SUCCESSFUL RECLAMATION IN DRY-LAND ENVIRONMENTS—A CASE STUDY[1]

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Abstract. Yampa Mining Co., a Washington Group International, Inc. subsidiary, assumed all responsibility for final closure of the De-Na-Zin and Gateway coal mines located on state and Navajo Nation land adjacent to the federally protected Bisti Wilderness in San Juan County, New Mexico. Mining at De-Na-Zin began in 1980, disturbing 170 acres, while mining at Gateway began in 1982, disturbing 144 acres. Final reclamation activities included backfill of remaining pits, topsoil replacement, revegetation, sediment pond construction, environmental monitoring and extended permit responsibility. The mines were revegetated with a mixture of native shrubs and grasses planted before the normal summer monsoon season. Although the sites receive only 19.1 cm (7.5 inches) of rainfall per year, no irrigation was used. Dry land reclamation in this environmentally sensitive area included experimental soil amendments to improve soil chemistry, a 5-year erosion study, and application of native rock material. Areas receiving soil and rock amendments had increased vegetation cover versus non-treated areas. The De-Na-Zin Mine received Phase III release in August 2003, the first such release on Native Indian lands approved by the federal Office of Surface Mining. The Gateway Mine received Phase III release in January 2004.

Additional Key Words: bond release, dry-land reclamation, soil chemistry.

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Introduction

Yampa Mining Co., a Washington Group International, Inc. subsidiary, assumed all responsibility for final closure of the De-Na-Zin and Gateway coal mines in San Juan County, New Mexico. The mines were previously owned and operated by Sunbelt Mining Company, Inc., a subsidiary of the Public Service Company of New Mexico. Mining at the De-Na-Zin Mine began in 1980, disturbing 170 acres, while mining at the Gateway Mine began in 1982, disturbing 144 acres. In 1989, Sunbelt determined that continued operation of the mines would not be cost effective, and began developing closure plans. Yampa Mining Co. took over operation of both mines in 1990. The initial reclamation bond for both mines totaled $5.9 million.

Natural Setting

The De-Na-Zin and Gateway mines are located in San Juan County approximately 35 miles south of Farmington, New Mexico (Fig. 1) adjacent to the Bisti National Wilderness Area (Fig. 2 and Fig. 3). The mines are located at an elevation of approximately 5,800 to 5,900 feet above mean sea level and receive an average of 19.1 cm. (7.5 inches) of precipitation annually.

Before mining, topography of the De-Na-Zin Mine was relatively level to gently rolling with fine sandy soils in low dunes. Vegetation was a shrub-grassland association dominated by rabbitbrush (*Chrysothamnus* Nutt. spp.), Indian ricegrass (*Achnatherum hymenoides* {Roemer & J.A. Schultes} Barkworth), and sandhill muhly (*Muhlenbergia pungens* Thurb.). Land use before mining was primarily grazing by sheep, cattle and horses. The mine area includes New Mexico state land and Navajo Nation land.

In contrast, the Gateway Mine is located in a badlands environment. Site geology consists of alternating layers of sandstone, siltstone, carbonaceous shales and coal seams. The native shales are high in sodium, resulting in heavy clay surface material with very little soil structure due to the high sodium content. Little vegetation occurred in the area prior to mining, with only a sparse cover of shrubs such as wild buckwheat (*Eriogonum corymosum* Benth.), rabbitbrush, and shadscale (*Atriplex confertifolia* {Torr. & Frem.} S. Wats.) occurring along washes. The Gateway Mine is located entirely on state land. The mine is bordered on three sides by the Bisti Wilderness Area, managed by the Bureau of Land Management (BLM).

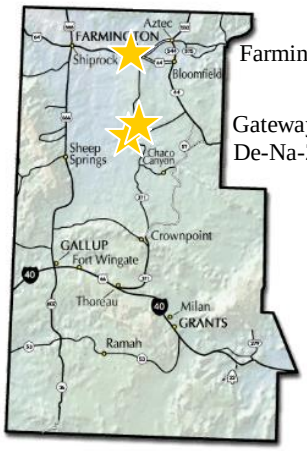

Figure 1. Location Map

Figure 2. Bisti Wilderness Features located on the undisturbed portion of the Gateway Mine

Figure 3. Bisti Wilderness Features located on the Gateway Mine. Known locally as a “hoodoo”

Reclamation

Backfilling, Grading and Topdressing Placement. The reclamation consisted of backfilling the existing open pits. The burden swell essentially compensated for the coal loss resulting in the restoration of approximate original contours. At the De-Na-Zin Mine, 466,376 cubic meters of spoil material was returned to the pit from adjacent spoils and stockpiles. An estimated 2,576,534 cubic meters of spoil material was moved into the Gateway pit to complete the regrading. The De-Na-Zin Mine was covered with 15 to 30 centimeters of topsoil material that had been removed prior to mining. Geochemical data and experimental plots showed that the spoil material at the Gateway Mine was more suitable than the native surface material, therefore no surface material was salvaged and regraded spoils were directly seeded. This regrading activity was completed in 1992 resulting in Phase I bond release and a reduction of the bond to $2.4 million. Two existing sedimentation ponds and dam structures at De-Na-Zin were incorporated into the final reclaimed surface. Both existing dam structures (Fig. 4) at Gateway were ultimately breached as required by the New Mexico mining permit.

Figure 4. Sedimentation pond and dam at the Gateway Mine. This dam was breached for Phase III bond release.

Revegetation. The De-Na-Zin and Gateway mines were revegetated with native grass and shrub species selected to support the proposed post-mine land use of grazing and limited wildlife

habitat (Table 1). Regraded areas were seeded just prior to the normal summer monsoons, or rainy season, that typically occurs in July.

Table 1. Revegetation species.

	Common Name	Scientific Name	Seeding Rate (lbs. pure live seed per acre)
De-Na-Zin Mine	Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.	0.75
	Shadscale	*Atriplex confertifolia* (Torr. & Frem.) S. Wats.	0.50
	Winterfat	*Krascheninnikovia lanata* (Pursh) A.D.J. Meeuse & Smit	0.125
	Streambank wheatgrass	*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould	0.125
	Western wheatgrass	*Pascopyrum smithii* (Rybd.) A. Love	0.75
	Blue grama	*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths	0.75
	Galleta	*Pleuraphis jamesii* Torr.	0.75
	Indian ricegrass	*Achnatherum hymenoides* (Roemer & J.A. Schultes) Barkworth	2.25
	Alkali sacaton	*Sporobolus airoides* (Torr.) Torr.	0.125
	Sand dropseed	*Sporobolus cryptandrus* (Torr.) Gray	0.05
	Rabbit brush	*Chrysothamnus nauseosus*	0.125
Gateway Mine	Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.	1.00
	Shadscale	*Atriplex confertifolia* (Torr.& Frem.) S. Wats.	1.00
	Broadscale	*Atriplex obovata* Moq.	0.50
	Greasewood	*Sarcobatus vermiculatus* (Hook.) Torr.	0.25
	Blue grama	*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths	0.50
	Galleta	*Pleuraphis jamesii* Torr.	0.75
	Indian ricegrass	*Achnatherum hymenoides* (Roemer & J.A. Schultes) Barkworth	1.00
	Alkali sacaton	*Sporobolus airoides* (Torr.) Torr.	0.25
	Sand dropseed	*Sporobolus cryptandrus* (Torr.) Gray	0.05
	Rabbit brush	*Chrysothamnus nauseosus*	0.125

Special Reclamation Activities and Monitoring

Soil Amendments

A variety of combinations of soil amendments (wood chips with nitrogen fertilizer, calcium chloride, gypsum, and phospho-gypsum) was applied to mined areas at the Gateway Mine to enhance vegetation establishment (Table 2). Native red caprock was also spread over portions of the mined area to mimic the color palette of the surrounding landscape. The soil amendment program was designed by Rocky Mountain Reclamation of Laramie, Wyoming. The purpose of the soil amendment program was to 1) improve vegetation cover and productivity in areas where amendments were used; and 2) compare the site-specific effectiveness of different combinations of amendments.

Table 2. Soil amendments employed at the Gateway Mine.

Treatment	Amendment(s)	Application rate per acre
1	Wood chips	20 tons
	Ammonium nitrate	160-250 lbs
	Diammonium phosphate	250-390 lbs
2	Calcium chloride	7.2 tons
	Gypsum	4 tons
3	Wood chips	80 tons
	Calcium chloride	20.5 tons
	Gypsum	11 tons
	Ammonium nitrate	1,210 lbs
	Diammonium phosphate	1,920 lbs
4	Phospho-gypsum	7.8 tons
5	Wood chips	80 tons
	Phospho-gypsum	16.4 tons
	Ammonium nitrate	1,030 lbs
	Diammonium phosphate	1,640 lbs

All treatment areas had greater vegetation cover compared to untreated areas. Treatment combination 3, wood chips, calcium chloride, gypsum, and fertilizer, was observed to have the most pronounced effect on vegetation establishment and growth. Five years after seeding, areas with this treatment averaged 8 percent live vegetation cover, while untreated areas averaged about 1 percent. Native caprock areas had similar vegetation cover as for Treatment 3. Live vegetation cover for other treatments ranged from 2 to 4 percent.

Reclamation Monitoring

Data collected to monitor reclamation success included vegetation cover, productivity, species diversity, surface and groundwater quality, and soil chemistry. Erosion rates were also collected for the Gateway Mine. Monitoring results were submitted to the New Mexico Mining and Minerals Division each year in an annual report. Results for vegetation cover and productivity are presented in further detail below.

Permanent 30-meter transects were set up on each year's reclamation acreage to establish approximately 1 transect per 2.5 acres of every years reclamation. Thirty of these transects were chosen by random lot to be sampled each year. Thirty reference area transects (in undisturbed sites near the mined areas) were located at each mine for vegetation comparison. Revegetation efforts were determined to be successful when mean foliar ground cover, species diversity, and productivity on revegetated areas are equal to, or better than, the reference areas (Table 3).

Table 3. Vegetation cover and productivity on reclaimed and reference areas.

DE-NA-ZIN MINE - MEAN VEGETATIVE COVER (%)						
	REVEGETATED AREA			REFERENCE AREA		
	GRASSES	SHRUBS	TOTAL	GRASSES	SHRUBS	TOTAL
2002	5.20	2.20	7.40	5.30	2.10	7.40
2001	8.83	3.59	12.42	9.88	3.23	13.12
2000	16.68	4.47	21.15	12.41	3.10	15.51
1999	14.50	4.50	19.10	11.70	5.70	17.30
1998	7.40	3.00	10.40	4.50	3.10	7.60

GATEWAY MINE - MEAN VEGETATIVE COVER (%)						
	REVEGETATED AREA			REFERENCE AREA		
	GRASSES	SHRUBS	TOTAL	GRASSES	SHRUBS	TOTAL
2002	0.00	2.35	2.35	0.21	0.44	0.65
2001	0.04	2.95	2.99	0.16	0.83	0.99
2000	0.01	2.96	2.97	0.27	0.34	0.61
1999	0.04	3.63	3.67	0.00	0.57	0.57
1998	0.12	2.81	2.93	0.01	0.94	0.95

DE-NA-ZIN MINE - MEAN VEGETATIVE PRODUCTIVITY (kg/ha)						
	REVEGETATED AREA			REFERENCE AREA		
	GRASSES	SHRUBS	TOTAL	GRASSES	SHRUBS	TOTAL
2002	110.8	51.5	162.3	50.2	0.4	50.6
2001	344.9	56.4	401.3	114.0	43.5	157.5
2000	224.5	72.6	297.1	96.0	35.1	131.1
1999	566.6	96.3	662.9	228.0	51.0	279.0
1998	96.2	206.7	302.9	127.2	0.0	127.2

GATEWAY MINE - MEAN VEGETATIVE PRODUCTIVITY (kg/ha)						
	REVEGETATED AREA			REFERENCE AREA		
	GRASSES	SHRUBS	TOTAL	GRASSES	SHRUBS	TOTAL
2002	0.3	82.4	82.7	1.6	20.2	21.8
2001	1.5	159.8	161.3	0.7	19.1	19.8
2000	0.4	74.5	74.9	0.0	23.0	23.0
1999	45.6	176.4	222.0	5.8	20.5	26.3
1998	2.3	226.5	228.8	0.0	29.1	29.1

The year-to-year variability of the data is related to the rainfall received in that area (Table 4). Northwestern New Mexico entered a drought phase in 2000. Normal rainfall has yet to return to that area. Normal rainfall for this area is 19.1 cm. (7.5 in.).

Table 4. Average rainfall for mine areas.

DE-NA-ZIN AND GATEWAY MINE RAINFALL AVERAGE (cm)						
2002	2001	2000	1999	1998	1997	1996
12.94	11.25	15.86	18.35	20.21	28.99	15.11

The New Mexico Coal Mine Reclamation Program Vegetation Standards require that revegetated areas achieve at least 90% of required vegetation parameters as compared to the reference area, with 90% statistical confidence. Parameters required for bond release include total production and live cover for Phase II, and total production, live cover, shrub density, and species diversity for Phase III (Figure 2). Based on the statistical evaluation of the revegetation data, Phase II bond release was granted for the De-Na-Zin Mine in 1999 and for the Gateway Mine in 2000. Phase III bond release was granted in 2003 for De-Na-Zin and January 2004 for Gateway.

Figure 2. Grazing on the De-Na-Zin Reclamation Project

Figure 3. The De-Na-Zin Project as an Operating Coal Mine

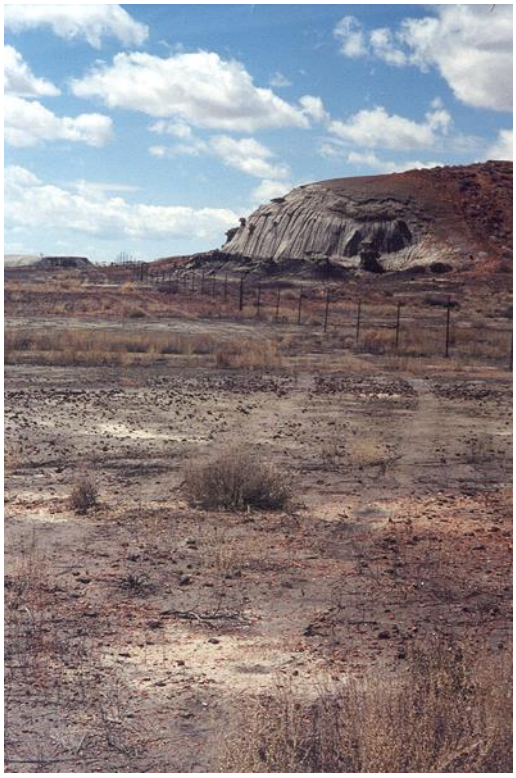

Figure 5. Gateway Mine undisturbed area

Figure 6. Gateway Mine revegetated area

Conclusions

The De-Na-Zin and Gateway mines were revegetated without the use of irrigation. Revegetation was accomplished by working within the ecological constraints of the area as much as possible, using the following techniques: 1) native grasses and shrubs were selected that are adapted to the local rainfall regime and soil conditions, including several species tolerant of high sodium contents; 2) seeding was conducted just prior to the normal monsoon season to take advantage of the normal rainfall to trigger germination; and 3) soil/spoil geochemical analyses were used to identify the best available topdressing material for placement on regarded spoils; and 4) soil amendments were used to improve vegetation establishment in areas with high sodium content. As supported by data collected for over 10 years, the revegetated mined area achieved vegetation cover, productivity and shrub density that is equal to or higher than undisturbed reference areas, enabling Yampa Mining Co. to achieve full reclamation bond release for both mines.