

## **Reclamation of Abandoned Coal Gob Piles and Stream Restoration in Yankee Canyon, Raton, New Mexico**

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Between the 1920s and 1971, a scattering of small, family-owned mines operated in Yankee Canyon, about eight miles northeast of Raton, New Mexico, providing coal primarily for the local market. Some of the gob (coal mine waste) material removed from the underground mines was dumped directly into ephemeral and intermittent streams near the mine openings. In 2004 the New Mexico Abandoned Mine Land Program began a project to reclaim seven gob piles and several smaller scatters of gob, safeguard two adits adjacent to a residence, and restore a degraded stream channel in Yankee Canyon. The two partially collapsed coal adits were backfilled and their locations marked with permanent survey markers. The gob sites, covering a total of three acres, presented several unique reclamation design challenges to the New Mexico Abandoned Mine Land (AML) Program.

The project sites (see map on page 7) range in elevations from 7,270 to 7,760 feet above sea level. The semiarid continental climate at Yankee is characterized by short, warm summers and long, cold winters. Precipitation averages about 20 inches annually, with most rainfall occurring in July and August, although weather records indicate that intense storms can also occur in late spring and early autumn. Plants grow slowly in this environment, given the high altitude, semi-arid environment, and short growing season.

### **Reclamation and Stream Protection at the Sonchar Mine**

At the Sonchar Mine site, the narrow valley setting and presence of many cultural resource avoidance areas, including the ruins of a scale house, loadout, and several small residences, significantly limited the area that could be disturbed and restricted construction equipment to narrow work zones. To flatten the excessively steep gob slopes, the gob material had to be graded in a two-step process: first by pushing the gob uphill away from the intermittent stream at the base of the gob and secondly by moving it around the avoidance areas and shaping it into landforms with maximum 2:1 slopes, that blended into the surrounding terrain (see photographs on pages 8 and following).

The gob material at the Sonchar Mine is moderately sodic (sodium adsorption ratios, or SARs, ranged between 20 and 31 and averaged 25), slightly acidic (pH ranged from 4.2 to 7.8 and averaged 6.0), and slightly saline (electrical conductivity ranges from 1.19 to 7.95 and averaged

5.43 mmhos/cm). The gob is high in clay content, ranging from 24% to 36% and averaging 31% clay.

A few inches of native subsoil trucked in from a pit excavated for gob disposal at a nearby site were placed onto the graded gob and incorporated along with lime, gypsum, wood waste, and compost. The AML Program experimented with mixing soil into the gob at this site based on an unpublished greenhouse study by Los Alamos National Laboratory that had shown that gob material from Madrid, N.M. mixed with native soils supported plant growth better than did either the native soils or gob material alone. Within the project area, however, the only visual difference noted between this soil-amended site and others where no soil was added was more growth at the soil-amended site of yellow sweet clover (*Melilotus officinalis*), a species not included in the seed mix.

A rock rundown, based on “rough-bed channel” design guidelines developed by H. Lorenz and the Department of Technology at the University of Munich in the 1950s (and used primarily for water channeling on German autobahns) (Schiechtl, 1980, pp. 16-17) was constructed to carry storm flows across the reclamation site. The channel is designed to be elastic and consists of rock properly sized for the design flow (in this case the 100-year, 24-hour storm) placed by hand onto a permeable bed of coarse sand and fine gravel with the joints in the rock filled with crushed gravel. The rundown was initially reinforced for flow shear resistance with several rows of juniper posts driven across the rock channel. Longer term channel reinforcement and protection from washout is provided by the roots of small trees planted along both sides of the rundown.

To protect the reshaped gob pile from being undercut by the intermittent stream that runs along the base of the gob pile, coir (coconut husk fiber) rolls and coir blocks were installed along the stream edge, along with live willow (*Salix*) cuttings, for bank stabilization.

On the re-graded, amended gob pile, 20-inch wide terraces were hand dug on eight-foot vertical intervals on contour and straw bales placed end-to-end along the terrace and staked in place. A variety of native seedlings were closely planted along the backfilled top edges of the straw bales. As a drought- and fire-tolerant pioneer species, New Mexico locust (*Robinia neomexicana*) accounted for about 35 percent of the seedling mix. Other species planted include skunkbush sumac (*Rhus trilobata*), fourwing saltbush (*Atriplex canescens*), and Woods’ rose (*Rosa woodsii*). A diverse, native seed mix with grasses, shrubs, and forbs was applied by hydroseeding with a bonded-fiber matrix. Species used include western wheatgrass (*Pascopyrum smithii*), sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), scarlet globemallow (*Sphaeralcea coccinea*), fringed sagebrush (*Artemisia frigida*), and prairie sage (*Artemisia ludoviciana*). These reclamation methods were typical for most of the other waste piles in the project, including those at the Franks Nos. 1 and 2 Mines, where gob characteristics are similar, the same coal seam having been mined.

## Reclamation and Stream Restoration at the Franks Nos. 1 and 2 Mines

Since space was limited at the Franks No. 2 Mine and local soil cover materials scarce, two of three gob piles at the site were reclaimed in place by incorporation of amendments (gypsum, lime, wood waste, and compost) into the gob materials. Straw bale and coir roll terraces with plantings of native seedlings were constructed on the gob steep slopes, branch packing installed in one deep gully, and the gob piles hydroseeded with native species. The third gob pile was buried in a pit excavated nearby and the gob material covered with salvaged topsoil, seedlings planted, and the surface seeding.

At the Franks No. 1 Mine, a residence, septic system and water well near the toe of the primary gob pile had to be avoided, limiting the extent of reshaping of the pile. The gob was graded to flatter slopes and amended, planted, and seeded similarly to the gob piles discussed above, while another smaller gob pile nearby was reclaimed in place.

Gob, trash, and old mining equipment including vehicles had been dumped along and into an ephemeral stream adjacent to the Franks Nos. 1 and 2 Mines. The most severely impacted section of the stream adjacent to the Franks Mines was deeply incised with advancing headcuts and areas with piping erosion. Summer thunderstorms and spring runoff were undercutting the gully walls, collapsing them into the creek, and threatening to undermine a portion of the landowner's driveway.

The AML Program designed relocation of a portion of the driveway, removal of trash and mining debris, and reconfiguration of 1,200 feet of the stream into a geomorphic, meandering pattern with maximum 2:1 side slopes. This portion of the stream drains 40 acres at the upper end and 60 acres at the lower end of the mine-impacted watershed. The Program used regional hydraulic geometry curves and the Rosgen Natural Channel Design method (Rosgen, 1996) to determine the new channel geometry. With the addition of 20 full meanders, stream sinuosity (the ratio of channel length to downvalley length) was increased from 1.07 to 1.22, lengthening the channel by 150 feet. Stream design parameters are listed in Table 1 below.

The gob dumped along the channel was buried under at least two feet of native soils during grading of the reconfigured channel. At the head of the relocated stream channel, a rock- and soil-filled gabion mattress rundown blanket was installed and seeded to prevent headcutting of the stream into the earthen pad on which the landowner's home is built. Another vegetated gabion mattress installation was placed at a culvert outlet into the channel. The stream banks and bottom were stabilized with live willow cuttings, rock lining at riffle points, planting of native seedlings, and hydroseeding with native seeds and a bonded fiber matrix. A sandstone bedrock outcropping controls grades at the lower end of the relocated stream.

Because the silty native soils at the relocated stream are erodible and completely free of rock, wicker weirs were constructed at the riffle points along the reconstructed channel to aid in stabilization of the channel base. Each wicker weir was constructed using three-foot long juniper posts driven in three rows across the channel bottom, flexible branches woven between the juniper posts, and four- to six-inch rock (see the photograph below). Coir rolls were placed along the outside of meanders to control lateral movement of the channel until growth of vegetation could establish more erosion-resistant banks. Seedlings were planted along the coir rolls.

The installation of 12-inch diameter coir rolls, being taller than the 8-inch design bankfull depth, turned out to be a mistake. The rolls narrowed and deepened flows at the riffles during flow events, contributing to headcutting at many of the 40 wicker weirs installed. In a 2008 maintenance project many of the coir rolls were shortened, a few rolls removed, and additional rock added at riffle points.

### Sunset Mine Reclamation

At the Sunset Mine, where another coal seam at higher elevations had been mined, the gob material was quite different from that at the Sonchar and Franks Mines. The Sunset Mine gob was very sandy (averaging 87% sand) and strongly acidic (with pH ranging from 3.2 to 4.4 and averaging 3.8, although low in pyritic sulfur). It supported almost no plant growth, largely because of the gob pile's low water-holding capacity and erodibility, its black color and south-facing exposure (leading to high surface soil temperatures), and its acidity. To alleviate these problems, shade fencing was installed and lime and compost incorporated into the gob, with additional lime mixed with the gob in individual seedling planting holes.

The open-weave, biodegradable coir shade fencing provided temporary protection for the planted native seedlings from wind and south and west sun exposure. Seedlings were planted six inches below the surface, both to place their roots below the extremely hot, black gob surface and at a depth where they could more easily access deeper soil moisture (Martin, 1976). Cardboard tubes protected the young stems from burial by the sand. By the time the tubes deteriorated, the seedlings were large enough to tolerate moderate stem burial. In this very droughty material, the seedlings were watered once at the time of planting and, using hydrogel time-release watering packages, for the first growing season. Long-term revegetation success at this challenging site has been acceptable, although some plant die back and mortality in recent drier years has been noticed.

## Results and Summary

The primary project in Yankee Canyon was constructed in fall 2004 and spring 2005, which fortunately were relatively wet years. At the end of the first season of growth in 2005, over 77 percent of the 7,400 native seedlings planted in that initial phase of work were in fair to good condition without supplemental irrigation (except for watering-in of the seedlings at the time of planting and as noted above at the Sunset Mine site where hydro-gel watering packages were used). 5.6 acres of land disturbed during construction and gob were successfully hydroseeded with native species.

Three subsequent small maintenance projects have followed. In 2008, more coir roll terraces were added for better erosion control at the Franks No. 2 steep, in-place gob reclamation sites and additional seedlings planted along the new terraces. Amendments were incorporated by hand into the steeper slopes of those gob piles, which were then reseeded for better vegetative cover. In 2009, portions of the 12-inch diameter coir roll installations were removed and more rock was added to riffle points in the restored stream to address the headcuts that had formed. The rock armor is capturing sediment and vegetation is moving in to cover and reinforce the rock.

In 2013 and 2014, the third maintenance project is underway to address impacts of the June 2011 Track Wildfire that burned across one edge of the reclamation site at the Sonchar Mine. This wildfire ignited a few rows of coir rolls and straw bales placed several years before, killing almost all of the seedlings planted along them. A gob fire was also kindled by the wildfire and extinguished in fall 2013.

In summary, these projects in Yankee Canyon have:

- enhanced public safety by closing open mine adits and extinguishing a gob fire;
- improved water quality by removing gob from stream channels and reducing erosion;
- slowed the movement of water across landforms and in streams, increasing infiltration into soils for a more resilient and drought-resistant landscape;
- stabilized the upland portion of an ephemeral stream;
- increased the nutrient content and soil fertility of previously bare soils;
- reshaped, vegetated, and connected highly disturbed landforms to the surrounding landscape; and
- upgraded the ecological functioning of a degraded landscape.

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Table I: Franks No. 1 Mine Stream Restoration Design Parameters

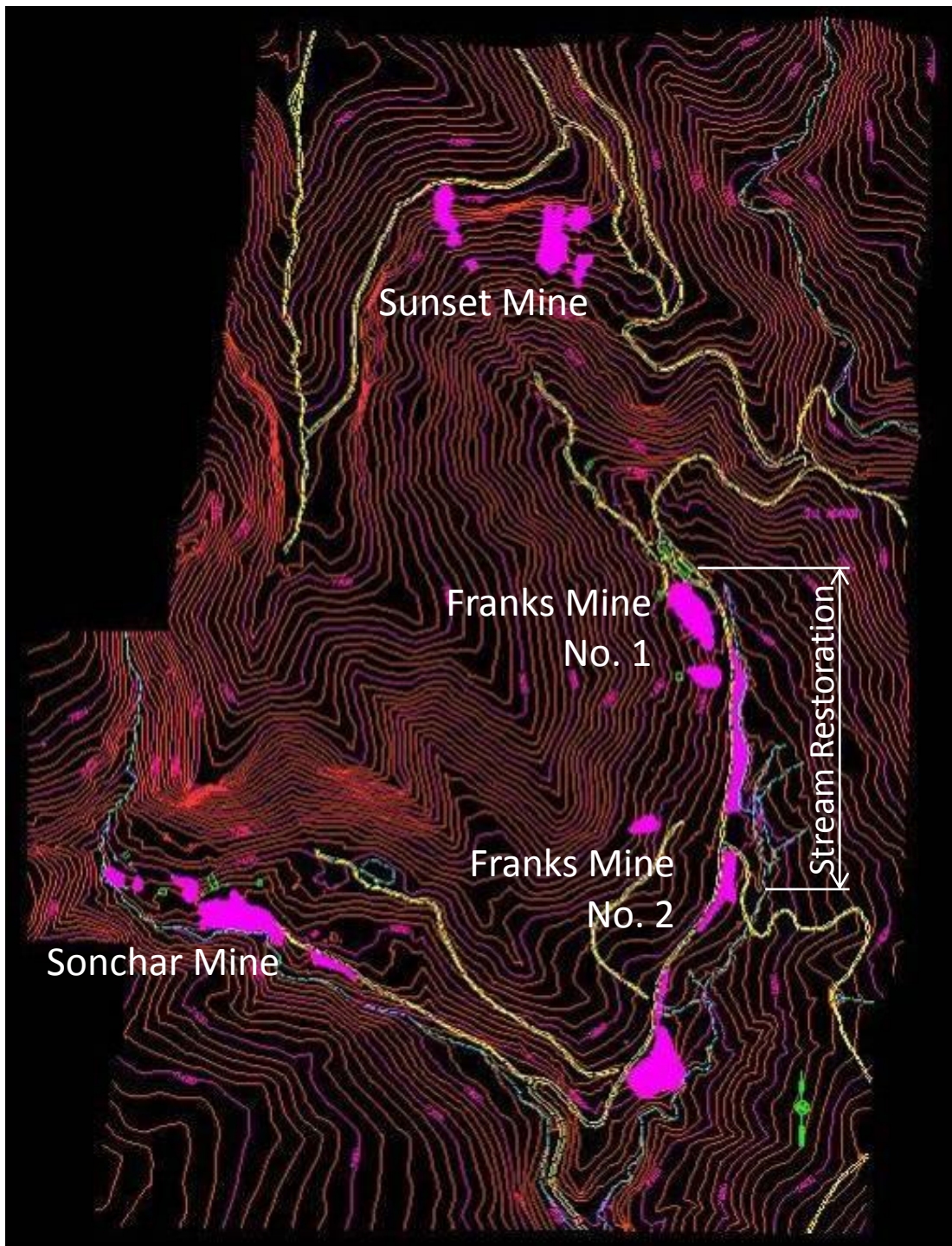
Rosgen channel type	“B”
Drainage area	40 acres upper end 60 acres lower end
Bankfull width	5.0’
Bankfull depth	0.7’
Flood prone width	7’ to 11’
Sinuosity	1.22
Meander length	56’
Valley meander length	46’
Channel slope	4.5% to 8.5%

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**References**

- Martin, A. (1976). A Review of Some Dune Afforestation Procedures. In *Conservation in Arid and Semi-Arid Zones: FAO Conservation Guide 3* (pp. 85-94). Rome: Food and Agriculture Organization of the United Nations.
- Rosgen, D. (1996). *Applied River Morphology*. Pagosa Springs, Colorado: Wildland Hydrology Books.
- Schiechl, H. (1980). *Bioengineering for Land Reclamation and Conservation*. Edmonton, Alberta, Canada: The University of Alberta Press.

Map of Project Sites



Pre-project topographic map of project sites (1" = 500'; contour interval 10'). Gob piles are colored magenta, two-track roads light yellow, and drainages blue. The approximate center of the gob piles is at 36°58'16" N 104°19'42" W.



Photographs



Sonchar Mine, April 2003. Note the timber loadout in the foreground.  
Abandoned vehicles were removed and recycled.

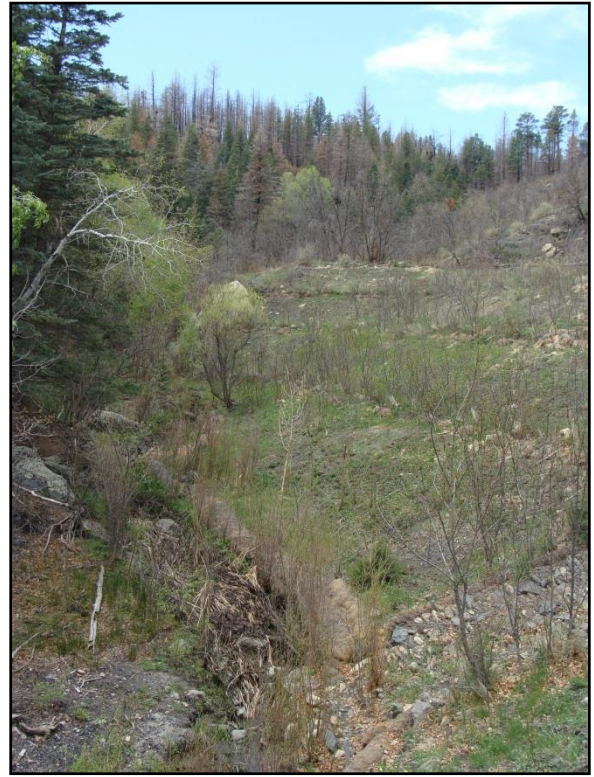


Sonchar Mine after a wildfire burned the timber loadout and area in foreground, Sept. 2012





Sonchar Mine site and intermittent stream,  
April 2003



Sonchar Mine site, May 2013. Some impacts  
of the 2011 wildfire are visible in background.



Sonchar Mine site immediately following the wildfire that burned across the northwest  
edge of the site, June 2011. A gob fire was ignited a few feet left of the power pole.





Rough-bed rock rundown at the Sonchar Mine site, May 2013. The trees planted along the rundown for root reinforcement and washout protection are just beginning to leaf out.



Willows at coir roll and coir blocks at the stream at the Sonchar Mine gob pile base, June 2009





Hydroseeded slopes and plantings of native seedlings along coir rolls at one of the Franks No. 2 Mine steep gob piles reclaimed in-place, August 2010



Branch packing of gully at a Franks No. 2 Mine gob pile, August 2010





Franks No. 1 Mine site with gob piles and degraded, incised stream channel, April 2003



Franks No. 1 Mine site with re-graded gob piles and restored stream channel, August 2010





Incised stream channel at Franks No. 1 Mine, looking upstream, July 2002



Restored stream channel with willows, May 2013





Newly installed wicker weir and coir rolls with native seedling plantings, 2005



Headcut at wicker weir, 2007



Restored stream, July 2009. Rock reinforcement added at two riffle points in fall 2008 is visible in lower left of photograph.





Vegetated gabion mattress at culvert outlet, August 2010



Near lower end of restored stream channel, looking upstream, May 2013





Sandy gob at the Sunset Mine, six months after seedling planting, October 2005. Cardboard tubes for seedling burial protection are visible inside the mesh tubes. Coir fencing runs north-south and east-west for seedling sun and wind protection.



Sunset Mine gob pile, July 2011. Some cardboard tubes at plantings are still visible.