# GEOMORPHIC RECLAMATION OF ABANDONED COAL MINES ON VERMEJO PARK RANCH NEAR RATON, NEW MEXICO: RECLAMATION AND REVEGETATION

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**Abstract**

The New Mexico Abandoned Mine Lands (AML) Program recently completed reclamation of the Swastika Mine on the Vermejo Park Ranch near Raton, NM. Historic mining activities left steep piles of coal waste which were eroding into the adjacent channelized ephemeral stream. Project goals were to reconstruct the stream channel, stabilize and restore the surrounding landform function, and reclaim and revegetate the entire disturbed area. The geomorphic design and construction phases of the project are described in another paper in this session presented by Water & Earth Technologies, Inc. (WET). This paper will focus on the reclamation and revegetation design and implementation provided by Habitat Management, Inc. as part of the WET team.

The project began in December 2008 with evaluation of the soils, hydrology, vegetation, wildlife, and wetlands and preparation of an Environmental Assessment (EA). The project was successfully completed in March 2013 and received a NM Mining and Minerals Division Excellence in Reclamation Award. Coal waste was removed to stable landforms constructed at repositories and/or regraded in place and then capped with clean soil. Before capping, gob was treated with either lime or gypsum to mitigate acid or alkaline soil conditions. After capping, soils were primarily amended with composted wood waste or Kiwi Power Organic Soil Treatment™ and Fertil-Fibers NutriMulch™ (6-4-1) on small areas difficult to access with equipment. All disturbed areas were seeded with either upland or wetland native seed mixtures comprised of locally observed species. After seeding, WoodStraw™ was applied to all slopes except the stream banks where turf reinforcement mat was installed.

Native upland and riparian shrubs encountered during excavation activities were removed from the ground using a tree spade and stored in burlap-lined cages before planting in reclaimed areas. When possible plugs of herbaceous wetland vegetation were also salvaged and replanted along the reconstructed channel.

## Introduction

In 2009, the New Mexico Abandoned Mine Lands (AML) Program initiated a project to reclaim several abandoned coal mines in Dillon Canyon on the Vermejo Park Ranch near Raton, New Mexico. The selected project design team included civil and hydrologic engineers, biologists, soil scientists, and archaeologists headed by Water and Earth Technologies, Inc. with partner Habitat Management, Inc. The selected construction contractor was Kiewit New Mexico Company with revegetation subcontractor 814 Solutions, LLC. Site evaluation began in January 2009, designs and construction specifications were completed in 2010 and 2011 and construction started in the spring of 2012. While the project was substantially complete by the fall of 2012, additional planting was completed in the spring of 2013. This project received the 2012 Excellence in Reclamation Award from the New Mexico Energy, Minerals and Natural Resources Department (EMNRD), presented to Water & Earth Technologies, Inc., Habitat Management, Inc., Kiewit New Mexico Company and 814 Solutions, LLC.

This project incorporated geo-fluvial modeling technology to develop a natural and sustainable meandering channel and floodplain that would mimic the natural conditions up and downstream. Project goals were to:

- reconstruct the stream channel,
- stabilize and restore the surrounding landform function, and
- reclaim and revegetate the entire disturbed area, while
- preserving historic cultural features associated with the canyon's rich mining history

The geomorphic design and construction phases of the project are described in another paper in this session presented by Water & Earth Technologies, Inc. This paper will focus on the reclamation and revegetation design and implementation provided by Habitat Management, Inc. as part of the design team.

## Site Description

The project location in Dillon Canyon is located approximately six miles west of Raton, New Mexico in Colfax County (Figure 1). There were several active coal mines in Dillon Canyon and its side canyons from the early 1900s into the 1950s. As with most pre-law coal mines, the low-grade coal waste (called "gob") was dumped out of the way of mining operations and left in large, often steep, unstable piles at the end of mining. The initial site evaluation and Environmental Assessment (EA) included eight sites throughout Dillon Canyon and its side canyons. The construction and revegetation projects completed to date and included in this paper were completed at the Swastika Mine and Dutchman Mine sites both at an elevation of approximately 7,165 ft.

At the Swastika Mine site, over 200,000 cubic yards of gob was abandoned in nine separate piles covering over 7 acres. The largest of these gob piles was immediately adjacent to the Dillon Canyon stream for a stretch of almost half a mile and was eroding into and contaminating the stream with coal fines and soluble salts. The Dutchman Mine site had only three small gob piles, but was further contaminated by alkali seep water flowing out of several leaking adits in the slope above the site.

The vegetation in Dillon Canyon is a transitional foothills shrub/scrub community with scrub oak and other shrubs on slopes, ponderosa pine in the narrow canyons, and open grassland communities on the valley floors. There are also substantial riparian and wetland communities along stream channels and around natural and mine-related seeps. The Raton area receives an average annual precipitation of 16 to 18 inches most of which falls as summer rain (Western Regional Climate Center 2014). The average high temperatures in July are 83 to 86°F and the average winter low temperatures in January are 14 to 19°F.

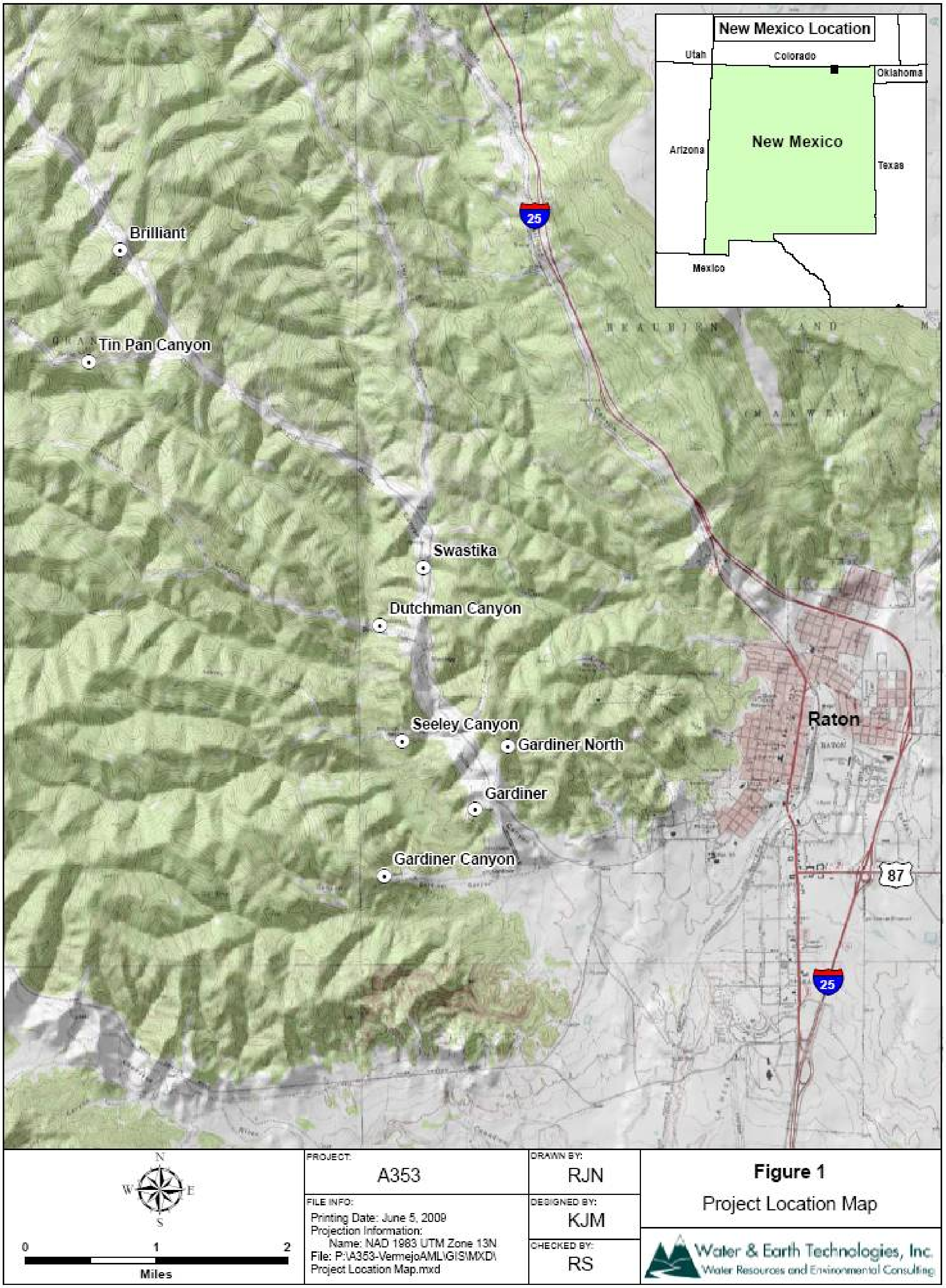

Figure 1: Project Location Map

## Environmental Permitting & Reclamation Planning

This project was federally funded by the Office of Surface Mining (OSM) through the New Mexico EMNRD AML program. As such, an Environmental Assessment (EA) was required to achieve a Finding of No Significant Impact (FONSI) before any ground disturbance occurred. Along with this, an Archaeological Survey and a State Historic Preservation Office (SHPO) approval of the study design and mitigation plan were also required. Additionally, work in the stream channel and disturbance to jurisdictional wetlands required the acquisition of an Army Corps and Engineers (ACOE) Nationwide 27 Aquatic Habitat Restoration, Establishment, and Enhancement Activities 404 Permit and development of a Wetland Mitigation and Monitoring Plan that preserved existing wetlands where possible.

Environmental assessment work began in January of 2009 and included field and data evaluations for vegetation, wildlife, aquatic habitat, cultural resources, soils, and a formal jurisdictional wetland delineation. Surveys for threatened and endangered (T&E) species were also conducted including bats, fish, southwestern willow flycatcher, and several plant species. The EA covered a large stretch of Dillon Canyon and several side canyons including Dutchman, Seeley, Tin Pan, and Gardiner Canyons. Whenever possible surveys were conducted to include data necessary for the project design in addition to the EA development.

The FONSI was issued in May 2010 at which point detailed design work began. EMNRD AML decided that the priority work areas were the Swastika Mine site in Dillon Canyon and the nearby impacted area in Dutchman Canyon.

## Channel Design and Construction

The channel designs included a 4,085 foot section of reconstructed channel through clean materials, reclamation and grading of over 200,000 cy of coal gob, and 44 acres of newly created geomorphic landforms while avoiding and protecting over 180 archaeological features. Geomorphic design was accomplished using Natural Regrade with Geofluv™ software (Carlson, 2007) to incorporate stable drainage and topographic variety into the reconstructed portion of Dillon Canyon. The construction was completed using GPS-controlled equipment to achieve precise grading results that matched specifications. Details of the engineering design and construction processes are presented in the paper by Spotts et al. (2014) in these proceedings.

## Revegetation Design and Construction

The revegetation design was developed and implemented concurrently with the construction design and implementation to maximize revegetation success and minimize duplication of efforts. Revegetation activities included capping of gob, soil amendment, seed bed preparation, seeding, transplanting, and erosion control. There were four types of revegetation areas that were each treated slightly differently.

1. Small scatter piles of gob with moderately suitable chemistry were reclaimed in place with the addition of soil amendments.
2. Partially removed and/or regraded gob piles and gob repository areas were sampled to determine soil amendments, capped with clean borrow material, and revegetated.
3. Locations where gob was entirely removed were sampled to determine soil amendments and revegetated.
4. Disturbed areas not effected by gob such as access roads and staging areas were reclaimed with or without the addition of soil amendments per soil testing results.

**Capping**
The capping of the gob material was critical to both prevent the gob from contaminating the stream and allow for successful revegetation. While some gob piles were supporting some vegetation, they generally had poor suitability for plant growth (Table 1), inadequate organic matter content, coarse texture, and a dark color which produced high soil surface temperatures.

Table 1: Gob Chemistry Before and After Grading On Two Representative Gob Piles

| **Gob Pile** | **Pre/Post Grading** | **Depth (inches)** | **pH** | **EC (µS)** | **SAR** | **Potential Acidity (t/kt)** |
|---|---|---|---|---|---|---|
| GP-5 | Pre | 0-6 | 4.4 | 0.39 | 0.73 | 2.2 |
| | | 6-12 | 4.2 | 0.77 | 0.66 | 2.8 |
| | Post | 0-12 | 6.6 | 4.6 | 8.2 | 4.1 |
| GP-3b | Pre | 0-12 | 7.4 | 2 | 15 | 1.4 |
| | Post | 0-12 | 7.8 | 2.7 | 11.5 | 6 |

The cap material came from one of three designated borrow location as well as from the new stream channel excavation. In the borrow areas, the first 12-inches of soil was removed and stockpiled for use as topsoil in reclamation, the next 60 inches were also stripped for cap material. All borrow soils were sampled and determined to be suitable grow media (Table 2). Whenever possible this material was directly hauled to the placement location, but much of it was stockpiled for later use. The borrow areas also served as gob repositories once the borrow material was stripped, and thus some of the cap material was placed back on top of the gob repositories to complete their reclamation. Sufficient borrow soil was excavated to provide a minimum of 6 to 12 inches of capping depth over all gob.

Table 2: Cap/Borrow Soil Material Chemistry

| **Site** | **Borrow Soil Horizon** | **Depth (inches)** | **pH** | **EC (µS)** | **SAR** | **Texture** | **Organic Matter (%)** |
|---|---|---|---|---|---|---|---|
| Swastika Borrow | A | 0-35 | 7.4 | 0.44 | 0.71 | L | 1.87 |
| | Bt | 35-54 | 7.4 | 0.77 | 0.79 | SCL | 1.63 |
| | Bk | 54-85 | 7.5 | 0.73 | 0.79 | SCL | 1.13 |
| Swastika Channel | A | 0-19 | 7.5 | 0.6 | 0.5 | SCL | 2.32 |
| | Bt | 19-64 | 7 | 2.4 | 0.6 | SCL | 2.62 |
| | Bk | 64-105 | 7.5 | 1.2 | 0.5 | SCL | 2.71 |

**Soil Amendments**
All gob and borrow soils were sampled prior to implementation to determine types and potential quantities of soil amendments. Areas where some or all of the gob was removed were resampled after final grading was complete to determine final soil amendments. Generally potential acidity, EC, and SAR increased with the exposure of unweathered gob materials (Table 1) and required more soil amendment than had been initially anticipated. Soil amendments included lime to neutralize potential acidity and SAR, gypsum to neutralize SAR, compost to increase soil organic matter, and fertilizers to increase nitrogen and modify the carbon: nitrogen (C:N) ratio of compost.

Lime and gypsum were applied with a hydroseeder directly on the graded gob/soil surface prior to cap application. Application rates for all amendments were based on laboratory analyses and varied by location (Table 3). Lime was applied as a mixture of fine-grained calcitic limestone ($CaCO_3$) with a calcium carbonate equivalent of 80 to 100% and fine-grained calcium oxide (CaO) kiln dust with a calcium carbonate equivalent of 120%. Gypsum ($CaSO_4$) was applied as a fine-grind, agricultural grade with at least 22% calcium (by weight).

Table 3: Soil Amendment Application Rates

| | | Application Rate* | | |
|---|---|---|---|---|
| | | Swastika | | Dutchman |
| **Amendment Type** | **Units** | **Gob/ Capped Gob** | **Native Soil** | **Gob/ Capped Gob** |
| Agricultural Lime (80-100% CaCO3) | tons/ acre | 0 - 18 | n/a | 0.2 - 1.2 |
| Kiln Dust Lime (CaO 20% CaCO3 equivalent) | tons/ acre | 0 - 4.5 | n/a | 0 |
| Gypsum (CaSO4) | tons/ acre | 0 - 3.5 | 0 - 2 | 0.2 - 1.2 |
| Nitrogen (Urea 46-0-0) | lbs/ acre | 2922 | 2922 | 2922 |
| Phosphorous (18-46-0) | lbs/ acre | 200 | 200 | 200 |
| Wood Waste Compost | cy/ acre | 400 | 400 | 400 |

* Amendment quantities were calculated for each area and rounded up to the nearest ton for application.

Lime and gypsum were incorporated into remaining gob and ripped to 12 inches before the clean borrow soil cap was applied. The combination of the amended gob and the clean borrow soil resulted in a suitable soil with a minimum rooting depth of 18 inches. Then, an inorganic fertilizer and compost were applied to on top of the cap. Western Wood Products in Raton supplied the composted sawmill wood waste, much of which came from the Vermejo Park Ranch. Compost was applied to all slopes up to 3:1 (horizontal: vertical) at a rate of 400 cy per acre. Compost was analyzed prior to import to the site to determine necessary fertilizer rates to adjust C:N ratio. Fertilizers included applications of both 46-0-0 and 18-46-0 to adjust the C:N ratio of the compost from 110:1 to 30:1.

On steeper slopes not equipment accessible and over archaeological exclusion sites, Kiwi Power Organic Soil Treatment™ and Fertil-Fibers NutriMulch™ (microbial stimulant) were applied a rate of 5 gallons/acre and 1 ton/acre, respectively. This combination of organic soil treatments stimulates plant growth through increased soil microbial fauna, improved soil structure, and nutrient release.

**Seed Bed Preparation**

Ripping to alleviate compaction, incorporate soil amendments, and prepare the seed bed is probably the most beneficial management activity for revegetation success. A rough final surface facilitates seed entrapment, moisture retention, and erosion control. All sites with a final grade no steeper than 3:1 (horizontal: vertical) were ripped to a depth of 12 inches after compost application using a bulldozer equipped with rippers. Ripping was done in two perpendicular passes with the final pass on the contour for added erosion control. In steeper areas where equipment could not be operated on the contour, the seedbed was prepared by ripping up and down the slope and then tracking a bulldozer up and down the slope and imprinting with the track grousers. The wetland areas in Dutchman Canyon were lightly harrowed only and not ripped prior to seeding. Seed bed preparation was conducted within 24 hours before seeding to prevent the formation of a soil crust that could inhibit germination.

**Seeding**

The vegetation surveys conducted for the EA and ACOE permit development were also use to support the development of seed mixtures. All revegetation areas were broadcast seeded with one of three native seed mixtures at a rate of 50 pure live seeds (PLS) per square foot. Due to seed size variability and slope variability, most areas were hand seeded. Rice hulls were used as an inert seed extender to improve seeding uniformity. The upland seed mixture (Table 4) was used in all areas disturbed by construction activities except those called out as wetland areas. Upland seed was also applied along with wetland seed in areas that were covered with turf reinforcement matting.

There were two wetland seed mixtures due to differences in water and soil chemistry at the Swastika (Table 5) and Dutchman (Table 6) wetland sites. The wetland seed mixtures were applied to all areas for which the designs suggested that the soils and hydrology would be consistent with a wetland habitat. The Dutchman site was fed by mine seeps which had created and saline/sodic soil chemistry with a pH up to 10. The wetland seeding species were selected for this wetland area based on their tolerance for high pH, EC, and SAR soils.

Table 4: Upland Seed Mixture

| **Species** | **Common Name** | **% PLS** | **PLS Lbs/ Acre** | **PLS/ Square Foot** |
|---|---|---|---|---|
| **Graminoids** | | | | |
| *Achnatherum hymenoides* | Indian ricegrass | 5% | 0.67 | 2.5 |
| *Bouteloua curtipendula* | side oats grama | 5% | 0.68 | 2.5 |
| *Bouteloua gracilis* | blue grama | 10% | 0.30 | 5.0 |
| *Bromus ciliatus* | fringed brome | 5% | 0.46 | 2.5 |
| *Elymus trachycaulus* | slender wheatgrass | 10% | 1.61 | 5.0 |
| *Nassella viridula* | green needlegrass | 10% | 1.30 | 5.0 |
| *Pascopyrum smithii* | western wheatgrass | 10% | 1.91 | 5.0 |
| *Pleuraphis jamesii* | James galleta | 5% | 0.72 | 2.5 |
| *Schizachrium scoparium* | little bluestem | 5% | 0.45 | 2.5 |
| *Sporobolus cryptandrus* | sand dropseed | 10% | 0.04 | 5.0 |
| *Graminoid Subtotal* | | *75%* | *8.15* | *37.5* |
| **Forbs** | | | | |
| *Artemesia frigida* | fringed sage | 5% | 0.02 | 2.5 |
| *Artemesia ludoviciana* | white sagebrush | 5% | 0.03 | 2.5 |
| *Dalea purpurea* | purple prairie clover | 2% | 0.14 | 1.0 |
| *Helianthus annuus* | annual sunflower | 3% | 1.39 | 1.5 |
| *Ipomopsis aggregata* | scarlet gilia | 2% | 0.69 | 1.0 |
| *Ratibida columnifera* | prairie coneflower | 5% | 0.15 | 2.5 |
| *Forb Subtotal* | | *22%* | *2.42* | *11.0* |
| **Shrubs** | | | | |
| *Rhus trilobata* | threeleaf sumac | 1% | 0.84 | 0.5 |
| *Krascheninnikovia lanata* | winterfat | 1% | 0.18 | 0.5 |

| | | | | |
|---|---|---|---|---|
| *Rosa woodsii* | Wood's rose | 1% | 0.43 | 0.5 |
| *Shrub Subtotal* | | *3%* | *1.45* | *1.5* |
| **Combined Totals** | | **100%** | **12.02** | **50.0** |

Table 5: Swastika Wetland Seed Mixture

| **Species** | **Common Name** | **% PLS** | **PLS Lbs/ Acre** | **PLS/ Square Foot** |
|---|---|---|---|---|
| **Graminoids** | | | | |
| *Deschampsia cespitosa* | tufted hairgrass | 7% | 0.12 | 3.5 |
| *Distichlis spicata* | inland saltgrass | 12% | 0.50 | 6.0 |
| *Eleocharis palustris* | common spikerush | 6% | 0.13 | 3.0 |
| *Muhlenbergia asperifolia* | scratchgrass | 10% | 0.15 | 5.0 |
| *Juncus arcticus (balticus)* | mountain rush | 12% | 0.09 | 6.0 |
| *Juncus torreyii* | Torrey's rush | 10% | 0.05 | 5.0 |
| *Pascopyrum smithii* | Western wheatgrass | 3% | 0.57 | 1.5 |
| *Phalaris arundinacea* | reed canarygrass | 12% | 0.49 | 6.0 |
| *Schoenoplectus tabernaemontani* | softstem bulrush | 5% | 0.20 | 2.5 |
| *Schoenoplectus maritimus* | cosmopolitan bulrush | 3% | 0.40 | 1.5 |
| *Scirpus pallidus* | cloaked bulrush | 5% | 0.11 | 2.5 |
| *Graminoid Subtotal* | | *85%* | *2.81* | *42.5* |
| **Forbs** | | | | |
| *Asclepias speciosa* | showy milkweed | 1% | 0.38 | 0.5 |
| *Helianthus nuttallii* | marsh sunflower | 5% | 0.5 | 2.5 |
| *Mimulus guttatus* | yellow monkeyflower | 5% | 0.02 | 2.5 |
| *Rudbeckia hirta* | black-eyed susan | 4% | 0.05 | 2 |
| *Forb Subtotal* | | *15%* | *0.95* | *7.5* |
| **Combined Totals** | **100%** | **7.21** | **3.76** | **50.0** |

Table 6: Dutchman Wetland Seed Mixture

| **Species** | **Common Name** | **% PLS** | **PLS Lbs/ Acre** | **PLS/ Square Foot** |
|---|---|---|---|---|
| **Graminoids** | | | | |
| *Distichlis spicata* | inland saltgrass | 15% | 0.63 | 7.5 |
| *Muhlenbergia asperifolia* | scratchgrass | 15% | 0.22 | 7.5 |
| *Juncus arcticus (balticus)* | mountain rush | 15% | 0.11 | 7.5 |
| *Beckmannia syzigachne* | American sloughgrass | 5% | 0.46 | 2.5 |
| *Schoenoplectus maritimus* | cosmopolitan bulrush | 10% | 1.34 | 5.0 |
| *Panicum virgatum* | switchgrass | 10% | 0.84 | 5.0 |
| *Pascopyrum smithii* | Western wheatgrass | 10% | 1.89 | 5.0 |
| *Puccinellia nuttalliana* | Nuttall's alkaligrass | 10% | 0.10 | 5.0 |
| *Phalaris arundinacea* | reed canarygrass | 10% | 0.41 | 5.0 |
| **Totals** | | **100%** | **6.00** | **50.0** |

**Transplanting**
Whenever possible native vegetation was salvaged at the beginning of construction for use in the final revegetation efforts. Wetland plugs and riparian and upland shrubs and small trees were dug up and stored as well as cuttings for willows and cottonwoods. This provided transplant vegetation with local provenance as well as species that are not commercially available.

*Wetland Plugs*
Wetland plugs were hand dug from the old channel before backfilling and stored in one-gallon pots until the new channel was constructed. Wetland plugs were stored in a completed section of stream channel that was flowing to allow for continuous sub-irrigation and the best chance of survival. Wetland plugs were planted back into the margins of the channel as soon as any given section of channel was completed and hydrated. Wetland plugs established and spread quickly which was apparent even before the end of the project.

*Tree/Shrub Transplants*
A total of 477 cottonwood trees (*Populus deltoides* and *P. angustifolia*) and willow trees and shrubs (*Salix amygdaloides* and *S. exigua)* were harvested with a 32-inch tree spade from the old channel before earthmoving began. The root ball was placed in a burlap-lined wire basket and moved from the digging areas to a nursery holding yard on-site. The baskets were stored close together under a shade cloth, packed with woodchips to prevent desiccation, and irrigated with a water truck on a daily basis. As a section of channel was completed and hydrated, the willows were planted next to the channel in wet soils and the cottonwoods were planted up gradient into mesic soils. Cottonwoods were fenced for protection from grazing by elk.

In addition to the riparian species, 45 upland trees and shrubs including Gambel's oak (*Quercus gambelii*), chokecherry (*Prunus virginiana*), three-leaf sumac (*Rhus trilobata*) rubber rabbitbrush (*Ericameria nauseosa*), honeysuckle (Lonicera sp.), gooseberry (Ribes aureum) and wax currant (*Ribes cereum*) were salvaged, stored in the nursery area, and transplanted back into the upland areas of the final landform farther from the channel.

*Willow/Cottonwood Cuttings*
Willow and cottonwood species can be easily established by planting branches cut off of established plants. A total of 15 poles of Rio Grande cottonwood (*P. deltoides*), narrowleaf cottonwood (*P. angustifolia*), and peachleaf willow (*S. amygdaloides*) were harvested in the spring of 2013 from along the Dillon Creek Channel within 1 mile of the Swastika site. Poles were 2 to 5 inches in diameter and 6 to 7 feet in length. The side branches were removed from poles and the poles were stored in water until planting several days later. Holes were augered down to the ground water table to ensure that the butt end of the pole was installed in the water table.

Additionally, a total of approximately 1,600 willow stakes were cut from locations upstream and downstream of the project area in the spring of 2013. Stakes were 18 to 36-inches in length and 1 to 2 inches in diameter. This part of the project was completed by a student volunteer group from the Raton area.

**Erosion Control**
Erosion control was achieved in revegetation area by two methods. Immediately adjacent to the stream channel one of two types of turf reinforcement mat (TRM) was installed to prevent scouring until the vegetation established on the banks. On slopes farther from the channel, Woodstraw™ wood strand mulch was applied.

*Turf Reinforcement Mat*
Two varieties of fully biodegradable TRM were used along the channel to prevent scouring until vegetation established. Landlok 450 was placed at approaches to cut banks in the most erosive areas, while Excel CC-4 was installed in the transitions between lower velocity point bars and straight reaches. The Landlok 450 can withstand a velocity of 18 feet per second when vegetated and biodegrades in 3 years. Excel CC-4 only withstands a flow velocity of 8.5 feet per second when vegetated and biodegrades in two years. Both TRM products were anchored into 12-inch deep trenches at the both the top and toe of the slope and secured with wire staples per specifications. Additionally, duckbill anchors were used to secure the TRM along the edges and where TRM segments overlapped. The duckbills were inserted 3 feet into the ground with an impact hammer and set with a jack. The friction disk will hold the fabric in place up to 300 psi.

*Woodstraw™ Mulch*
Woodstraw is an engineered wood strand mulch with several advantages over straw mulch. It is weed free, resistant to high winds, easily conforms to the slope, requires no crimping or tacking, not palatable to animals, and lasts over 4 years. Woodstraw was applied to all revegetation areas except those covered with TRM. Woodstraw was applied to most slopes by hand, but was applied with a straw blower to areas that were easily accessible. Application rates were based on slope steepness and manufacturer specifications (Table 7). Contour ripping and application of Woodstraw was a critical component to the geomorphic designed slopes on the recontoured gob piles and repository areas.

Table 7: Woodstraw Application Rates

| Slope | Woodstraw Application (Lbs/Acre) | Ground Cover |
|---|---|---|
| 0-5% | 4,000 | 40% |
| 6-33% | 7,500 | 50% |
| >33% | 13,800 | 70% |

**<u>Wetland Preservation</u>**
The landowner requested that, when possible, existing wetlands be preserved. In two areas along the new channel alignment, existing wetlands fed by subsurface springs and seeps were preserved. On the west side, a faux ox-bow feature was created by constructing a sturdy backfilled embankment on the upstream end to prevent the realigned channel from reestablishing surface flow into the area. A hydraulic connection between the oxbow wetland and the natural springs and seeps was provided by a constructed French drain to convey the flow from the backfilled seep and spring locations. On the east side, a smaller wetland area was preserved by not excavating the area and grading the adjacent landform to direct runoff into the wetland.

## Project Challenges

This project had a number of challenges from the outset such as steep slopes, complex designs, in-stream construction, shallow ground water, wildlife, and limited work area.

- Steep slopes and short transitions from up the gradient project boundary to the channel made for difficult equipment access and necessitated hand work for revegetation. Almost 25% of the total reclaimed area was steeper than 33%.

- The detailed geomorphic designs and grading plans required GPS-equipped machinery, special training for operators, and extreme attention to details especially on the side drainages to make sure that all surfaces integrated together as designed.
- The entire reclaimed landform was designed to be constructed without rock lining or riprap and used contour ripping and Woodstraw mulch to enhance slope stability.
- Working in the stream required detailed planning and phasing to complete grading work accurately without washing out.
- A shallow ground water table made for muddy working conditions and increased importance of sediment and erosion control structures in the stream channel.
- Wildlife including bears and snakes required extra vigilance when walking in the work area.
- Cultural resources such as buildings, foundations, and other structures identified during detailed archaeological surveys completed before and during the EA development had to be marked and avoided which severely limited work area.

Several more challenges also because apparent as the project progressed. Archaeological sites that were not identified during the initial surveys, primarily because they were buried, added approximately 20% to the construction budget due to avoidance, redesigns, and construction delays. Additionally, a severe drought from April 2012 – May 2013 (Figure 2) resulted in a worse than expected initial seedling establishment and transplant survival.

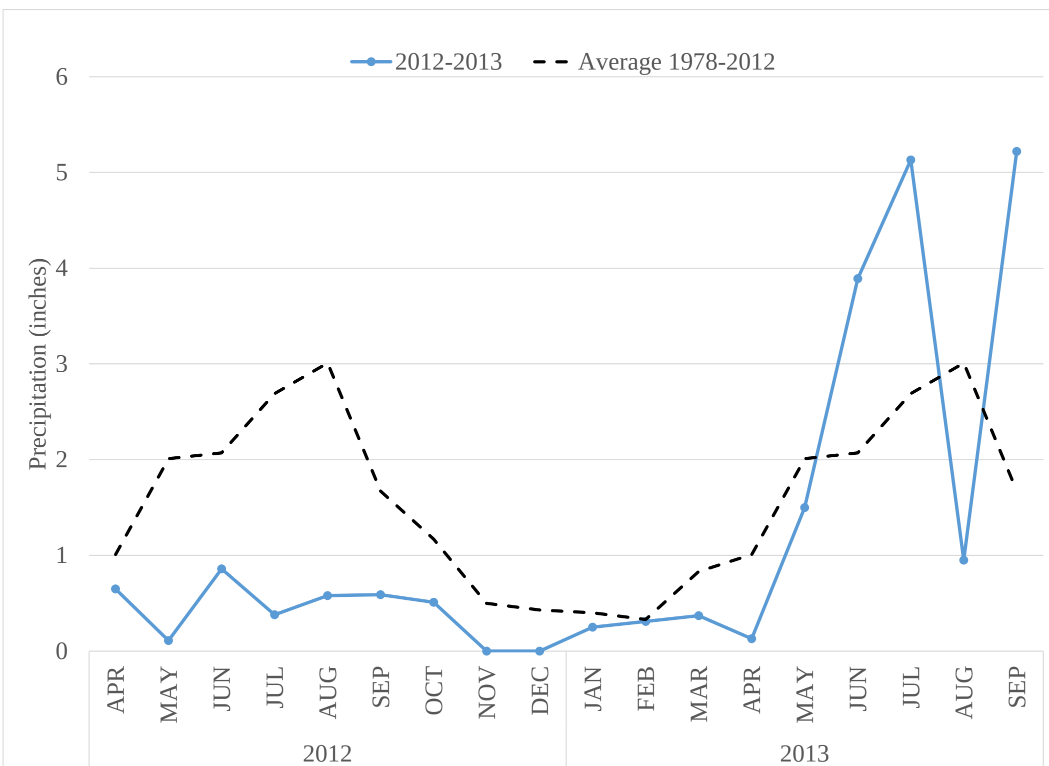

Figure 2: Precipitation 2012 - 2013

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