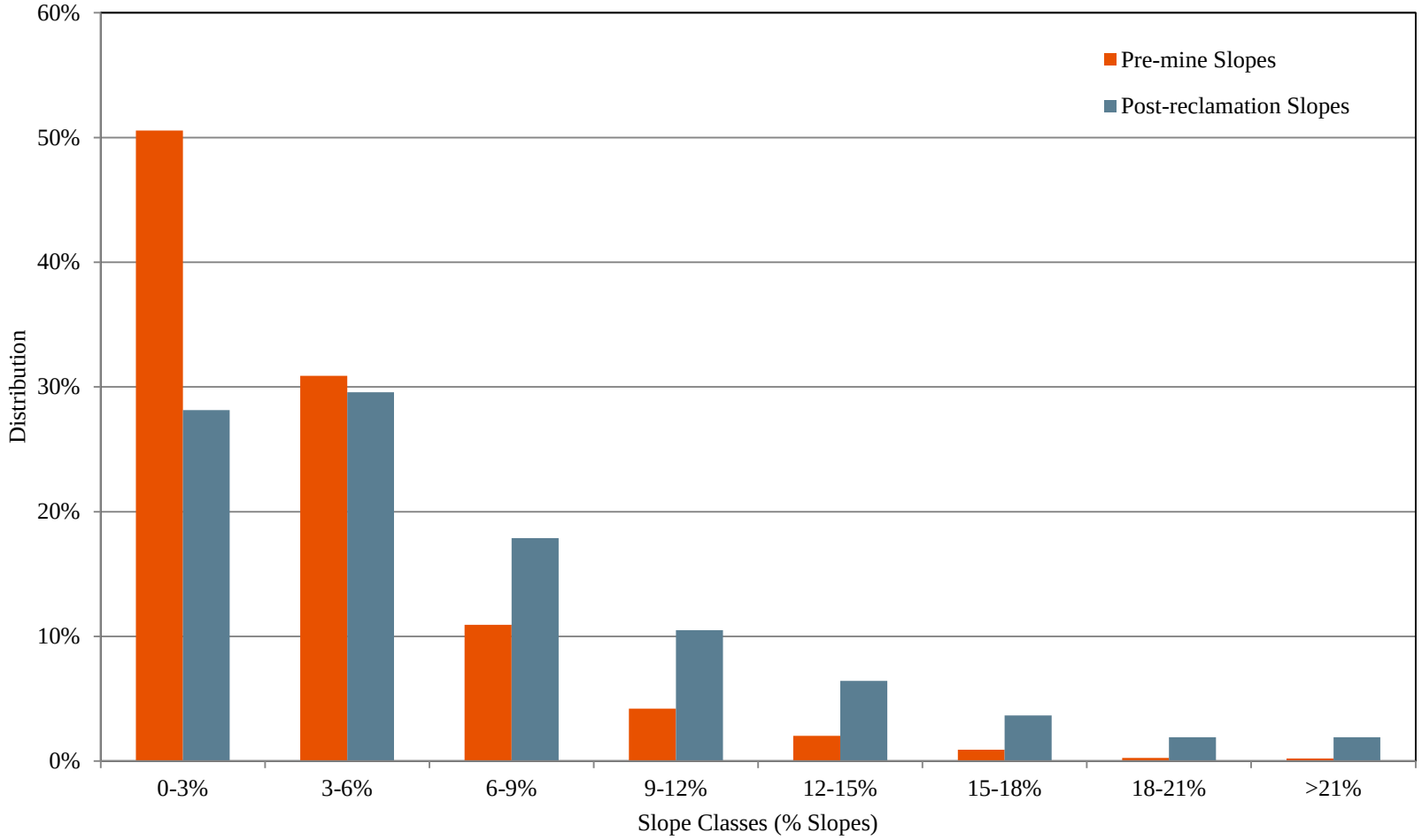
Persons or organizations responsible for data collection, analysis, and preparation of this permit application package section:

Ron Van Valkenburg	Norwest Corporation
Kent Applegate	Salt Lake City, UT
Matt Owens	
BHP Navajo Coal Company	

References

Dunne T., and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Feeman, San Francisco, California.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.



Notes:
- Pre-mine slope analysis is provided on Table 13.1-1
- Post-reclamation slope analysis is provided on Table 34.1-1

Figure 34.1-1 Histogram Comparison of Pre-mine and Post-reclamation Slopes

Table 34.1-1 Post-Reclamation Final Surface Configuration Slope Analysis for Area 4 North, Area 4 South, and the Pinabete Permit Area

Slope Class	Area 4 North Resource Area		Area 4 South Resource Area		Pinabete Permit Area	
	Acres	Percent (%)*	Acres	Percent (%)*	Acres	Percent (%)*
0 – 3%	~~1,598.3~~1,189.4	~~38.7~~29.1	~~478.7~~377.9	~~33.2~~25.5	~~2,076.9~~1,567.5	~~37.3~~28.1
>3 – 6%	~~1,298.4~~1,196.1	~~31.4~~29.3	~~455.1~~450.4	~~31.6~~30.4	~~1,753.6~~1,646.4	~~31.5~~29.6
>6 – 9%	~~552.2~~701.9	~~13.4~~17.2	~~238.2~~293.3	~~16.5~~19.8	~~790.4~~995.1	~~14.2~~17.9
>9 – 12%	~~370.7~~418.1	~~9.0~~10.2	~~136.0~~166.8	~~9.4~~11.3	~~506.7~~584.8	~~9.1~~10.5
>12 – 15%	~~242.0~~265.4	~~5.9~~6.5	~~85.6~~92.4	~~5.9~~6.2	~~327.6~~357.8	~~5.9~~6.4
>15 – 18%	~~50.0~~154.1	~~1.2~~3.8	~~24.2~~50.4	~~1.7~~3.4	~~74.2~~204.4	~~1.3~~3.7
>18 – 21%	~~6.7~~7937	~~0.2~~1.9	~~7.6~~26.8	~~0.5~~1.8	~~14.3~~106.5	~~0.3~~1.9
>21%	~~10.5~~83.4	~~0.3~~2.0	~~14.3~~22.6	~~1.0~~1.5	~~24.9~~106.0	~~0.4~~1.9
Total*	~~4,128.8~~4,088.1	100.~~1~~0	~~1,439.7~~1,480.5	99.~~8~~9	5,568.6	100.0

* Total percent may not equal 100 due to rounding

Appendix 34.A

Final Surface Configuration Technical Report – Pinabete Permit Area

February 2014

APPENDIX 34.A

FINAL SURFACE CONFIGURATION TECHNICAL REPORT – PINABETE PERMIT AREA

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APPENDIX 34.A

FINAL SURFACE CONFIGURATION TECHNICAL REPORT – PINABETE PERMIT AREA

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INTRODUCTION

This technical report provides supporting information and fluvial geomorphic design inputs used to create the geomorphic final surface configuration (FSC) for the Pinabete Permit area (permit area).

BACKFILLING AND GRADING DESCRIPTION

The draglines operating in the permit area will be used for overburden and interburden removal. Dragline cut widths are generally 150 to 160 feet and lengths vary from several hundred to 20,000 feet, depending on pit geometry and planned mining sequence. Multiple coal seams within each cut require that the draglines conduct multiple passes in order to uncover successively deeper seams as each exposed seam is removed. Generally, each dragline will operate on the highwall side of the pit to expose the upper seams and will uncover the lower seams from the spoil side. The proposed Pinabete mining operations and stripping layout are discussed in Section 20 (Mining Operations). Support Facilities, including overburden stockpiles, are discussed and presented in Section 22 (Support Facilities).

Developing the final surface contours (FSC) requires that a balanced backfill surface be determined first. The initial step in this process was to model the associated dragline spoils that result from the coal removal sequence. Modeling of the mined-out cuts and illustrating the resulting dragline spoils was accomplished using a combination of QUICKSURF™ software and dragline spoil modeling techniques that jointly operate in an AutoCAD environment.

Dragline spoil modeling is performed using routines that provide elevated contour drawings of the spoil peaks and valleys based on range diagram calculations inherent in the software programming. The spoil configuration consists of inputting AutoCAD drawn entities representing a 38° slope (measured from horizontal) that commences at the toe of the lowermost coal seam and includes a 30’ wide bench approximately midway between the toe and spoil peak. Waste or unrecovered coal is assumed to remain in the pit and is accounted for by adding 8% of the total coal thickness to the pit floor surface prior to placement of the dragline spoils. The bank overburden material is also swelled 25% for spoil balance calculations. Final material cut/fill balance is achieved by incrementally raising or lowering the spoil peaks and valleys to match the modeled stripping volume. Any such adjustment is maintained within the operating parameters of the draglines.

Modeling to determine the dragline spoil surface also includes spoil displaced by coal haulage ramps that traverse the spoils. Spoil volumes for these entities are locally balanced to the cut volumes within corresponding cut(s) depending on the complexity of the mining and/or ramp configuration. Exhibit 34.2-1 shows the final post mining configuration at the end of the 25 year permit term.

After the dragline spoils are modeled, the next step in developing the final surface configuration (FSC) is to bring the dragline spoils to a balanced state by cutting the spoil peaks and filling the valleys. This creates an adjusted surface to either begin manipulating for FSC or to commence placement of truck loader assist overburden stripping volume. The resulting balanced surface will, in many cases, contain low areas that do not properly drain as well as elevated areas possessing slopes that exceed the allowable maximums. These areas require further grading to develop an acceptable FSC where material balance is maintained throughout.

In addition to the iterative surface manipulations, drainages are also integrated into the FSC. Drainages were generally located where the final cut(s) and coal haulage access ramps create depressions in the spoil contours and can be incorporated into the graded spoils to allow proper drainage of the spoils. Spoil drainage gradient determination are either based on the gradients of the undisturbed portions of the associated drainage or maintained in a concave profile to insure hydraulic stability. The upper drainage gradients mimic the undisturbed gradient while the slope of the lower reaches is lessened to the extent possible. Generally, the overall gradient is kept as flat as practical to minimize the volume of material required to fill the final voids or ramps. Ramp areas and final pit voids are commonly graded with dozers using locally available fill. In some cases, material is dozed from the final highwalls to assist in regrading the final voids. When such areas require more fill than the dozers can practically push, additional material is obtained from more distant spoil areas using the truck/loader operation. Additionally, any remaining box-cut spoil will be utilized in these areas to minimize the additional disturbance for backfill material. The resulting FSC is a materially-balanced surface with stable drainages and contours that approximate the pre-mining conditions. The FSC surface is considered balanced when the cut-fill volume variance is less than 5%. The cut-fill volumes calculated and shown by Exhibit 34.2-2 is 94.2 million cubic yards (Mcyds) (cut) and 91.2 Mcyds (fill) which is a variance of 3%.

GEOMORPHIC RECLAMATION APPROACH

Natural Regrade Software

The Carlson Natural Regrade™ software was utilized to develop the FSC reclamation surface. This is a computer model that applies fluvial geomorphic principles to develop a landscape design that generally mimics the natural landscape, as it would evolve over time under existing physical and climatic conditions. The software identifies the type of drainage network that would tend to form over a long period of time given the site's earth material, relief, and climate to achieve a stable landform. The product of the model represents the guide to design and build a suitable stable landform. The input variables are:

- Boundary Conditions
    - Disturbance limits
    - Drainage basins
    - Local stream base level for the main channel

    - Elevation at the head and mouth of the main drainage channel
- Watershed Characteristics
    - Reference Watershed
        - Length between channels, ridge to head length
        - Meander wavelength, A-channel length
    - Target drainage density
    - Stream Classification
        - Width to depth
        - Sinuosity
- Hydrologic/Hydraulic Parameters
    - Precipitation from the 2-year, 1-hour (2yr-1hr) and 50yr-6hr storm events to determine the bankfull and flood-prone flows
    - Runoff coefficient
    - Offsite drainage basins
    - Maximum discharge velocity

Boundary Conditions

Boundary conditions include identification of the overall regrade boundary, potential drainage basin, location of the channel elevations and the head and mouth of the channels. The grading limits were generally set by the mine plan disturbance schedule and stripping layout presented on Exhibit 20.1-1. The main drainage channels within the permit area are the Cottonwood and Pinabete Arroyos. These main channels are not disturbed or diverted by the Pinabete mining activities. Tributary channels to the Chaco, Cottonwood and Pinabete Arroyos which are affected by the Pinabete mine plan disturbance are identified with labels (Part 1 through Part 13c) along the grading limit boundary on Exhibit 34.1-1.

Watershed Characteristics

Watershed characteristics include drainage density, ridge to head of channel distance, stream width/depth ratio and channel sinuosity. The drainage basins and watershed analysis data from field investigations conducted in the Pinabete permit area have been used to develop the FSC reclamation surface.

Within Rosgen's channel classifications (Rosgen 1996), channels are classified based on slope and overall channel geometry. A-channels are those which have a slope greater than 4 percent, and tend to occur at the headwaters of a channel or near the ridge lines. In the Natural Regrade Global Settings, the input for Maximum distance from ridgeline to channel's head is 90 ft. and the 'A' channel reach value is 70 feet.

Drainage Density

Drainage density is a measure of channel spacing and is the ratio of the total length of channel to the drainage area. The drainage density of pre-mine drainage basins in the permit area varies from a low of 20 ft/acre to a high of 260 ft/acre depending on the amount of relief and presence of bedrock outcrops. The drainage density in the North portion of the permit area has significant relief, resulting in a higher drainage density than the South portion. The appropriate drainage density for a reclamation area should be a function of terrain aspect and slope as well as precipitation and soils. The overall reference drainage density of the permit area is between 25 and 80 ft/acre (the lower being on the South and the higher being on the North). Based on the extent and location of the Pinabete grading limits within the study area, a target drainage density of 60 ft/acre (+/- 30%) was used for the FSC design.

Table 34.A-1 Final Surface Configuration Drainage Densities

Drainage Density (Ft./Ac.)	Area (Ac.)	Drainage Density (Ft./Ac.)
Part 1	45.4	90
Part 2	143.6	44
Part 3	86.5	85
Part 4	98.1	89
Part 5	66.7	80
Part 5b	80.8	41
Part 6	74.7	78
Part 7	113.0	59
Part 8	232.6	50
Part 9	100.7	72
Part 10	685.2	74
Part 11	152.7	57
Part 12	553.8	57
Part 12A	35.9	90
Part 13A	546.1	58
Part 13C	52.5	78
Part 13D	146.1	71
Total	3,214.3	64

Overall, the design drainage density result is 64 ft/acre.

Stream Classification

As previously stated, the Natural Regrade model utilizes principles described by Rosgen (Rosgen 1996). The Rosgen classification for a natural channel is based on slope, width to depth ratio, entrenchment ratio, sinuosity, and streambed particle size. The Rosgen classification scheme describes channels as A through G using multiple and single thread channels to differentiate between geological settings.

Channels A and A+ are narrower channels that exist in slopes greater than 4 percent. Multiple thread D

and single-thread F and G are transitional formed channels that exist as the channel develops a more stable form and are generally associated with high erosion rates, sediment transport and deposition. B type channels have a relatively low sinuosity, with stepped transitions generally related to resistant rock strata generally occurring in narrow canyons with limited sinuosity. Types C and E differ through their width-to-depth ratio and sinuosity. An E channel generally has a lower width-to-depth ratio, is generally stable but is sensitive to disturbance of bank material and vegetation. A type C channel tends to migrate laterally through cutbank erosion and subsequent deposition.

Based on these classifications channel types A, C and E are generally utilized in developing stable reclamation designs. The model defaults create A and A+ channels at slopes greater than 4 percent and Bc for slopes less than 4 percent.

These channel characteristics were utilized for all tributaries within the Pinabete reclamation area:

- Width-to-depth
    - 10 – when the slope is greater than 4 percent
    - 12.5 – when the slope is less than 4 percent
- Sinuosity
    - 1.15 – when the slope is greater than 4 percent
    - 1.2 to 1.4 – when the slope is less than 4 percent

Hydrologic/Hydraulic Parameters

The Natural Regrade model estimates widths and depths for the channel based on precipitation during the 2yr-1hr and the 50yr-6hr storm events. Precipitation depths for these storm events are determined from the NOAA Atlas 14 based on the location and the elevation of the proposed reclamation site. The precipitation depths for the proposed reclamation area are 0.60 and 1.72 inches for the 2yr-1hr and 50yr-6hr storms, respectively.

The Natural Regrade model defaults to using the 50yr-6hr storm event and the Rational Method using a 0.89 runoff coefficient to estimate peak discharges for sizing the channels. Field investigation determined that a 0.75 runoff coefficient calculated channel widths and depths that were representative of the existing hydrologic conditions in the permit area. However, the Natural Regrade default runoff coefficient (0.89) was used in the Pinabete FSC design to allow some over-sizing for the drainage channels. The Rational Method immediately concentrates the full runoff volume into the hydrology model at the head of channel but not distributed along the length of the channel which also add a factor of safety in the channel designs. Use of the 50yr-6hr storm event in lieu of the 100yr-6hr storm in context of the Natural Regrade model is reasonable based on; 1) the 0.89 runoff coefficient which is conservative and adds a factor of safety in the channeldesigns, and 2) the effect of immediate concentration of runoff into the drainage by the Rational

Method is also conservative. As a result, these factors effectively model the 100yr-6hr storm in context of the Natural Regrade model.

The Natural Regrade model uses the permissible velocity method which uses a parameter called the maximum discharge velocity. A value of 4.5 feet per second was used for the Pinabete FSC. This value is the default value in the Natural Regrade model and represents the minimal channel erosion.

REFERENCES

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.