RECLAMATION OF SALINE SODIC SOILs UNDER SEMIARID CONDITION: COMPARATIVE EFFECTS OF DIFFERENT CHEMICAL, ORGANIC AND INDUSTRIAL AMENDMENTS[1]

E.F. Aboukila[2], P.D. Stahl, C.F. Strom, and S.J. Day

Abstract: A leaching experiment was conducted with soil columns to investigate the comparative efficacy of different chemical, industrial, and organic soil amendments in calcareous saline sodic soil reclamation under semiarid condition. Soil amendments used included gypsum (G), sulfur (S), ferrous sulphate (FS), pyrite (P), and langbeinite (L) (soluble potassium-magnesium sulphate mineral). Industrial byproducts used were water treatment residuals (WTR) (by-products from the production of potable water), spent lime (SL) (byproduct from sugar purification process), and thinstillage (TS) (byproduct from alcohol distilleries). The amendments were added to calcareous saline sodic soil collected from Wamsutter, WY ($CaCO_3$ = 4.38%, electrical conductivity (EC) = 6.6 dSm^{-1}, exchangeable sodium percentage (ESP) = 23.4%, and soil pH = 8.5). All amendments were applied alone or in a combination with compost (C). Gypsum, sulfur, ferrous sulphate, and pyrite were applied at equivalent rates of gypsum requirements for treating sodic soil. Whereas, application rates of water treatment residuals, spent lime, langbeinite and thinstillage were evaluated using a batch study experiment. Compost application rates were calculated to increase soil organic matter by 1%. In three replicates, treatments were applied to the soil, filled in soil columns, and then incubated in the field capacity moisture and a constant temperature at 25 C^o for one month. After incubation period, water was continuously added to each column. Leachates were collected every 0.5 pore volume of water and up to 4 leaching events. The results demonstrated that EC, SAR, and soluble cations of leachate of the first leaching event were significantly higher than those of the subsequent leaching runs. Moreover, the concentration of removed soluble cations was lower than the control. TS, TS+C, L and L+C were the best treatments in leaching rates. Whereas the S, P, and WTR treatments were the lowest in leaching rates.

Additional Key Words: Gypsum, sulfur, ferrous sulphate, pyrite, langbeinite, water treatment residuals, spent lime, thinstillage, compost.

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COMPARISON OF BASAL AND AERIAL COVER FOR TOTAL VEGETATION COVER AND TOTAL GROUND COVER ON OIL AND GAS SITES IN WYOMING[1]

Cindy Adams[2]

Abstract: Oil and Gas (O&G) reclamation in the Western United States has expanded greatly with the onset of gas development in the last decade. Successful revegetation of well pads, road right-of-ways (ROWs), and pipeline ROWs is quantified based on various methodologies outlined by the specific Bureau of Land Management (BLM) office which regulates development of that site. Although specific methodology varies between BLM offices, measurement of total vegetation cover and total ground cover are two vegetation parameters generally collected as part of revegetation evaluations. Basal cover and aerial cover are two forms of cover measurement utilized in reporting total vegetation cover and total ground cover for evaluation of site stability.

Basal and aerial cover data were collected using the point line intercept method at O&G sites throughout southwestern Wyoming. Three years of data were statistically analyzed to determine if there was a significant difference between aerial and basal cover for total vegetation cover and total ground cover within and between years. Results of this statistical comparison will be presented.

Additional Key Words: vegetative cover, sampling, reclamation

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THIRD YEAR SURVIVAL AND HEIGHT GROWTH OF AMERICAN CHESTNUT ON POST-BOND RELEASE SURFACE MINES IN EASTERN KENTUCKY [1]

Hannah Z. Angel[2], Christopher D. Barton and Patrick N. Angel

Abstract: The Forestry Reclamation Approach (FRA) has been utilized to reestablish native hardwood forests on sites impacted by surface mining in Appalachia. The American chestnut (*Castanea dentata*) was formerly an important hardwood species throughout the forests of eastern North America, but introduction of an exotic fungal blight (*Cryphonectria parasitica*) in the early 20th century decimated *C. dentata* populations. Surface mine spoils in the Appalachian coal region have been suggested as potential sites for the establishment of founder populations of blight-resistant chestnut hybrids which may then act as reservoirs for chestnut dispersal into surrounding forests. Three post-bond mine lands in eastern Kentucky that were reclaimed as hay land pastures were dozer ripped and planted with bareroot 15/16 backcross chestnuts. A study to examine the need for using weed mats and tree shelters on these sites was initiated due to concern of herbaceous competition and browsing from deer and elk. At each site, 25 chestnuts were planted in each of twelve plots that contained the following treatments (n=3): (1) control; (2) weed mats; (3) tree shelters; and (4) tree shelters plus weed mats. After three years, seedling survival has declined in all treatments but still significantly higher in the shelter (65%) and shelter + mat (60%) treatments than the mat (40%) and control (27%) treatments. Seedling height growth was limited between years 2 and 3 of the study (<20 cm for all treatments), but height was still greater in the two shelter treatments (124 and 127 cm for shelter and shelter + mat, respectively) than the mat (67 cm) and control (78 cm) treatments. Browse was moderate on the non-sheltered seedlings, while low on the sheltered plots. Limited growth and sapling mortality may be attributed to stress from a prolonged drought. In addition, increased browsing in the sheltered treatments over that observed in year 2 might be due to the height of the shelter (120 cm) which no longer provides protection when the shoot exceeds the shelter height.

Additional Key Words: reforestation, restoration, herbivory, competition.

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SURFACE RECLAMATION OF THE CAPTAIN JACK MILL SUPERFUND SITE[1]

N. Anton[2], T. Bragdon, M. Boardman, J. Jenkins, and C. Van Drie

Abstract: The Captain Jack Mill Superfund Site is located in Boulder County, approximately one mile south of Ward, Colorado. The surface contamination remedial action was completed during summer/fall 2012 and included the excavation of several mine dumps and consolidation of this material at two on-site repositories using a vegetated soil cover system and stormwater runon and runoff controls; reclamation of disturbed and excavated areas; and installation of access prevention features. Contaminants at the site include elevated concentrations of lead and arsenic in mine waste that present a human health risk to onsite residents and visitors. The remedy has successfully reduced these risks, while reclaiming a mountainous stream habitat area of approximately 5 acres.

To reduce infiltration and the potential leaching of metals from consolidated materials, the repositories were constructed by placing the more acid generating materials deeper in the repository and adding lime amendment to the top surface; consolidating calcite-containing mine material next; and then installing a 2-foot thick vegetated soil cover system. The remedy also included ancillary activities such as a demolition of the former mill and associated structures, construction of a concrete adit portal extension to increase repository volume, restoration of an onsite residential property, and installation of a mining influenced water diversion/detention system.

As a cost-effective approach, the remedy utilized onsite borrow soil/rock materials and imported reformed calcium carbonate waste from sugar beet processing, manure compost, and fertilizer as soil amendments. Reclamation approaches were implemented on steep mine dump areas, including soil amendment of the native subgrade after excavation, placement of fiber rolls, seeding and hydro-mulching, placement of erosion control blankets, and placement of down logs and slash from clearing and grubbing activities. Reclamation of other disturbed areas included road resurfacing and creek bank restoration with riprap armor, growth media, seed, erosion blankets, and willow cuttings.

Additional Key Words: None.

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REGEVETATION OF OVERBURDEN DUMP SLOPES IN AREAS ALTERED BY IRON MINING, CARAJÁS-PA, BRAZIL[1]

I.R. Assis[2], L.E. Dias, G.C. Rocha, L.C Lemos Neto and C.H.S. Rezende

Abstract: Revegetation works on the overburden dump slopes in iron mining areas have shown low sustainability. This study was carried out in the Carajás National Forest, Pará State, Brazil, and aimed to evaluate seeding methods (manual and hydroseeding) and fertilizer doses (0, 200, 400, 600 kg ha^{-1} of NPK 4-14-8), seeking greater sustainability of the revegetation process. The experimental design was a randomized block using three replications. It was used a species cocktail in each plot, with dimensions of 10x40 m. The seeding occurred in April 2010 and the first evaluation, four months after seeding, consisted of determining available nutrients and organic matter content (OM) in the soil, and biomass production. Biomass production was estimated using square with size of 50x50 cm, hurled three times in each plot. The soil samples were collected at 0-5 and 5-20 cm depth. There was a significant effect of seeding method only for potassium in 0-5 cm and OM in 5-20 cm, and the highest values for hydroseeding. For both seeding methods was observed significant effect, where it was linear and positive for available P and K about the applied dose, to the two depths. The fertilizer dose effect in the OM was observed just for hydroseeding, with higher values than manual process. There was no significant effect of seeding method on biomass production, and found slightly higher rates for manual process. However, the dose effect on biomass production was significant, linear and positive solely for hydroseeding. Therefore, there is no clear definition about the best seeding method. However, increasing the fertilizer dose was more effective using hydroseeding.

Additional Key Words: Manual planting, hydroseeding, biomass, land reclamation.

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SILVERTIP PIPELINE SPILL REVEGETATION[1]

L. J. Ballek[2] and L. Alvey

Abstract: This presentation will provide an overview of activities related to the revegetation of areas on Montana State Land disturbed during cleanup operations to remove crude oil from the shores, backwater areas, and islands of the Yellowstone River. This oil was deposited following a pipeline break that released over 1,000 barrels of oil into the Yellowstone River near Laurel Montana on July 1, 2011.

The pre-incident site conditions ranged from near pristine riparian and wetland plant communities to severely impacted communities. Local vegetation and soil was disturbed by vehicles, foot traffic, heavy equipment, staging area operations, and other actions taken to access and remove crude oil from areas where it came to rest.

The initial task on each site was to determine if there was damage related to the oil clean-up operation that required active revegetation. Any soil or vegetation disturbance was examined, looking for foot traffic routes and tire or tracked vehicle impacts.

If soil and vegetation disturbance from clean-up activities was evident on a site, the crew characterized the plant community, soils and weeds by identifying the dominant plant species in the existing plant community and estimating the percent cover of trees, shrubs, herbaceous plants, and noxious weeds. Based upon this information a reclamation seed mix and treatment were determined and each area of disturbance was documented by recording GPS points and photos. These revegetation treatments were completed in fall of 2011 and follow up inspections of revegetation success were conducted in spring and fall 2012.

Lessons learned during this project will be shared in the presentation including: active revegetation efforts versus natural recovery; the identification of areas of high energy, likely to be disturbed by high flows on a regular basis and, therefore, not candidates for revegetation efforts; and the short term and long term impacts of "All Terrain Vehicle" (ATV) use in the spill clean-up activity on riparian vegetation.

Additional Key Words: Remediation, Mitigation, Revegetation Design, Seed Mix Calculations, Revegetation Specifications, Trail Rehabilitation.

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RESTORATION OF SURFACE DISTURBANCES ON THE SHORTGRASS STEPPE OF NORTHEASTERN COLORADO[1]

S.A. Barr[2], J. Jonas, M.W. Paschke

Abstract: The recent discovery of oil and gas resources has led to unprecedented localized and distributed disturbances to the shortgrass steppe ecosystem in northeastern Colorado. Reclaiming these surface disturbances to native communities primarily through seeding has proven challenging. At present, seed mixes and rates are generally similar across private and public sectors (3-10 species at rates ranging from 400-600 PLS m^{-2}). The objective of this study is to determine an optimal seed mix diversity level and corresponding seeding rate for reclamation purposes on the shortgrass steppe. From this study, we aim to make recommendations to public and private industries about ideal seeding rates and seed mixes for restoration activities related to disturbances such as oil and gas exploration. This study has treatments spanning five seed mix diversity levels (5-50 species) and five seeding rates (400-1600 PLS m^{-2}) using a response surface regression experimental design implemented at twelve sites across three different locations in northeastern Colorado. Treatments are evaluated based on the biomass and diversity of seeded, volunteer native, noxious, and non-native species, and the density of seeded species. Our results show greatest restoration success occurring at a seed mix diversity level of 44 species and a seeding rate of 1155 PLS m^{-2} when desirability was maximized across all nine response variables. These preliminary results suggest that greater seed mix diversity levels and higher seeding rates could lead to greater restoration success.

Additional Key Words: seeding rate, seed mix diversity, restoration success, reclamation

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AILANTHUS ALTISSIMA INTERFERS WITH BENEFICIAL SYMBIONTS AND NEGETIVELY IMPACTS OAK REGENERATION[1]

Jenise M. Bauman[2], Caitlin Byrne and Shiv Hiremath

Abstract: The invasion of Tree-of-Heaven (*Ailanthus altissima*) has been documented in disturbed landscapes leading to biodiversity loss and degradation of ecosystem function. *Ailanthus* interferes with the restoration of native species by its aggressive growth habit, alteration of nutrient cycles, and allelopathic chemical production. Recent studies suggest that allelopathy has a negative effect on the growth of red oak (*Quercus rubra),* possibly by interfering with the symbiosis of beneficial ectomycorrhizal fungi (ECM). This fungal symbiont is essential for healthy tree growth and the unavailability of these fungi may impede the success of seedling regeneration. This study investigated the effects of *Ailanthus* on biomass production and ectomycorrhizal fungal (ECM) colonization of red oak (*Q. rubra)* seedlings on a reclaimed coal mine site in eastern Ohio. Six plots were designated in an existing riparian buffer zone in a wetland at The Wilds Conservation Center in Muskingum County. Three of the plots were in an area where mature *Ailanthus* was present. The other three plots were located in the same riparian zone that was without *Ailanthus.* Naturally regenerating two-year-old red oak seedlings were selected for study (10 seedlings per plot, 60 seedlings total). The oak seedlings were sampled for biomass (g) and ECM root colonization. Two-year-old oak seedlings growing among mature Tree-of-Heaven produced significantly less biomass, specifically in root production than the oaks growing without the invasive tree ($P = 0.02$). There was a decrease in ECM colonization ($P = 0.001$) and a shift in ECM community composition in plots where the Tree-of-Heaven was present ($P = 0.0004$). The increase in root biomass and ECM colonization may aid in the plant's competitive ability for belowground resources, important for reestablishment. These data suggest that areas impacted by the invasion of Tree-of-Heaven may require restoration with plant species less reliant on ECM colonization when planting in soils immediately following invasive species removal.

Additional Key Words: native tree generation, riparian buffer restoration.

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MATURE SUBALPINE TREE AND SHRUB TRANSPLANTING AT THE CLIMAX MINE, CLIMAX, CO[1]

R. F. Bay[2], K. E. Carlson, and A. Hilshorst

Abstract. As part of reclamation activities, 1,459 trees and shrubs were transplanted on the Climax Mine property during the summers of 2005, 2006 and 2007. The majority of transplants were Engelmann spruce (*Picea engelmannii*), the dominant tree species on the Climax property. Other transplanted species included subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), several willow species (*Salix* spp.), shrubby cinquefoil (*Dasiphora fruticosa*), dwarf birch (*Betula nana*), and currant species (*Ribes* spp.). Trees and shrubs with 32 – 60-inch root balls were harvested using a tree spade within the mine's affected area and placed in burlap-lined cages for transport and temporary storage before planting in reclaimed areas. Transplants were placed in holes deep enough to cover to the root crown, backfilled with a mixture of topsoil, old woodchips, and composted biosolids (4:1:1), and mulched with woodchips. All transplants were watered in within 2 days of planting and treated with a general mycorrhizal inoculant.

Each transplanted tree and shrub was monitored for survival and growth in 2005, 2006, 2007, 2008, 2010 and 2012. Overall, transplanting was relatively successful with 68% total survival as of 2012. Shrubs were more successful than trees with 96% of shrubs surviving compared to only 63% of trees. Survival was greater for spruce trees (64%) than fir trees (41%). Also, survival was greater in shorter (<6 ft tall) trees with 72% still alive in 2012 compared to only 56% of taller trees. Tree survival dropped substantially between 2010 and 2012 from 71% to 63%, likely due to drought conditions and heavy elk damage. Elk damaged 25% of the trees, but only 26% of damaged trees died. There was also a significant difference in survival for different planting locations and soil types. The goal for this project was 50% survival after the first growing season. Thus, survival is better than expected and the goal has been surpassed after several growing seasons.

Additional Key Words: Mine reclamation, revegetation, shrub, spruce, willow

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USING TEXAS RAPID ASSESSMENT METHOD FOR PRE-MINE AND POST-MINE WETLAND EVALUATIONS[1]

E.D. Bearden and J.D. Wooten[2]

Abstract: The Texas Rapid Assessment Method (TXRAM) is the new standardized method used to evaluate the condition of streams and wetlands requiring a U.S. Army Corps of Engineers permit in the Fort Worth and Tulsa Districts within Texas. TXRAM is a tool for use in determining the potential impacts of fill activities and benefits of mitigation efforts for USACE-authorized activities under Section 404 of the Clean Water Act. TXRAM is a rapid, repeatable, field-based method of assessing ecological condition of waters of the U.S. It is not focused on specific ecological functions or societal values but is useful in determining impact and mitigation associated with USACE activities. It provides a single score of condition for waters and was developed to fit the regulatory needs of the Corps districts.

Projects requiring notification to the USACE for authorization under a Section 404 / 10 permit, particularly those requiring compensatory mitigation, will require TXRAM evaluation once the final method is published. TXRAM will be used to assist the USACE and project applicants in determining appropriate mitigation requirements. TXRAM has been performed on both premine and postmine waters to help determine mitigation needs.

Additional Key Words: Function, mitigation

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THE CONSTRUCTION AND INITIAL RESULTS OF A DEMONSTRATION PASSIVE TREATMENT SYSTEM FOR REMOVING SULFATE AT A SITE ON VANCOUVER ISLAND, BRITISH COLUMBIA[1]

E. P. Blumenstein[2], R. J. Schipper[3], and J.J. Gusek[3]

Abstract: Sulfate is beginning to gain attention and be regulated in mining influenced water (MIW) discharges worldwide. Currently, the effective removal options are limited with reverse osmosis (RO) filtration and/or chemical precipitation most commonly implemented. These systems are burdened by high capital costs (equipment, construction) as well as high operational and maintenance (O&M) costs (power consumption, chemical usage, sludge production, and operations staff). There is a need to develop an alternative technology that can economically remove sulfate from MIW and achieve compliance with these new and anticipated regulations.

Until recently, anaerobic passive treatment cells such as biochemical reactors (BCR), also known as sulfate reducing bioreactors (SRBR), successive alkalinity producing systems (SAPS), and reducing alkalinity producing systems (RAPS), have primarily focused on increasing pH to circum neutral levels and removing metals (aluminum, cadmium, copper, iron, mercury, nickel, lead, selenium, thallium, uranium, vanadium, zinc, among others). In contrast, a hybrid passive demonstration system has been built at a coal mine site on Vancouver Island, British Columbia for the primary purpose of removing sulfate from MIW. The demonstration system was based on bench test results.

The demonstration hybrid passive treatment system has a design flow rate of approximately 70 gallons per minute (4.5 L/sec) and consists of a BCR, a separate sulfide polishing cell, and an aerobic polishing system (including an aeration cell and a settling pond). Power is required to pump MIW influent from an underground mine pool to the BCR and for active aeration and mixing in the aerobic polishing system. Active aeration was used in lieu of a constructed wetland due to space constraints on the site. Bench results, construction of the demonstration system, and preliminary demonstration system results will be discussed.

Additional Key Words: passive treatment, biochemical reactor, sulfide polishing cell, aerobic polishing system, sulfate, sacrificial iron

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A COMPARISON OF SOIL CONDITION, VEGETATION COMMUNITIES, AND SOIL REDOX CHARACTERISTICS OF SURFACE MINED WETLANDS AND NATURAL WETLANDS IN SOUTHERN ILLINOIS[1]

B. Borries[2], K. W. J. Williard, J. Schoonover, and S. Indorante

Abstract: Wetland ecosystems along Galum and Bonnie Creek were relocated at the Burning Star #4 mine in Perry County, Illinois during surface coal mining (1983-1998). By 2001 the riparian wetlands were reconnected to the restored Galum and Bonnie Creek channels. A study was conducted in 2012 to compare soil condition, vegetation, and soil redox characteristics of mined wetlands to nearby natural wetlands. Soil samples were collected at 0-15 cm and 15-30 cm depths from eight mined wetlands and four natural wetlands and analyzed for soil organic matter, total carbon, bulk density, soil texture, total nitrogen, extractable phosphorus, and pH. Percent cover of each plant species present was determined using 0.25 meter quadrats. Soil redox characteristics were analyzed using IRIS (Indicators of Reduction in Soils) tubes. In addition, a smaller number of 90 cm soil cores were extracted using a gouge auger and described based on the soil texture, color, aggregation, and carbon content of each soil. Preliminary results indicated no significant difference in soil organic matter content and bulk density in the top 15 cm between the forested mined wetlands and natural wetlands, but below 15 cm, organic matter was higher and bulk density lower in the natural wetlands. Emergent marsh mined wetlands were significantly lower in organic matter and higher in bulk density than the natural wetlands in both the upper and lower soil samples.

Additional Key Words: Wetland Biogeochemistry, Soil Pedogenesis, Wetland Restoration

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A COMPARISON OF STREAM CHEMISTRY IN THREE RESTORED ILLINOIS COAL BASIN STREAMS: INITIAL CONDITIONS VS. 10 AND 20 YEARS POST-RESTORATION[1]

B. Borries[2], K. W. J. Williard, J. Schoonover, and J. Nawrot

Abstract: Can water quality in streams relocated during surface mining be restored following reclamation? Three large streams and riparian ecosystems – Galum, Bonnie, and Pipestone Creeks – were relocated at the Burning Star #4 and Denmark Mines in Perry County, Illinois. The reclamation plan included restoring the streams and adjacent riparian wetlands in a similar location and configuration as pre-mining. Now, more than 10 years (Burning Star #4 mine) and 20 years (Denmark mine) after reconnecting the streams to their upstream watershed a comprehensive reassessment of the water quality and biological communities of the streams is being conducted. Grab samples were collected from 1979-2012 and included samples taken before mining, during mining, and after mining. Samples were analyzed for sulfate, dissolved oxygen, temperature, specific conductivity, total suspended solids, total dissolved solids, manganese, iron, zinc, alkalinity, nitrate, fluoride and chloride. Qualitative multi-habitat macroinvertebrate sampling was conducted using a dipnet; riffles and pools at Pipestone Creek were sampled quantitatively using a mini-ponar dredge and a surber sampler. Preliminary data from sampling conducted immediately following the reconnections indicated the streams were recovering to a condition similar to other un-mined Southern Illinois streams. Using the additional data collected during 2012-2013, temporal and spatial trends will be analyzed statistically. Grab samples collected over the last year and from the 5 year post-restoration sampling are being used to show whether or not water quality is continuing to improve. Preliminary sulfate and temperature data indicate increasing sulfate levels and temperatures as the streams progressed through the mines. In the Burning Star #4 streams a significant decrease was seen in sulfate levels since the 5 year post-restoration sampling. Temperature did not change significantly since the 5 year post-restoration sampling in any of the streams.

Additional Key Words: Stream Restoration, Water Quality, Aquatic Macroinvertebrates

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INFILTRATION IN RECONSTRUCTED CHANNELS[1]

Kirsty Bramlett[2], John C. Stormont, and Mark Stone

Abstract. Geomorphic mine reclamation seeks to restore land to a natural state that mimics former conditions and the surrounding environment. Comparing characteristics of post reclamation channels with preexisting channels of comparable order within the same watershed aids evaluation of the effectiveness of replicating former conditions. Field tension infiltrometer tests were conducted in reconstructed channels and preexisting natural channels in a reclaimed surface coal mine in northern New Mexico. In-channel material included mine spoil, top soil dressing, and undisturbed soils. Tension infiltrometer measurements were used to estimate hydraulic conductivity under saturated and near-saturated conditions. Data from these measurements provide input to subsequent numerical simulations of surface runoff and channel infiltration, and yield insight into expected channel response to storm events. Run-off history from a 1000 hectare watershed in response to one year of climate data was estimated with a digital elevation model employing the Spatial Analyst tool in ArcMap 10.0. The output from this model was the runoff hydrograph that would travel through the constructed channel. This information was converted into a time variable pressure head boundary condition for a transient unsaturated/saturated soil water simulation using HYDRUS2-D that included the channel and adjacent soils. The simulation estimated infiltration and subsequent redistribution of water into soils adjacent to the channel and evapotranspiration at the surface. Results indicate little net recharge is anticipated principally due to infrequent periods when water is expected to be in the channel.

Additional Key Words: Fluvial geomorphology, mine reclamation, channel reconstruction, tension infiltrometer, soil water infiltration.

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COMPARATIVE ANALYSIS OF MULTIPLE SOFTWARES USED IN AIDING GEOMORPHIC RECLAMATION[1]

Kristin M. Brown[2]

Abstract: A comparative analysis of three software packages used for aiding in geomorphic reclamation was conducted by the author. Using the appropriate software for modeling site conditions and engineering design is of utmost importance. Sometimes, it may help to use different software packages to achieve proper geomorphic reclamation dependent on the site conditions and engineering design goals to be met. Two of the software packages analyzed are RIVERMorph® and Carlson Natural Regrade. These software packages are based off of the Rosgen and Geofluv Method of natural channel/stream design, respectively. A summary of the analysis findings of these and other software packages will be presented.

Additional Key Words: Surface Coal Mining, Hydrology, Watershed, Restoration

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GEOCHEMICAL MODELING OF URANYL SORPTION AT A COLORADO TEST SITE[1]

Kristin M. Brown[2]

Abstract: Geochemical modeling was conducted in order to compare laboratory results with a hypothesis of what processes were taking place at the Rifle Integrated Field Research (IRFC) site. The conceptual model for this project has three main features: 1) Since we can see that ferrihydrite colloids were formed in the laboratory from site samples, they are considered present. 2) In general, uranium is known to sorb to ferrihydrite colloids, which leads to the question 3) Do uranium ions sorb to ferrihydrite colloids at the Rifle IFRC site? According to the laboratory data presented above, uranium ions should not sorb to ferrihydrite colloids at the Rifle IFRC site. A simple geochemical model was run in order to compare the laboratory results to conditions at the Rifle IFRC site based on this conceptual model.

Additional Key Words: Uranium, Mining, Hydrology, Geochemistry

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GROWTH OF SWITCHGRASS ON RECLAIMED SURFACE MINE[1]

Carol Brown[2] and Jeff Skousen

Abstract: Growing crops for biofuel production on agricultural land has caused a moral dilemma of choosing biomass crops for fuel instead of food for a growing world population. This has increased interest in growing biofuel feedstocks on marginal lands. Switchgrass (*Panicum virgatum* L.), a warm-season perennial grass, has been shown to be a viable bioenergy crop because it produces high yields on marginal lands under low water and nutrient conditions. From previous studies, switchgrass yields on marginal croplands varied from 5000 to 8000 kg ha^{-1}. West Virginia contains immense acreages of reclaimed surface mine lands and could offer enough area for the production of switchgrass as a feedstock for a biofuel industry. For reclaimed lands, yield targets of 5000 kg ha^{-1} were set. Two studies were established to determine switchgrass yields of different varieties and under different harvesting times on mine sites in West Virginia. In the first study, three varieties of switchgrass were tested on two mine sites, Hampshire Hill and Hobet. The Hampshire Hill mine site, which was reclaimed in the early 1990's using top soil and treated municipal sludge, consistently had the highest yield of the two sites with a fifth year yield of 9066 kg ha^{-1} averaged across varieties. Cave-in-Rock variety produced 15600 kg ha^{-1} of biomass which was more than the other two varieties, Shawnee and Carthage, at 8600 and 3000 kg ha^{-1}. The other mine site, Hobet, was prepared using crushed, unweathered sandstone, and yields of switchgrass were 890 kg ha^{-1} for the fifth year of production, with Cave-in-rock producing the most biomass at 1275 kg ha^{-1}. The second study looked at one- and two-cut harvesting systems. The first cut was done in July and the second in October. Yields were not significantly different between the two harvesting systems in 2011 with a one-time harvest at the end of the growing season giving 3029 kg ha^{-1}, while the two-cut system gave 2922 kg ha^{-1}. Our results showed that Cave-in-Rock and Shawnee both produced over 5,000 kg ha^{-1} at Hampshire Hill, but no varieties grown at Hobet reached this yield. The type and quality of soil and the variety of switchgrass selected for seeding should be taken into consideration in order to produce high yields of switchgrass.

Additional Key Words: bioenergy, biofuel crops, reclaimed mined lands,

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CAN ELK MITIGATE DISTURBANCE RISK ASSOCIATED WITH NATURAL GAS DEVELOPMENT?[1]

Clay B. Buchanan[2], and Jeffrey L. Beck

Abstract: Ungulates offer an opportunity to understand the impacts of energy development on wildlife because ungulates must balance resource selection and food acquisition with the risks of human disturbance. Our study was based in the 500-km^2 Fortification Creek Area (FCA) of northeastern Wyoming, USA, where over 700 coal bed natural gas (CBNG) wells have been developed since 2000. Our previous work in the FCA indicated elk (*Cervus elaphus*) avoidance of roads led to a concomitant reduction of high quality habitat used by elk of approximately 30–42%. Our research focused on elk response to disturbance risk associated with CBNG development, including fine-scale temporal (day and night) resource selection relative to forage production. We used environmental and anthropogenic infrastructure data to develop mixed effects resource selection models to identify temporal elk resource selection shifts using ~114,000 GPS locations from n = 55 female elk. We assessed the relationship between forage availability and observed selection shifts to quantify the ability of elk to reduce disturbance impacts through daily movement patterns. Our results suggest elk did not shift daily resource selection patterns to decrease CBNG development impacts. Elk did not return to before development areas, classified as high elk use, during nighttime hours when vehicle traffic was lowest. High use areas averaged greater than 5 km from high traffic roads and greater than 2 km from low traffic roads during both day and night. Elk also selected for areas of higher juniper cover, but this pattern did not link with changing forage production. This study was conducted during years of above average rainfall, which may have buffered the impacts of development through increased forage production. However, our results suggest elk are consistently avoiding roads associated with CBNG development thus reducing human activity and maintaining refugia should be included in future management planning.

Additional Key Words: resource selection, forage availability, indirect effects

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RECLAMATION OF ABANDONED MINE LAND THROUGH POULTRY LITTER BIOCHAR AMENDMENT[1]

U. Buyantogtokh[2] and M. Guo

Abstract: Long-term soil fertility improvement is critical to successful reclamation of abandoned mine land (AML) with revegetation. As a nutrient-rich, recalcitrant organic co-product of poultry litter (PL) pyrolysis, PL biochar shows the potential as a promising soil amendment for revegetating abandoned mine land. Greenhouse trials were conducted to evaluate the feasibility of reclaiming AML with PL biochar soil amendment. Raw PL waste from local broiler farms was converted to biochar by slow pyrolysis at 300°C and applied to a rocky, strongly acidic, and nutrient-poor AML soil collected from a coal mining site at 0, 10, 20, and 30, respectively. The PL biochar-amended soils were packed in separate 5-L growing pots, adjusted to moisture at 60% of the water holding capacity, and stabilized in the greenhouse for 30 d with necessary moisture maintenance. Seeds of poverty oatgrass (*Danthonia spicata*), a native grass identified at the AML site were planted in the pots at the recommended rate and soil depth. Growth of oatgrass in the soil pots was monitored for 6 months with measurements of seed germination, tiller development, plant height, and biomass yield. Leachates from the pots were collected and analyzed for nutrient leaching losses. After plant harvest the test soils were examined for various fertility parameters and compared by statistical synthesis. The results showed that PL biochar amendment at 30 g kg^{-1} significantly improved the growth and biomass yield of poverty oatgrassthe in the AML soil. The treatment reduced the acidity of the soil by 90% and improved its porosity. The organic carbon content, cation exchange capacity, and plant-available N, P, K, Ca, Mg, and S contents of the amended soils were also substantially elevated as compared to the unamended control soil. It was evident that at appropriate application rates, PL biochar served as an ideal fertility enhancer for conditioning poor, acidic AML soils.

Additional Key Words: Abandoned mine land reclamation; poultry litter; biochar; soil fertility.

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GEOMORPHIC RECLAMATION OF ABANDONED COAL MINES ON VERMEJO PARK RANCH NEAR RATON, NEW MEXICO

II. RECLAMATION AND REVEGETATION[1]

K. E. Carlson[2], R. F. Bay, R. Spotts, P.E., Z. Isaacson

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 October 2012 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 amended with composted wood waste or Kiwi Power Organic Soil Treatment™ and Fertil-Fibers NutriMulch™ (6-4-1) on 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.

Additional Key Words: Abandoned mine reclamation, revegetation, riparian restoration, wetland construction, shrub, soil amendment

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USING THE RQ-11 RAVEN A AND THE T-HAWK FOR OVERSIGHT INSPECTIONS OF SURFACE COAL MINES IN WEST VIRGINIA[1]

N.L. Carter[2], L.J. Monette, D.T. Beaman

Abstract: The Office of Surface Mining Reclamation and Enforcement (OSMRE) personnel have been testing new technology to supplement its current Surface Mining Control and Reclamation Act (SMCRA) mandated oversight inspection activities on surface coal mines. In the spring of 2011 OSM was offered the use of the RQ-11 Raven A. The Raven is a small unmanned aerial vehicle currently owned by the Department of the Interior and operated by trained personnel from the United States Geological Survey (USGS.) It can be equipped with various cameras to capture both digital stills and video, and in true color and infrared. Initial proof of concept testing was conducted in the fall of 2011. The results of this initial test were positive, and additional field testing was conducted in late 2012. The next phase of the project added the use of the RQ-16A T-Hawk Micro Air Vehicle (MAV) and concentrated, not only on the ability to capture high quality images in order to scale mining related structures such as ponds, spillways, and sediment ditches, but also provided a true cost to benefit ratio of the use of this technology. More concentration was spent on the efficiency of the Raven and MAV's use by using them in a practical real time application. This technology is capable of covering large areas of terrain in a short span of time which may also increase productivity. This cannot replace personnel in the field but it already seems to be shaping up to be an asset to our overall effectiveness and efficiency, while also increasing the overall safety to our field personnel.

Additional Key Words: Office of Surface Mining, OSM

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CREATIVE APPROACHES TO OLD RECLAMATION CHALLENGES[1]

Dan Close[2]

Abstract: Bentonite mine land reclamation within Wyoming's Big Horn Basin is facing ever-increasing challenges. With an eleven-year average rainfall of 5", sodic soils, and an explosion of invasive weeds, achieving timely bond release is an issue that requires fresh eyes on old problems. Invasive weed control, overburden management, and agency partnering will be presented as examples of innovative solutions. In these examples, traditional approaches will be questioned and the results of alternative methods will be shared.

Although chemical control of cheatgrass is effective, it is not a long-term solution, it is costly, and it does not answer the issue of failed seeding due to pre-treatment weed invasion. M-I SWACO is currently running trials with stockpiled vs. live topsoil, topsoil treatment prior to seeding, seed mix customization, assisted succession with aggressive perennial species, and upwind seed source management.

M-I has also found that reclamation concepts based on premine vegetation and soils inventories, which might not reflect current restoration objectives, have not necessarily resulted in successful revegetation. Efforts to redefine these parameters, and the subsequent revision of material salvage and seeding procedures based on these findings and the translation of these concepts into operator-friendly language appears to be yielding promising results. Examples of failed-site mitigation will also be shared.

M-I has also found value in partnering with governmental agencies. This strategy has resulted in additional project resources, elevated corporate commitment, and more-flexible working relationships with regulatory entities.

The objective of this session will be to encourage managers to revisit their reclamation protocols through active monitoring and creative thinking. Although the examples presented reflect specific situations, the creative approach concept can be extended to, and utilized by, anyone involved in land restoration planning.

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APPROACHING OIL AND GAS PAD RECLAMATION USING DATA MINING: A FRAMEWORK FOR THE FUTURE[1]

Michael F. Curran[2], Benjamin J. Wolff, Peter D. Stahl

Abstract: A database framework was constructed with the purpose of creating a restoration decision management tool by compiling oil and gas pad reclamation data to identify successful restoration practices. Pre-existing data were secured from public and private databases across three Wyoming production fields: Jonah Infill, Moxa Arch in the Greater Green River Basin and the Wamsutter field in the Atlantic Rim area. The framework includes tables for measurements of reclamation practices (e.g. soil handling methods and amendments, seeding mix and timing, and weed management), geographical and climate data (e.g. precipitation, slope, aspect, elevation and temperature) and monitoring data (e.g. vegetation composition and structure along with soil analysis and grazing). Microsoft Access and ESRI ArcGIS were employed to build the reclamation database for consistent and reliable data storage, manipulation and retrieval. The long-term goal of the project was threefold: to deliver an operational framework to analyze and isolate trends leading to reclamation success and failure, to provide a strong decision management tool for limiting uncertainty and estimating associated risk under variable environmental conditions, and to offer a flexible and sharable database that allows for additional data input from diverse sources. Database performance was found to be dependent on data consistency and validity. Querying populated data along with uniting imported data has revealed multiple strengths and weaknesses with the database framework. Operation of the database was demonstrated.

Additional Keywords: environmental risk management, restoration, database

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DEFINING OIL AND GAS PAD RECLAMATION SUCCESS ON WYOMING BLM LANDS[1]

Michael F. Curran[2], Benjamin J. Wolff, Peter D. Stahl

Abstract: For oil and gas pad reclamation to achieve long-term success in Wyoming's semi-arid and arid environments, ecosystem processes must be reestablished on disturbed well pads. Determining the state of ecosystem processes requires measurements such as nutrient cycling, soil formation, energy capture and soil biota which are not mandated by regulatory agencies. On Bureau of Land Management (BLM) lands in Wyoming, oil and gas pad reclamation is regulated by both Wyoming Department of Environmental Quality (WDEQ) and district-based BLM Field Offices. WDEQ's Storm Water Pollution Prevention Plan (SWPPP) emphasizes erosion control and lack of noxious weeds, while BLM Field Offices employ a range of vegetative cover and soil protection requirements that vary among field offices. Conflicting regulatory criteria may have adverse effects on long-term ecosystem health by imposing rapid and intensive compositional and structural-based reclamation. Ultimately, it is the regulatory agencies, not the academic and scientific community that define reclamation success and failure. The objective of this paper is to compare the regulatory definitions of reclamation success among the WDEQ and BLM Field offices. Using a Wyoming oil and gas reclamation database and scientific literature, we hope to highlight the long-term effects of different regulatory criteria on oil and gas pad reclamation.

Additional Keywords: Wyoming Department of Environmental Quality, Restoration, Ecosystem Processes, Bureau of Land Management, Environmental Regulation

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CHALLENGING THE IDEA OF REFERENCE SITES AS INDICATORS FOR OIL AND GAS PAD RECLAMATION SUCCESS[1]

Michael F. Curran[2], Benjamin J. Wolff, Peter D. Stahl

Abstract: Oil and natural gas pads on Bureau of Land Management (BLM) lands in Wyoming are required to be reclaimed to the standards set by the BLM field office having regulatory jurisdiction. While reclamation criteria vary among field offices, each office requires disturbed sites to meet vegetation criteria based on comparison to an undisturbed reference site. Individual reference sites may not only experience extreme shifts from year to year, but may also demonstrate drastic variation in vegetative structure and composition among reference sites within the same soil series. The objective of this paper is to evaluate and challenge the effectiveness and practicality of using individual reference sites as definitive guidelines to determine reclamation success on disturbed well pads in Wyoming oil and natural gas production fields. A quantitative analysis of a Wyoming reclamation database containing data covering vegetative and soil measurements on both disturbed well pads and undisturbed reference sites from 2005-2012 was examined to address this contention. The inquiry revealed problems with using a single reference site per pad as the conclusive indicator for reclamation success. We recommend using a combination of multiple reference sites and NRCS soil series maps, which strongly influence ecological site descriptions, to develop median criteria for identifying trends leading to reclamation success or failure on disturbed well pads.

Additional Keywords: Ecosystem processes, Reclamation Standards, Ecological Site Description, Soil mapping

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USE OF SPOIL AS A LOW PERMEABILITY BARRIER[1]

Mariana da Rosa[2], Carmen T. Agouridis, and Richard C. Warner

Abstract. Specific conductance and selenium (Se) are two water quality parameters of emerging concern in the Appalachian Coal Belt region. Isolation of high specific conductance and Se producing spoils using a low permeable barrier is one method of minimizing the leaching of these constituents. Ideally, the material used to form the barrier should be readily accessible, have low levels of specific conductance and Se, and be capable of achieving a low permeability with the proper moisture adjustment. Brown and gray sandstones are often readily available at mine sites in the Appalachian coalfieds. Spoil samples and water quality samples from the University of Kentucky Bent Mountain Research Complex near Pikeville, Kentucky indicate that these spoil types hold promise in meeting the criteria of being a low specific conductance producing material. However, these sandstones have higher sand contents than those typically used in compacted barriers or liners in landfills. The objective of this study was to assess the potential of using brown and/or gray sandstones to create a low permeability barrier. To meet the objective of the study, a total of four spoil samples (identified as M1-M4) were collected in 2012. Each spoil sample was obtained from a different mine in eastern Kentucky. Samples M1 and M2 consisted of brown sandstone; sample M3 was gray sandstone; and sample M4 was a mixture of brown and gray sandstones. Each spoil sample was screened and analyzed for soil texture. Spoil moisture content-density relationships and spoil saturated hydraulic conductivity-moisture content relationships were developed for each sample using double ring permeameters. Maximum saturated hydraulic conductivity values ranged between a low of 5.9×10^{-8} cm s^{-1} to a high of 3.1×10^{-7} cm s^{-1} in the laboratory for the <2mm fraction. These saturated hydraulic conductivity values were comparable to soils used to construct liners in landfills particularly in instances where the percentage of fines in the spoils were about 50% or greater. When in the field, however, it is expected that these saturated hydraulic conductivity values will typically be 2-3 orders of magnitude higher due to rock fragments. These results demonstrate that brown sandstone, with its higher fines content, is likely a more suitable media than gray sandstone for constructing a low permeability barrier to isolate high specific conductance producing and/or Se generating spoils. Based on these laboratory results, field assessments of brown sandstones for this application are recommended.

Additional Key Words: Proctor, hydraulic conductivity, water quality.

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PASSIVELY-ENHANCED LIME MIXING AND DISSOLUTION[1]

T. P. Danehy[2], B. R. Leavitt, B. J. Page, R. M. Mahony, C. A. Neely, C. F. Denholm, S. L. Busler, M. H. Dunn

Abstract: Water-powered lime dosers have been used for many years to feed pebble quicklime (CaO) and, more recently, hydrated lime ($Ca(OH)_2$) at mine drainage treatment facilities where electric power is not available. Lime utilization at these facilities has historically been poor when pebble lime is used due to the low solubility, high density, and large particle size of the pebble lime. This has resulted in the use of mixing channels downstream of the dosers to provide contact time with the treated water as well as agitation and mixing that at times have limited effectiveness. To improve pebble lime utilization at the Manor treatment facility near Clearfield, Pennsylvania, two passive mixing technologies have been developed and deployed. The "MixWell", inspired by diversion well technology and a Trompe-driven air lift mixer "A-Mixer" are used in series to increase chemical utilization and reduce sludge handling costs. The result of this modification is an estimated 40 to 50 percent reduction in lime usage, leading to a savings of over $10,000 per year in chemical cost.

Additional Key Words: Water Treatment, Mine Drainage, Slaking, Aquafix.

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EFFECTS OF DISTURBANCE OF SALT-AFFECTED SOILS IN A WYOMING NATURAL-GAS PRODUCTION AREA[1]

Samantha J. Day[2], Jay B. Norton, Calvin F. Strom, and Emad F. Aboukila

Abstract: Energy development in the state of Wyoming often requires disturbance of naturally salt-laden soils, which often increases salt content in soils salvaged for reclamation. Saline soils are the most common salt-affected soils in Wyoming, but disturbance effects to sodic soils are most difficult to mitigate because of crusting and dispersion of clays. More information is needed to understand the extent and range of effects of disturbance on Wyoming's high desert sodic and saline-sodic soils. Saline and sodic soils from seven recently reclaimed natural-gas well pads and undisturbed pairs were sampled (0-15 cm) in 2012 and analyzed for differences in texture, pH, and soluble salt and sodium (Na) contents. Additionally, two of the seven recently reclaimed well pads and their two adjacent undisturbed areas (one with sodic and one with saline-sodic soil) were further sampled, with four 0- to 15-cm depth samples from each of the four areas, for a total of 16 samples. These samples were analyzed for texture, bulk density, dry and water-stable aggregate distributions, electrical conductivity (EC), ponded infiltration, total organic carbon (TOC) and nitrogen (N) content, calcium carbonate ($CaCO_3$) content, microbial biomass C and N, pH, and root biomass. Paired difference analysis across the seven sites indicated that disturbance and reclamation caused significant increases in EC, sodium adsorption ratio (SAR), and percent base saturation. Analysis of variance of data from the intensively sampled sites indicate that reclaimed sites had much finer textured soils with increases in EC from 0.61 to 8.51 dS m^{-1} on the saline-sodic site and from 0.29 to 1.75 dS m^{-1} on the sodic site, and decreases in OC by more than 60% and a loss of N by 24-34% on both disturbed sites as compared with undisturbed sites. Disturbed sites also exhibited cloddier soils than their undisturbed counterparts. Reclamation projects in Wyoming face limiting conditions such as low annual rainfall, long and cold winters, and difficult management implications from large operations and widely spread drilling locations. Addressing these challenges includes understanding the negative consequences of disturbance and possible options for mitigating these consequences.

Additional Key Words: sodic, saline-sodic, reclamation, soil structure

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FEMALE WILD TURKEY ECOLOGY ON A MIDWEST RECLAIMED SURFACE MINE[1]

K. S. Delahunt[2], R. G. Tebo, J. R. Nawrot, and C. K. Nielsen

Abstract: Most research on Eastern wild turkeys (*Meleagris gallopavo silvestris*) has occurred in extensively forested habitats atypical of midwestern landscapes or reclaimed surface mines. We studied the ecology of female wild turkeys on a reclaimed surface coal mine consisting of a mixture of agriculture, forest, and grassland cover types in southern Illinois. Sixty four hens at the 3,400 ha CONSOL Energy- IDNR Burning Star 5 Fish and Wildlife Area were fitted with backpack transmitters during 2008-10. We quantified causes of hen and nest mortality, daily nest and weekly hen survival rates, nesting rates, and nest success. To examine the effects of mine land reclamation practices on wild turkeys we also examined nesting habitat variables, hen and brood home ranges, and habitat selection of wild turkeys. Nests were located closer to forest cover ($P<0.0001$), closer to roads ($P<0.0001$), and further from agricultural edges ($P<0.0004$) than random locations. Nests were less visible and had a greater presence of mid-successional species such as briars and vines than at random sites. Visual obstruction of the nest at 4 m, the presence of trees/shrubs, and presence of grasses were the only covariates that explained variation in nest survival. Compared to failed nests, successful nests were closer to forest cover and roads. Mean home range size was 429.2 + 17.5 ha. During the 4-week brooding period, brooded hens used 97.6 + 8.1 ha. Greater than 83.3% of brooding locations were located in forest cover. Roost trees selected by hens had a mean diameter at breast height of 64 cm, while 51.2% of the hen roost trees were white oaks (*Quercus alba*). Our research identifies habitat variables important for promoting wild turkey success on reclaimed mines and agriculture-dominated landscapes. The project is continuing to assessing predator interactions and movement associated with nesting hens on the reclaimed mine site.

Additional Key Words: habitat, Illinois, nesting

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FIELD SIMULATION OF DIFFRERENT APPROACHES TO REVEGETATE AN ACID SULFIDE SPOIL IN BRAZIL[1]

L. E. Dias[2], I. R. de Assis, J. M. Esper and O. A. Ferreira

Abstract. This work was developed at a gold mine company in Paracatu, MG, Brazil with the aim to evaluate the use of different layers and materials to cover an acid sulfide substrate to promote adequate conditions to plant growth and to reduce acid drainage. In 2011 we set a field experiment to test two materials (crushed limestone and laterite) to form a break- capillarity layer, two materials (clay material from Oxisol and saprolite) to form a sealing-layer and two materials (saprolite and topsoil material from an Oxisol) to form a cover layer. These treatments were also compared with an additional one where the three layers were formed by saprolite. All plots received a drainage system to collect drained water and a mix of seeds from five herbaceous species. Eight months after we evaluated vegetal biomass production and collected non-deformed and deformed samples from each layer of each plot to physical and chemical characterization. The use of topsoil as cover layer provided better chemical and physical characteristics to plant growth than the saprolite which showed high content of arsenic. Clay material to form sealing layer is more efficient to avoid high availability of arsenic to plants. We also observed a close correlation with available arsenic and biomass production. The collection of drained water from the plots starts at the next rain season: November 2012 to March 2013.

Additional Key Words: Gold mine, land reclamation, arsenic.

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THE FATE OF NITROGEN IN BIOSOLIDS AMENDED MINERAL SANDS MINE SOILS[1]

Jon Dickerson[2], W. Lee Daniels, Greg Evanylo and Kathryn Haering

Abstract: Techniques using high rates (i.e., rates greater than those required to supply the first year's plant available N - PAN) of biosolids for reclaiming disturbed lands have proven successful in establishing vegetative cover by improving soil physical and chemical characteristics, as well as adding available N, P and other essential nutrients. However, this practice also raises concerns about environmental and human health risks due to N and P leaching potentials in sandy mine soil systems that are shallow to ground water. This study was conducted on the Carraway-Winn Research Farm in Dinwiddie County, VA, on a mineral sands (e.g., Ti and Zr oxides) mining site that consisted of recently re-graded sandy tailings without topsoil return. Our overall objective was to compare the effectiveness of a "reclamation rate" of biosolids (21 Mg ha^{-1}; 5x agronomic or ~600 kg ha^{-1} PAN) vs. a 1x agronomic rate (~4 Mg ha^{-1} or 120 kg ha^{-1} PAN) vs. standard inorganic fertilization (115 kg ha^{-1} N) vs. a 0 N control. Total P and K additions were also balanced across all treatments. The experiment was seeded to reclamation grasses in April 2011, and vegetation and N and P leaching were monitored for over one year. First-year vegetation establishment was hindered by hot, dry conditions, but a wide array of weed species invaded the plots and total biomass production was much higher on the two biosolids treatments. The plots were re-seeded in the fall of 2011 and another application of fertilizer N was made to the fertilized control only. Subsequently, standing biomass production was substantially higher on the biosolids-treated plots, particularly at the higher rate (5X agronomic), than on the N-fertilizer plots. Larger leaching losses of both nitrate-N and Ammonium-N occurred from the N-fertilizer treatment than from either of the biosolids treatments. The total one-year mass N leached was ~ 2, 65, 2 and 8 kg ha^{-1} for the 0-N control, N-fertilizer, 1x biosolids, and 5x biosolids treatments, respectively. The maximum one-time nitrate-N leaching concentrations for the conventional fertilizer treatment and the 5x biosolids treatment were 63 mg L^{-1} and 3 mg L^{-1}, respectively. A pulse of ortho-P occurred in leachates from all treatments in late summer 2011 following several heavy rain events, but total one-year mass loss was relatively low (0.1 to 0.5 kg ha^{-1}). Due to minimal leaching losses of total N from the biosolids treatments in this sandy system, beneficial use of biosolids continues to be indicated as a safe and productive alternative to use conventional N fertilizers.

Additional Key Words: Nitrate-N leaching; revegetation, agronomic rate, PAN

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SEED SOURCE AND SAGEBRUSH HABITAT RECLAMATION SUCCESS ON THE MOWRY FORMATION[1]

M. Dillon[2] and M. Cornia

Abstract: The successful restoration of Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) on reclaimed bentonite mining land is increasing in importance due to new emphasis on the conservation of sagebrush habitat coupled with an increase in the amount of sagebrush habitat disturbed by mining activities. Efforts to reestablish sagebrush habitat on a large scale in Wyoming's Bighorn Basin have been generally unsuccessful, especially on disturbed sagebrush habitat of the Mowry Formation. Poor (shallow, sodic, and clay rich) soils and low precipitation (17 cm per annum) are often attributed to this low success though seed source should also be considered due to the ecological differences between the Bighorn Basin and commercial seed collection sites. Sagebrush seed was collected from stands in local areas with environmental conditions similar to those of reclaimed land. Collected sagebrush seed was planted along with nonlocal commercial seed in test plots on Mowry reclamation to determine any differences in success between the seed sources. Preliminary results indicate that locally collected seed from certain sites was more successful than nonlocal seed. Further testing will occur with locally collected seed and with seedlings grown from it on reclaimed land in the Mowry Formation. Testing will also be expanded to include local seed from other shrub species.

Additional Key Words: Bentonite, Mowry Formation, Wyoming big sagebrush.

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APPLICATION OF LANDFORM GRADING TO RECLAIM A FORMER WYOMING URANIUM MINE[1]

J.K. Murphy[2], and M.R. Donner

Abstract: The Wyoming Abandoned Mine Land Program has recognized the advantages of employing landform grading, or topographic reconstruction, techniques to develop geomorphically stable reclamation landforms. Application of these approaches, which result in diverse reclamation landscapes that blend with the native terrain, has allowed the Wyoming Program to alleviate physical site hazards while also improving long-term site stability. Landform grading can also reduce maintenance commitments, reduce reliance on structural controls, and provide reclamation that increases benefits for the landowner or land management agency. Since 2007, this technique has been used to reclaim multiple historic surface mines throughout Wyoming ranging in size from less than a hectare to more than 80 hectares. Through the course of multiple reclamation projects and application of lessons-learned, the proficiency and overall reclamation success for sites reclaimed in this manner continues to increase.

The Bullrush and North Spoils reclamation project, completed in 2012, is the largest application of landform grading to date for the Wyoming Program. Reclamation of this former surface uranium mine in the Gas Hills of central Wyoming included more than 1.3 million cubic meters of mass grading across 80 hectares. The Project Team developed a reclamation landform that reduced remnant highwalls, addressed unsuitable, radioactive spoils, and re-established a historical drainage. Development of the reclamation landform was complicated through the need to incorporate an existing, stormwater run-on ditch constructed under a previous project, tie-in with planned reclamation of an adjacent tailings pond, and incorporate future site and surrounding land use. Expanding on lessons-learned through application of the landform grading at other sites, the Project Team addressed the site constraints by developing three design surfaces, including two for a large, closed basin and a third for the historical through drainage.

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DESIGN, DEVELOPMENT, AND FIELD EXPERIENCE WITH WOOD-STRAND EROSION CONTROL MULCH FOR MINE AND PIPELINE PROJECTS[1]

J.H. Dooley[2], D.N. Lanning, M.C. Perry

Abstract: Engineered wood-strand mulch was developed under funding from the USDA, USFS and DOI as a weed-free, long lasting, wind stable alternative to agricultural straw for erosion control on highly disturbed public lands. Since its commercial introduction in 2005, wood-strand erosion control mulch has been used on at least fifteen mine and pipeline projects across eight western states. This paper reviews the science and design process that led to the technical features of wood-strand mulch, and reports results of a survey of land managers, project leaders, and erosion control contractors to assess performance versus design criteria for the material. The survey is designed to be consistent with the content of a similar survey of experience with post-wildfire treatments by the Forest Service published in 2002. In this survey, participants are asked to score functional performance of the erosion control materials used on their project against the design objectives that led to its development. Results of the survey are being used to improve the material and update guidelines for its specification and use for erosion control on mines, pipelines, and other severely disturbed areas.

Additional Key Words: surface water hydrology, soil, slope, erosive, rainfall

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RECLAMATION PLANNING FOR ENERGY DEVELOPMENT PROJECTS: WAMSUTTER, WY; A CASE STUDY[1]

C. Driessen[2], B. Teson, D. Marshall, R. Ansotegui

Abstract: Successful reclamation reduces the severity of impacts of energy development to the environment. Limited soil resources, minimal precipitation, and invasive plants are common challenges associated with reclamation in the Rocky Mountain region. Salts and clays accumulate in shallow soil horizons in this semi-arid climate. Construction processes that modify the soil structure can mix material rich in salts and clays with suitable coversoil. Identifying appropriate depths for soil salvage prior to disturbance maximizes the amount of suitable growth medium available for reclamation.

Pre-disturbance reclamation planning begins with a comprehensive site assessment of soil resources and vegetation communities. The first task in the assessment is mapping changes in soils and vegetation communities. Landscape position, plant community composition and cover, and soil conditions are documented within each mapped division. Evaluation of soil resources includes excavating a soil pit to identify changes in soil characteristics and sampling each horizon. The soil samples collected within each division are analyzed for pH, electrical conductivity, sodium adsorption ratio, saturation percentage, lime, and texture. Laboratory results and the field assessment information identify the depths and severity of limitations to plant growth. This leads to a soil salvage plan that avoids these limitations and maintains a viable growth medium for reclamation. The soil salvage plan is part of a comprehensive reclamation plan that also includes soil treatment, seed mixes, weed management, and monitoring for each site.

Natural gas producers in the Wamsutter natural gas field in south-central Wyoming have been developing pre-construction reclamation plans since 2009. Results show significant improvement in reclamation soil chemistry as a direct result of improved soil salvage. These improved soil conditions allow faster progress toward reclamation success. This reduces the severity and duration of construction related disturbances and their impacts to the environment, as well as reducing the costs of reclamation.

Additional Key Words: Soil salvage, coversoil, pre-disturbance inventory, reclamation

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FROM BS TO BMP- USING BIOSOLIDS FOR TACONITE TAILINGS RECLAMATION [1]

P. Eger[2], C. Lincoln, T. McMillen, K. Hamel, K. Dykhuis, C. Maxwell, J. Takala

Abstract: Establishing acceptable vegetation on the coarse fraction of taconite tailings was a major problem for Minnesota's iron mining industry. Reclamation rules required percent cover equal 90% after three to five years and vegetation be self-sustaining after ten years. Despite repeated application of seed and fertilizer, less than 10% of the coarse tailings areas met standards. Typical cover on coarse tailings, even after five years, ranged from about 30 to 50%.

Starting in the 1990's, studies were conducted to evaluate the addition of various organic amendments (e.g. municipal and yard waste compost) to improve vegetative success. Additions of about 20 dry ton/acre produced vegetation that met reclamation standards. However, availability and cost of the amendments limited their use. Biosolids, due to high nitrogen content and concern for water quality, were limited to much lower application rates. An agronomic rate that supplied about 100 lbs. N/acre improved vegetation, but a second application was required to meet standards. In 2002, a study was conducted to examine the effect of adding biosolids at higher than agronomic rates and determined that 200 lbs. N /acre met reclamation standards without adversely impacting water quality.

In 2005, this application rate was approved as a BMP (Best Management Practice) for reclamation of coarse taconite tailings. Since that time, biosolids have been applied at three sites. In addition, sites that had been previously reclaimed but had not achieved required cover were top dressed with biosolids and vegetation now exceeds 90% cover.

At one site (United Taconite), the biosolids application has been so successful that a portion of the tailings basin has been leased to a local farmer for hay production. Biosolids have been applied annually since 2008; hay production is about 50% above typical yields for the region and soil development has begun.

Additional Key Words: percent cover, revegetation, organic amendments, yield

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LONG-TERM TRENDS OF SPECIFIC CONDUCTANCE IN WATERS EMERGING FROM HEADWATER VALLEY FILLS IN VIRGINIA, USA[1].

D.M. Evans[2], C.E. Zipper, P.F. Donovan, and W.L. Daniels

Abstract: Mining in the central Appalachian coal fields impacts water quality and quantity and can lead to degraded stream structures and functions. Environmental regulations designed to limit impacts to streams have recently focused on valley fill (VF) operations and their tendency to raise stream water electrical conductivity (EC). However, the relative impact of the VFs, which often occur in watersheds that also contain surface and underground mining, is poorly understood. The duration of the impacts of mining activities and VFs on stream water EC is also uncertain. We analyzed water quality monitoring records from 137 VFs in southwest Virginia (USA) for levels and temporal trends in specific conductance. Valley fills had a mean area of 12.0 (±12.9) ha and had water quality data records ranging from 1.1 to 21.4 years and from 21 to 417 samples. Mean specific conductance (SC= EC at 25°C) ranged from 227 to 2866 µS cm^{-1} and continued to rise after the valley fill was revegetated at many VFs. Quadratic models suggest that SC peaks at a mean of 9.5 (± 3.7) years after the start of VF construction disturbance. The area of the VF and the amount of deep mining were significant predictors of mean SC during and after mining disturbance. While, the years the VF was disturbed and the maximum bare ground were also significant predictors of mean SC during the disturbance.

Additional Key Words: Salinity, total dissolved solids

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STREAM RESTORATION INITIATIVE AT THE JEWETT LIGNITE MINE[1]

Jeremiah McKinney[2], Jacob Young and Derrell Ezell

Abstract: In 2009 Texas Westmoreland Coal Company embarked on a mission to not only improve the stream restoration efforts at the Jewett Mine, but to build a process that would be recognized as the premier stream restoration program in the US. This ambitious effort stemmed from the awareness being placed on the growing emphasis across the country relating to the overall stream function, stream protections and the obstacles faced with wetland mitigation. The overall process involves a collaborative effort between several sources including the regulating bodies involved with the mine reclamation, academia, regional consulting engineers, local land owners, and the Jewett Mine personnel. As with all best practice process, excellence begins with planning and design. Planning includes the gathering of baseline data of the impacted stream channel and is a vital step in the process. The design component feeds from this data and ensures that a natural channel is developed for construction. The construction process has been greatly enhanced by the advent of dozer GPS through which digital terrain models can be used to guide the operator in building the envisioned plan. Additionally, significant advancements achieved through the use of innovative technologies have resulted in final streams that exhibit increased geo-fluvial characteristics and require far less reinforced structures. Enhanced revegetation efforts utilizes several other "best practice techniques" such as hydromulching with native grasses, the planting of high quality hardwood species and the use of specialized irrigation to ensure a high success rate in any condition. The Jewett Mine has paved a new path forward with respect to stream restoration by studying the stream channel prior to disturbance, developing a plan that honors the original system and transitioning that plan into an effective means of construction. By this, the Jewett Mine is confident that it is living one of their core values - environmental excellence.

Additional Key Words: wetland mitigation, digital terrain models, hydromulching, irrigation

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PREDICTING THE INFLUENCE OF RESTORATION ON GREATER SAGE-GROUSE LEK DISTRIBUTION[1]

B.A. Fitzpatrick[2] and M.A. Murphy

Abstract: A current need in restoration ecology is to better understand how restoration and development decisions will influence distribution of breeding sites for declining species. Greater Sage-Grouse (*Centrocercus urophasianus*), a species warranted but precluded under the Endangered Species Act of 1973, has experienced a reduction in its distribution and population decline in association with anthropogenic disturbance. Sage-grouse are closely tied to sagebrush habitat; development within this habitat is known to negatively influence lek or breeding site occupancy. Our goal is to understand how disturbance influences distribution and connectivity of leks in the Powder River and Bighorn basins. We implemented a stratified random sampling design to capture variation in development and habitat fragmentation across the study area. We developed a map of lek distribution using 460 leks from Wyoming Game and Fish department sage-grouse database, 81 pseudo-absences, and important environmental and anthropogenic characteristics. We present a pilot lek distribution model based on relating 2012 field data to limiting factors across the landscape: percent sagebrush, well density, road density, and topographic relief. Distribution of leks is negatively related to disturbance; both amount and configuration of disturbance surrounding leks decreases probability of lek occurrence. This information will compliment research in the Bighorn and Powder River basin by giving managers an idea of how landscape change is influencing breeding site distribution. The final lek distribution model will be used to predict changes in lek occurrence in the face of different scenarios of landscape change. This model will be used in conjunction with information on current and predicted future functional connectivity (e.g. gene flow) to aid in identifying areas that will be important for sage-grouse lek persistence. Our research will provide a scientifically-based decision-making tool for prioritizing development, protection, and restoration.

Additional key words: Powder River and Bighorn basins, lek distribution, restoration

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FEDERAL AGENCY BENEFIT ANALYSIS OF A REMEDIATION MONITOING TOOL FOR ABANDONED MINE LANDS [1]

L. M. Barber Franklin[2] and D. R. Neuman

Abstract: The general strategy for cleanup of abandoned hard rock mine sites has been to remove waste materials from stream channels, consolidate waste in repositories, or cap waste in place. This paper describes a synthesis of data collected from remediated mines in an attempt to understand how effective this strategy has been in protecting the environment and reducing risks to human and ecological health. In 2006, the Abandoned Mine Lands (AML) Post-Remediation Assessment Protocols and Handbook (Handbook) was developed as a reclamation monitoring tool and guide for the Bureau of Land Management (BLM) and the US Forest Service (USFS). Since the development, twenty-four reclaimed hard rock AML sites across Montana and one in South Dakota have been monitored using this protocol. We were tasked by the BLM to evaluate the usefulness of the Handbook and effectiveness of the remedial actions. The monitoring results were compared by mine feature (mine/shaft, waste removal area, waste rock dumps, repository, soil borrow areas, wetlands, stream/riparian areas, etc.) or public safety and general maintenance issues to obtain commonalities among sites. Exposed waste (or waste left in-place), weeds, and erosion were the top three issues negatively impacting reclamation. Historical structures, fencing/signs, and exposed waste were among the top reported public safety issues. General maintenance highest priorities were weeds, exposed waste, soil erosion, and fencing/signs. Waste repositories were generally well vegetated, erosionally stable, and water diversion structures were operating properly. Areas from which mine related wastes were removed displayed seeps, acid mine drainage, and some exhibited evidence of upward movement of contamination into surface soils. In response to the results, updates were made to the handbook which addressed ecological function and revegetation of seeded species and reclamation success at hard rock AML sites.

Additional Key Words: Mine Reclamation Evaluation Database (MRED), revegetation success, reclamation techniques, US Forest Service, Bureau of Land Management

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FACTORS INFLUENCING THE ESTABLISHMENT OF VOLUNTEER VEGETATION ON QUARRY OVERBURDEN[1]

J.A. Franklin[2], D.S. Buckley

Abstract: Abundant sunlight and rainfall in the southeastern U.S. favor the rapid establishment of vegetation on bare ground. A dense herbaceous cover and seedlings of woody species appear within 1 to 2 years on some sites, even without seeding. On other sites vegetation develops slowly, and some reclaimed areas remain essentially bare for several years unless seeded. We followed the development of volunteer species on quarry overburden over a 3-year period. Twelve rectangular plots were constructed: six of the plots were lightly graded with a single pass of a bulldozer, and the other six remained ungraded. Liquid lime was applied to one half of each plot, and fertilizer (20:20:20) was applied at a rate that provided 100 Kg/ha or 400 Kg/ha N to randomly selected plots in a manner that created three replicates of all lime, fertilizer, and overburden placement treatment combinations. Within each plot, seedlings of *Castanea dentata* (American chestnut), *Pinus echinata* (shortleaf pine) and *Quercus alba* (white oak) nursery seedlings were planted, and one quarter of each plot was left unplanted. No herbaceous cover was seeded. By the end of the third growing season, the amount of herbaceous ground cover on plots ranged from 0 to 33%. The number of volunteer species was most strongly influenced by the distance from the intact forest, and was not influenced by the species of tree planted. The number of volunteer species was greatest on southern and eastern aspects, and was also influenced by grading, fertilization and lime treatments.

Additional Key Words: reforestation, colonization, primary succession.

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DECOMMISSIONING OF AN ANAEROBIC PASSIVE BIOCHEMICAL REACTOR AT THE STANDARD MINE SUPERFUND SITE, CRESTED BUTTE, CO[1]

Neal Gallagher[2], Eric Blumenstein, Tom Rutkowski, John DeAngelis, and Christina Progess

Abstract: A pilot anaerobic biochemical reactor (BCR) with a design flow rate of 1 gpm (3.8 lpm) was operated at the Standard Mine Superfund Site from 2007 until fall 2011 targeting heavy metals and acidity in mine adit drainage. The pilot system was entirely passive, with the exception of a feed pump, which was necessary due to topography associated with the ideal location of the pilot reactor on-site. Solar energy was used to power remote monitoring and sampling equipment, as well as to meet pumping demand. BCR treatment relies on biological and chemical reactions within an anaerobic reactor comprised of organic and inorganic materials including woodchips, straw, limestone and bacterial inoculum. The Standard Mine BCR was constructed at an elevation of 11,000 ft (3,353 meters) above MSL with an average annual snowfall of 400 inches (10.2 meters). Contaminants of concern (COCs) in the site mining influenced wastewater (MIW) include cadmium, copper, lead, and zinc. Despite extreme alpine conditions, consistent high metals removal was observed in BCR effluent since the beginning of operation. In available data from 2009 through 2011, the average percent removal efficiency for cadmium, copper, lead, and zinc exceeded 98% or was below the analytical detection limit. BCR treatment of cadmium, copper, and lead to less than 5 µg/L was demonstrated indicating that BCR is capable of approaching or meeting stringent aquatic life water quality standards.

Decommissioning of the BCR cell was performed in August 2012. The overarching objectives of decommissioning were to extract design criteria for a full scale reactor, as well as to characterize the spent substrate to determine full-scale disposal requirements. Substrate samples were collected in triplicate at eight locations throughout the 29 inch substrate column after the substrate was allowed to drain for approximately 24 hours. Samples were analyzed for total metals, Toxicity Characteristic Leaching Procedure (TCLP), paint filter, and alkalinity. Pilot substrate was disposed of in a repository on site. However, at full scale, substrate disposal off-site may be necessary. To determine if spent substrate will be subject to RCRA Subtitle C disposal requirements, TCLP and paint filter tests were performed providing insight into acid leachable RCRA metals and free liquids contained in the substrate respectively. Total metals analysis was performed separate of TCLP testing to determine the location of deposition of total COC metals throughout the substrate column, allowing probable removal mechanisms to be identified. As the BCR ages, substrate limestone is depleted acting as a buffer to influent acidity. As limestone is depleted, there is a migration of the active reaction front where microbiological sulfate reduction occurs. Measurement of substrate alkalinity throughout the column allows identification of the rate of limestone dissolution within the substrate. This dissolution rate is often a major limiting factor in BCR operational lifespan and varies substantially according to site water characteristics. Limestone dissolution rate data therefore provides design engineers with the ability to design a full scale BCR to operate effectively within a probable lifespan. Data from decommissioning activities at the site as well as analysis of these data are provided.

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COMPARISON OF VEGETATION COVER VS PRECIPITATION ON A RECLAIMED COAL MINE IN NORTHEASTERN WYOMING[1]

Dawn Gardner[2] and Brenda Schladweiler[3]

Abstract: Vegetation cover on a reclaimed area will vary according to various landscape, biological, and meteorological factors including precipitation timing and amount. Mining operators in an arid or sub-arid environment attempt to minimize any adverse effects associated with lack of precipitation or poorly timed precipitation by instituting best management practices in all reclamation efforts.

Vegetation cover data is widely collected as part of any interim revegetation monitoring program on reclaimed coal mine lands as an indicator of overall site stability. Cover data can vary over time within a bonding period, i.e., from a recently seeded area to an older, more established seeded area. It can also vary widely depending on moisture availability during any given year in that bonding period.

Long-term vegetation data collected on a coal mine in northeastern Wyoming was evaluated to determine statistical correlation between total vegetation cover, total ground cover, and individual species cover with precipitation amounts and timing. Results of this evaluation will be presented.

Additional Key Words: climate, monitoring, reclamation

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SOIL PROPERTY RECOVERY ON A NATURAL GAS PIPELINE RECLAMATION CHRONOSEQUENCE[1]

C.K. Gasch[2], S.V. Huzurbazar, P.D. Stahl

Abstract: Vegetation properties are often the focus of reclamation monitoring and a criterion for bond release. Examination of soil properties in addition to vegetation measurements may provide a more robust assessment of ecosystem recovery following reclamation. We examined soil properties on a set of reclaimed natural gas pipelines that spanned recovery ages of less than one year to 55 years. For two consecutive years, we measured soil moisture, carbon and nitrogen, conductivity, alkalinity, and microbial community structure. We analyzed our data with a simple Bayesian model, which allowed an intuitive and simultaneous examination of soil property means and variances. These models also allowed us to quantify the probability that a soil property in a reclaimed site was similar to that of the undisturbed reference sites. Initial analysis suggests that the variance of most soil properties was particularly sensitive to disturbance and reclamation—especially within the first few years of recovery. The response of the variance to disturbance, reclamation, and recovery was not necessarily accompanied by a shift in the mean value of the property. Patterns for all soil properties changed over time, with soil properties generally shifting to be more similar to those of the undisturbed reference sites (in terms of their mean and variance) as recovery time increased. We suspect that these trends in altered variability coincide with the degree of spatial heterogeneity in soil properties that exist following disturbance and reclamation, which is coupled to patterns of vegetation recovery. These results emphasize the importance of soil property recovery on vegetation re-establishment in reclamation scenarios.

Additional Key Words: reference sites; posterior predictive distributions; soil carbon and nitrogen; soil microbial abundance; soil moisture; variance

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A SHORT HISTORY OF PYRITE AND ACID ROCK DRAINAGE: AN ENGINEER'S PERSPECTIVE OF ARD[1]

James J. Gusek[2]

Abstract. With advance apologies to the best-selling author Bill Bryson[3], this paper will examine the ubiquitous problem of acid rock drainage (ARD) from an engineer's perspective. From the origins of pyrite in anoxic marine sediments, coal bed measures, and hydrothermal environments, to the observations of Agricola in the 16th century, to the GARD guide of the 21st century, the history of pyrite is probably as old as life itself. How this history might be perceived with regard to controlling ARD is a relatively recent development.

The conventional wisdom for controlling of ARD relates to the disruption of a four-pointed biogeochemical relationship, the "ARD Tetrahedron". From an engineering perspective, controls have two major components: the *mechanisms* of biogeochemical disruption and the *technologies* for implementing those mechanisms. The successful merging of mechanisms and technologies is required to mitigate ARD; this is the current engineering challenge.

Additional Key Words: mining influenced water, abandoned mines, pollution prevention

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GEOTECHNICAL-GEOPHYSICAL VOID MAPPING AND FOAMED-SAND BACKFILLING OF THE RAPSON COAL MINE, COLORADO SPRINGS, COLORADO – CASE STUDY[1]

Kanaan Hanna[2], Jim Pfeiffer, Steve Hodges, Al Amundson, Richard Palladino,

and Tom Szynakiewicz

Abstract: The presence of mined out areas of voids underlying residential areas represents a significant risk to public safety and infrastructure. The Country Club Circle (CCC) Colorado Springs neighborhood is underlain by the abandoned Rapson Coal mine, which was worked from 1900 to 1915 prior to residential development. Through the years, numerous subsidence-sinkhole events have repeatedly occurred, causing serious safety hazards and damaging structures, streets, and utilities. The Colorado Division of Reclamation, Mining and Safety (CDRMS) developed a comprehensive abandoned mine subsidence risk assessment and reclamation program through a proactive method for delineating and mapping mines that exist beneath the residential area. In order to develop proactive solutions to minimize risk where mine workings are present, Zapata Incorporated (ZAPATA) implemented a multi-phase subsurface geotechnical exploration plan that included a variety of high-resolution geophysical technologies, focused exploratory boring, and imaging of existing mine workings. Based on the results of the geotechnical-geophysical studies, CDRMS initiated the mine reclamation plan to stabilize the remaining voids and caved areas beneath the neighborhood using foamed-sand slurry and low-mobility grouting. This paper describes the collaboration between DRMS, ZAPATA, Cellular Concrete Solutions (CCS), and Hayward Baker Inc. (HBI) to facilitate completion of the geophysical investigation and subsidence mitigation work.

Additional Key Words: Mine Subsidence, Subsidence Risk, Sinkholes, Abandoned Mines, Geophysical Voids Detection, Mine Workings Mitigation, Ground Stabilization.

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BIOCHAR FOR RECLAMATION IN THE ROCKY MOUNTAINS: CONTEXT, SCIENCE AND POLICY - CAN WE FIND A NEXUS THAT WORKS?[1]

A. Harley[2], B. McMullen, and M. Williams

Abstract: Aggressive fire suppression has changed the vegetative structure and composition of many western US fire-adapted ecosystems, increasing the likelihood of high severity, catastrophic wildfires. Additionally, the mountain pine beetle epidemic has caused forest mortality across 4 million acres of Colorado alone, further exacerbating the problem of accumulated energy loading and increasing the risk for more frequent and larger catastrophic fires. Reclamation of disturbed lands, especially those associated with resource development, both current and historic, is a value-added market for reclamation products produced from low-value woody biomass feedstock. The proximity of mining impacted sites to sources of low-value biomass feedstock provides an interesting nexus between multiple public and industry environmental issues. The third potential benefit involves the sequestration of carbon within the soils while improving landscape ecosystem functionality. While not the driver in this current scenario, the advantages cannot be discounted in a long-term carbon strategy. Biochar is a generic term given to any carbon-rich end product of pyrolysis, the combustion of biomass under essentially anoxic conditions. The array of feedstock and production variables allows for the engineering of properties specific to particular site conditions. Biochar engineered for increased moisture holding capacity has been successfully deployed to address erosion and sedimentation of abandoned mine waste rock piles on public land threatening a surface drinking water supply. Due to the multiple public institutions involved in this new technology, close co-ordination of multiple stakeholders (government, NGOs, water utilities) was paramount throughout the life cycle of the project. The novel nature of this project has generated both support and criticism that has required a flexible technical and business approach. This case study will be used to provide a template for bringing innovation to reclamation through a partnership model that manages both champions and critics with diverse agendas, while addressing the goals of reclamation and ecosystem restoration.

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A COMPARISON BETWEEN PROPOSED WELL PAD RECLAMATION VEGETAL COVER STANDARDS AND THEIR ASSOCIATED MULTIPLE LAND USE VEGETATION COMMUNITIES AND WELL PADS[1]

Mark Heil[2], Bruce A. Buchanan, and Heather McDaniel

Abstract: In 2012, a study of desirable vegetal cover on well pads and their associated vegetation communities was conducted in the Bureau of Land Management (BLM) Farmington Field Office (FFO) area. The study was conducted to determine whether FFO proposed vegetal cover standards are appropriate. The well pads are located in three distinct vegetation communities designated as multiple-use lands. The vegetation communities chosen were badlands, pinyon-juniper, and sagebrush. Ten sites in each of the three vegetation communities were randomly located on land undisturbed from oil and gas activity, for a total of 30 sites. Three 100 foot (ft) line-intercept transects were conducted at each undisturbed site, for a total of 90 transects. Five well sites were chosen in each of the three vegetation communities, for a total of 15 sites. Three 100 ft line-intercept transects were conducted at each well site, for a total of 45 transects. It was found that vegetal cover in each of the three vegetation communities was consistently lower than the FFO standards. It was also found that well site vegetal cover from the sagebrush community was consistently lower than the FFO proposed standard for the sagebrush community. It was determined that there are statistical differences between vegetal cover on well sites and vegetal cover data from the associated vegetation. Vegetal cover data from the well sites displayed very little change from one community to the other, implying that the vegetation community may not be an appropriate factor for determining a vegetal cover standard. Variability of vegetal cover was found to be significantly high in the vegetation communities and the well sites, suggesting that a single value depicting a standard for vegetal cover is not unrealistic.

Additional Key Words: land use planning, sagebrush, pinyon-juniper, reclamation, vegetation, vegetal, cover, transects, reference area, vegetation community, multiple-use lands, well site

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ECTOMYCORRHIZAL SPECIES BENEFICIAL FOR PLANT ESTABLISHMENT ON ABANDONED MINE LANDS[1]

Shiv Hiremath[2], Kirsten Lehtoma, and Jenise M. Bauman

Abstract. Plant-microbe community dynamics influences the natural succession of plant species where a pioneer vegetation facilitates the establishment of a distantly related, later successional plant species. This has been observed in the case of restoration of the American chestnut (*Castanea dentata*) on abandoned mine land; the Virginia pines (*Pinus virginiana*) facilitated the establishment of chestnut seedlings. This was presumably because of the natural mycorrhizal networks of pine which aided the survival and growth of the chestnut seedlings. In this study we assessed the survival and propensity of introduced mycorrhizal fungi on Virginia pine to colonize the backcrossed American chestnut. Seedlings were planted in Perry State Forest located in southeastern Ohio. This area was mined for coal in the 1950s and had very little reclamation was done aside from experimental tree plantings. The site selected has very little topsoil or organic matter, high concentrations of soil aluminum, high soil temperatures, and a pH of 3.6. Virginia pines were inoculated using ectomycorrhizal (ECM) cultures of *Amanita rubescens*, *Laccaria laccata*, and *Pisolithus tinctorius* via liquid media. After three months, roots were scored for mycorrhizae, transplanted, and grown for two years in the greenhouse. Chestnut seedlings were inoculated with *P. tinctorius* by the state tree nursery and planted as one-year-old seedlings. Mycorrhizal colonization was verified and 600 pines and 100 chestnuts were planted in May of 2005. After seven growing seasons, pines and chestnuts were measured and sampled for ECM colonization. Growth measurements showed that pines had significantly more aboveground biomass compared to chestnut (P = 0.003). Moreover, pines that were originally inoculated with *P. tinctorius* were larger than pines inoculated with any other ECM (P = 0.021). Also, there were distinct differences between pine and chestnut with regard to root colonization by ECM fungi (based on root morphology). DNA sequencing is currently underway and will determine differences in mycorrhizal colonization between tree species and survival of the introduced fungal inoculum.

Additional Key Words: root colonization of fungi, chestnut restoration, American chestnut.

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CLOSURE CRITERIA FOR WASTE ROCK LANDFORMS IN WESTERN AUSTRALIAN GOLDFIELDS[1]

A. McR. Holm[2], and B. Sinclair

Abstract: Regulators of rehabilitated landforms on mine sites in Western Australia require these landforms to be demonstrably stable and supporting self-regenerating vegetation before consenting to release environmental bonds. Under recent mine closure guidelines, mining companies are required to define closure criteria and measurement tools to demonstrate achievement of these criteria. There are few accepted methodologies for establishing quantitative closure criteria relating to landform stability or vegetation condition. Consequently, demonstration of mine closure has been subjective and uncertain.

In this poster we present rehabilitation results over seven years on Waste Rock Landforms (WRL) in the Western Australian goldfields. These are presented in relation to closure criteria relating to landscape stability (erosion and vegetation cover) and vegetation condition (species composition and density). We compare rehabilitation progress using closure targets derived from a) natural local ecosystems and b) a successfully rehabilitated WRL thereby providing guidance for establishing useful reference sites.

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SITE CHARACTERIZATION AND EVALUATION OF RECLAMATION ALTERNATIVES AT THE BLACK PINE MINE[1]

K.T. Houck[2], D.J. Clary, and M.R. Donner

Abstract: The Black Pine Mine is located approximately 8 miles northwest of Philipsburg, in Granite County, Montana, and is included in the Montana Environmental Custodial Trust, which was formed following ASARCO's settlement with the State of Montana. The site covers over 1,000 acres and is comprised of 52 lode and 15 mill site claims and over 157 unpatented lode claims on lands administered by the Forest Service. The Montana Department of Environmental Quality, Abandoned Mine Lands Bureau (MDEQ/AMLB) is tasked with performing investigations and developing reclamation plans to address environmental and physical hazards across the site. Environmental hazards are associated with elevated metals concentrations resulting from mining at the site that is impacting downgradient groundwater, stream, and soils and sediment quality. Physical hazards include remnant mine buildings, rubble, and open and partially collapsed mine portals and shafts.

MDEQ/AMLB performed a site characterization to investigate the extent and degree of contamination associated with four contaminated media at the Black Pine Mine: surface water, soil, sediment, and groundwater. The general site characterization objectives are as follows:

- Confirm the nature and extent of soil, sediment, surface water, and groundwater contamination – including synoptic sampling of South Fork Lower Willow Creek
- Confirm the characteristics and volumes of waste and impacted materials
- Support a human health and ecological risk assessment
- Locate and characterize potential repository locations
- Collect and analyze surface water and groundwater samples to assist in determining if the mine pool influences water quality at the site

Based on the results of the site characterization, reclamation alternatives are under evaluation. Reclamation alternatives will address human health and ecological issues.

Additional Key Words: Remediation, Hydrology, Stream Water Quality, Waste Management

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ECOLOGICAL RESTORATION PLAN FOR ABANDONED UNDERGROUND COAL MINE SITE IN EASTERN[1]

Zhenqi Hu[2], Wu Xiao, Yanling Zhao and Fengjiao Wang

Abstract: In China, the growth in coal production has expanded very rapidly in recent years. With the westward movement of coal mining operations, a large number of coal mine sites have been abandoned in the eastern region, leaving a legacy of mining-related subsidence land, coal waste piles, and brownfield sites. These mining hazards can cause air pollution, acid water, soil degradation, decrease in biodiversity, and landscape destruction. Due to the historical development of mine sites, most cities were built around coal mines, thus, abandoned coal mine sites are now located in the centre or at the edge of rapidly expanding cities. These abandoned mine sites severely impact urban development and public safety, making coal mines closure planning, brownfield sites treatment, and utilization one of the most pressing problems.

This paper uses Datong coal mine in Huainan as a case study. It describes the natural setting and the mining history. Coal mine topography, soil contamination, land use, water pollution, and vegetation system are monitored and assessed. Based on the city plan of mining area, in accordance with suitability evaluation of soil and vegetation for rehabilitation, the ecological restoration function zoning of Datong is delineated, which lays the foundation for macro guidance of ecological restoration and detailed technical design. Based on the monitoring, assessment, and function zoning, a detailed ecological restoration plan for Datong abandoned underground coal mine site has been prepared.

Additional Key Words: abandoned mined land, reclamation of land, revegetation

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CO-TREATMENT OF ACID MINE DRAINAGE WITH MUNICIPAL WASTEWATER USING THE ACTIVATED SLUDGE PROCESS: IMPACTS ON WASTEWATER TREATMENT PERFORMANCE[1]

T.A. Hughes[2] and N.F. Gray

Abstract. Co-treatment of acid mine drainage (AMD) with municipal wastewater (MWW) using the activated sludge process is a novel active treatment technology utilizing the adsorbent nature of activated sludge biomass and the alkalinity of MWW to achieve neutralization and metal removal. Wastewater treatment performance, activated sludge health, and AMD remediation during co-treatment were evaluated in laboratory-scale plug-flow and sequencing batch reactors (SBRs). Synthetic AMD containing Al, Cu, Fe, Mn, Pb, and Zn at a range of concentrations and pH values was formulated to simulate three potential co-treatment processes, i.e. (i) adding raw AMD to the activated sludge aeration tank, (ii) pre-treating AMD prior to adding to the aeration tank by mixing with digested sludge, and (iii) pre-treating AMD by mixing with screened MWW. Continuous AMD loading did not cause any significant changes in removal efficiency for chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5). Consistent biological removal of organics and the abundance of protozoa and rotifers demonstrated the tolerance of a wide range of activated sludge microorganisms to continuous AMD loading. Significantly improved phosphate removal, achieving final effluent total phosphorus (TP) concentrations <2 mg/L, was observed in reactors loaded with Fe- and Al-rich AMD. Final effluent suspended solids concentrations were elevated in control and test reactors, owing to deterioration in activated sludge floc morphology; however, these changes were not linked to AMD loading. Final effluents from all three simulated processes were net-alkaline, and dissolved metal concentrations were significantly decreased during co-treatment, with 50-100% removal achieved for all metals. Only Mn and Zn removals were significantly inhibited by high influent acidity. In terms of overall metal removal and neutralization, pre-mixing AMD with screened MWW was the most effective co-treatment process. A significant fraction of MWW alkalinity was consumed during co-treatment, suggesting a need for an alkali supplement to maintain pH stability.

Additional Key Words: Metals, neutralization, sewage, remediation, wastewater treatment plant

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THE CONTRIBUTION OF ACTIVE SURFACE MINES IN THE CONSERVATION OF LOWER PLANT COMMUNITIES IN THE SOUTH WALES COALFIELD, UNITED KINGDOM.[1]

R N Humphries[2]

Abstract: The overwhelming perception of surface mining is that it has significant adverse long term effects on the conservation of flora and fauna, and there is typically a net loss in biodiversity and particularly those which have been identified as Biodiversity Action species and habitats under the Convention on Biological Diversity (CBD). These are enshrined in UK legislation and policy as to their protection, enhancement and promotion.

The mining legacy of the coal and iron industrial revolution in the coalfields of South Wales is thousands of spoil tips scattered across the landscape and dating from the early 1800s. Many of these have vegetation and habitats that are now recognised to be of important for biodiversity and even have their own action plan for preservation. In particular, it is recognised that the tips in South Wales are important for lower plants (lichens, bryophytes and fungi) species. Some tips are of such national importance they have been given statutory protection as nationally important Sites of Special Scientific Interest (SSSI).

The issue of their conservation in South Wales became topical in the mid-late 2000s with several studies being commissioned by the regulating authority, the Countryside for Wales. In cases of particularly rich assemblages on old tips these have the potential for and have actually halted a number of future surface mine prospects.

In the case of lichens and bryophytes, these delicate pioneer assemblages, are not only under threat from agriculture, forestry and public pressures, but also from vegetation development and succession. Without intervention many high quality sites are likely to be lost through competition and shading by grasses, bracken, heather, bilberry, scrub and woodland.

As a result of surveys undertaken in 2012 we have found that colonisation of new coal mine wastes is relatively rapid resulting in equivalent lichen assemblages (to those found on the 150 year old tips) establishing with twenty years. It is argued that new surface mines provide a means of sustainably conserving the assemblages by the creation of new lichen heath habitat through the commissioning of new mines.

Additional Key Words: lichens, overburden, soil mounds, sustainability

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IS THE DEFINITION OF SCALE THE KEY TO OUR UNDERSTANDING AND DELIVERY OF THE COMPONENTS OF STRUCTURE, DIVERSITY AND FUNCTION IN THE RESTORATION OF ECOSYSTEMS?[1]

R N Humphries[2]

Abstract: With the full implementation of the Convention on Biological Diversity (CBD) the planning authorities and regulators in the UK will have to review the impact of development and management on the natural resources by 2020. This entails the enactment of legislation and policy to protect, enhance and restore ecosystems and ecosystem services. Surface mining and other industries in the UK will have to embrace the concept of ecosystem services and be ready to deliver satisfactory schemes with all the necessary elements.

Whether we have sufficient understanding of the ecosystems being considered and clarity in what needs to be achieved may be highly debateable. Whilst there is growing enthusiasm for adopting ecosystem goals and for a more ecological approach to restoration, we are seemingly stumbling around for guidance beyond regularly rehearsing 'what a good thing this might be'. Somewhat simplistic and hypothetical models have been suggested over the past 30 years. How and what these are focussed on when dealing with actual schemes is not well elucidated or defined leaving practitioners and regulators with little go on when faced with a mining proposal or a restoration scheme.

This paper introduces and examines a measurable and workable concept of scale based on vegetation communities as a means whereby we might usefully understand what is needed to be provided for in the components of a Canopy-Age-Regeneration-Genetic-Indicator –Exotic Model. It is concluded that this understanding enables better design and evaluate the restoration of ecosystems and their services, before and after surface mining, and will enable the mining industry to meet the challenges posed by CBD and the new and emerging legislation and policies.

Additional Key Words: biological diversity, ecosystem services

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ACHIEVING CONTEMPORANEOUS GEOMORPHIC RECLAMATION AT EL SEGUNDO MINE, NEW MEXICO[1]

Emily Hydrusko[2]

Abstract: Traditional coal mine reclamation in the southwest includes rolling hills with 7:1 side slopes incised with large drains generally located along ramps to each pit. This approach leaves much to be desired in creating a natural post-mining landscape and creates maintenance issues prolonging the release of reclaimed lands. The El Segundo Mine is cultivating a geomorphic method to contemporaneous reclamation. The method includes using volumetric cut and fill balance, traditionally used in mine reclamation to create the final post mining topography, to develop a base set of contours. Once this set of contours is completed and the drains checked for capacity of the entire watershed, the side slopes can be divided into small Geofluv boundaries or sub-watersheds to be designed using Natural Regrade on Carlson or other similar methods. Each small area must meet the criteria for reclamation set in the mine permit including drainage density. Each area must be cut and fill balanced to ensure there is enough material to build the design effectively. When all the areas are designed they can be combined on one map depicting all of the geomorphic contours blended into the original post-mining topography contours. Implementing the designs takes skill and extensive planning. In order to make this as contemporaneous as possible the designs are scheduled to be put in when the mining operation is in that particular pit or in the pit closest to an area. Allowing for short hauls and ease of access for idle equipment to continue finish work. The detail of these designs can create some issues with timing contemporaneous reclamation. As each designed area is implemented it can leave a stable landform requiring little post reclamation maintenance. Fast paced surface mining can produce a stable, natural looking landform contemporaneously through careful design and planning throughout the mine life.

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CANOPY COVER ESTIMATION USING AERIAL PHOTOGRAPHY FOR A MIXED CONIFER ZONE, NORTHERN, NEW MEXICO[1]

Darrell Inskeep[2], Mark Heil, Bruce A. Buchanan, and Derek Heafey

Abstract: In 2012, an evaluation was conducted to determine if aerial photography could be used to accurately estimate canopy cover. The 5.7-hectare study site is located in the Goat Hill subsidence area, at the Chevron Mining Inc. molybdenum mine in Taos County, New Mexico. Canopy cover data were derived from 25 randomly placed sites. Each site had three 20m parallel transects, where a densiometer was used to read canopy cover every two meters along each transect (10 readings per transect, 30 per study site). A mean canopy cover of 28.1% was derived from the field data. An aerial photography layer (NAIP, 2009) was clipped to the study area and was converted into a single-band format with an attribute table containing the range of pixel values and the number of pixels associated with each value. A visual comparison of histograms for field data and the aerial photograph pixel values determined that the two datasets were similar in composition and that the field data was representative of data embedded within the aerial photograph. The aerial photograph was split manually into two classes of reflectivity pixel values, by multiplying the field-derived canopy cover percentage by the sum of reflectivity values within the aerial photograph. A visual comparison of the original aerial photograph and the modified aerial photograph in the study area determined that the threshold reflectivity value was affective in determining areas either with or without canopy cover in the study area. The analysis suggests that aerial photography can be used to estimate canopy cover within the study area and elsewhere on the mine. This technique has potential application for areas that may be difficult to access on foot, but are visible with aerial photography.

Additional Key Words: aerial photography, mixed conifer, canopy cover, mine subsidenence, inaccessible areas, reflectivity, remote sensing, GIS, vegetation

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CONTROL OF WATER-SOLUBLE METALS AND REVEGETATION OF ACIDIC MINE WASTE BY SOIL REMEDIATION[1]

S.R. Jennings[2] and D.R. Neuman

Abstract: Acidic mine waste and degraded soil with elevated metal levels are a prevalent source of water quality impairment. The effectiveness and cost of abandoned mine site remediation is highly variable. Soil amendment techniques have been developed for stabilization of mine waste, control of metal mobility, mitigation of water quality impacts and revegetation. These techniques are typically moderately costly and highly effective compared to conventional engineered cap and cover closure designs. Development of these *in-situ* or phytostabilization techniques has occurred over a period of several decades. Laboratory, greenhouse, and field examples are available that show the evolution and permanence of these technologies in controlling metal mobility and facilitating establishment of stabilizing vegetation. Lime, organic matter and fertilizers are common soil amendments and lead to nutrient-dominated soil solutions when compared to the metal-dominated soil conditions prior to treatment. These remediation techniques have been applied to thousands of acres of mine and metal affected land in Montana and Colorado resulting in decreased metal mobility, robust revegetation and diminished human and ecological risk.

Additional Key Words: lime, organic matter, tailing, remediation, treatment, phytostabilization

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CONSERVING AN S1/G5/T2 MUSTARD AT A SOUTH-CENTRAL MONTANA COAL MINE THROUGH NURSERY PROPAGATION AND TRANSPLANTING[1]

G. L. Johnson[2] and R. A. Prodgers

Abstract. Protected rare plants can hinder mine development if not conserved. Spring Creek Coal Mine (SCCM) in south-central Montana adopted a proactive conservation/propagation program for an uncommon but not formally protected variety of perennial mustard found in a topsoil-stripping area. The objective is to reestablish a self-sustaining population of *Physaria didymocarpa* (Hook.) A. Gray var. *lanata* A. Nelson, woolly twinpod, in reclamation and elsewhere within the permit area. This recognized variety is rated S1 in Montana (at risk, imperiled); the G5 (common, secure) global designation refers to generic *Physaria didymocarpa* (common twinpod), whereas T2 (less imperiled than S1, it occurs also in WY) refers to the trinomial (var. *lanata*). In the wild, fruits aren't produced every year and empty capsules are common, hence prospects for collecting seed appeared dim. Fifty mature plants were collected from the nexus of the population, transplanted, and used for tissue culturing (cloning) and later for seed collection. Between 500 and 1,000 plants annually were transplanted into the mine permit area beginning in fall 2008. In addition to the problems inherent to a stenotopic functional annual of very limited competitive ability, these limitations have manifested in the transplant program:

- Windblown dust accumulation in the foliage inhibited plant survival. The epithet "lanate" refers to long, tangled, woolly hairs.
- The fresh scoria into which transplants were planted in a few months became a dense sward of 5 dm tall kochia (*Bassia scoparia*) with a scattered twinpod understory. Kochia was more successful in capturing water, nutrients, and light.
- Disturbed or placed scoria subsequently becomes a magnet for yellow sweetclover (*Melilotus officinalis*), a tall nitrogen-fixing legume and copious seeder that overtopped and apparently competed with twinpod, the growth and survival of which did not appear to be assisted by increased mineral N, if present.
- Herbivory from ungulates and insects.

Spring transplanting is now performed into both mined and unmined areas. While transplants survive, a self-sustaining population is not yet assured. Further transplanting and adaptive practices continue at the mine. These lessons may guide others similarly engaged.

Additional Key Words: rare plant conservation, tissue culture propagation, outplanting, habitat, competition.

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GEOCHEMICAL PROPERTIES OF WEATHERED SOILS AND UNDERLYING OVERBURDEN OF THE POTTSVILLE GROUP IN CENTRAL APPALACHIA[1]

D.K. Johnson[2] and W.L. Daniels

Abstract: Coal surface mining in the Appalachians can contribute significant amounts of total dissolved solids (TDS) to headwater streams, especially below large active mining disturbances and valley fills. The objective of this study was to characterize the TDS elution potential of a range of geologic strata used in surface mine topographic reconstruction and valley fills and, specifically, to investigate the variations between well-weathered surficial materials and fresh unweathered materials at depth. Twelve weathering sequences were sampled (by horizon/strata from soil surface to approximately -20-30m) from materials originating in the late Pennsylvanian Pottsville Group in Central Appalachia. Profiles were described using field methods, as well as physical and chemical lab methods, in an effort to develop criteria for selecting optimal materials for use in surface mine reconstruction with respect to TDS production. All profiles were evaluated with depth for saturated paste pH/EC, Munsell color, hardness/ resistance penetration and other readily observable field properties. Results to date indicate that bulk soil/soil pH and EC increase within the rock saprolite layer and then abruptly at the Cr horizon –R layer contact and that a combination of spoil/soil color and relative hardness can be used to identify that transition. However, color alone (e.g. brown) was not always predictive of EC generation. Thus, as we expected, careful segregation of pre-weathered soil horizons from underlying rock saprolites and hard rock overburden may be a viable field mine operations approach to limit TDS elution potential of spoils on surface mining sites. Similarly, pre-mining identification of high TDS producing strata using a combination of field and laboratory techniques, coupled with subsequent appropriate handling strategies by mine operators can help to limit impairment to headwater streams.

Additional Key Words: TDS, pH, depth, electrical conductivity, weathering.

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KERBER CREEK RESTORATION PROJECT: CASE STUDY EMPLOYING STATISTICAL TECHNIQUES TO ANALYZE EFFECTS OF RESTORATION ACTIVITIES, SAGUACHE, CO[1]

T. I. Klein[2], L. Archuleta, J. Willis, N. Tedela, B. Sanchez

Abstract: The Kerber Creek watershed, located in Saguache County, Colorado, has been undergoing restoration since 1991 to address the impacts of historic mining activities in the upper watershed. These efforts have produced reasonable, albeit limited, quantities of data on stream morphology, water quality, fish and macroinvertebrate populations, and vegetation cover within the watershed. However, to date there has not been a concentrated attempt to evaluate the effects of restoration on these variables. The objectives of this case study are to employ robust statistical techniques to analyze the effects of restoration on sinuosity in the Kerber Creek watershed and to assess the validity and feasibility of using these statistical methods as project evaluation tools. Sinuosity was measured at five restored sites using National Agricultural Imagery Program one-meter resolution aerial imagery from 2005, 2009, and 2011. The phytostabilization index was used to represent the extent to which the floodplain was restored at each site through in-situ treatment of mine waste deposits, termed phytostabilization. Repeated measures analyses of variance was subsequently performed to evaluate the effects of time (i.e., natural channel evolution) within sites and the extent of restoration among sites on changes in sinuosity. Simple linear regression analysis was then employed to elucidate the nature of the relationship between extent of phytostabilization and within-sites sinuosity means. No treatment was found to have a significant effect on sinuosity at the 0.05 or 0.10 levels of significance. Similarly, the regression coefficient for the phytostabilization index was not significant ($p > 0.20$), and the correlation coefficient was relatively low ($r^2 = 0.357$). Although these results indicate that restoration activities in the Kerber Creek watershed have not significantly improved sinuosity, a number of methodological issues, including the suitability of statistical models and the phytostabilization index, lack of sufficient data, and the presence of outliers, require cautious interpretation. Most importantly, this case study reveals the necessity for intensive monitoring regimes to accurately analyze project results and identifies numerous variables that must be considered when designing a statistically valid restoration project evaluation technique.

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ANTIMONY REMOVAL FROM MINE WATER USING ADSORBENT MEDIA[1]

D. T. Klempel[2]

Abstract: Antimony presents a unique challenge in mine water treatment. It is present in groundwater as an oxyanion and is similar to arsenic in many ways, but is often not handled by conventional arsenic treatment technologies. Antimony is generally not a prevalent species, and not nearly as much research has been dedicated to treatment technologies. However, when present, it can pose a significant compliance challenge. In some cases, required discharge limits even challenge the ability of available technology to achieve compliance.

One example is the Drumlummon Mine near Helena, MT, an underground gold mining operation originally mined in the late 1800's. The mine was dormant and flooded for nearly a century when exploration began again in 2007, followed by dewatering. A 68 m^3/hr (300 gpm) treatment plant was constructed within the mine to treat discharge for arsenic; as dewatering continued and mining operations commenced the water quality changed significantly, and antimony surfaced above the discharge limits. In order to maintain mining operations, a variety of technologies were screened and tested to determine a technically and economically feasible approach.

For antimony, the EPA identifies only two treatment approaches as best available technologies (BATs), reverse osmosis and coagulation/filtration. These BATs are often not practical and sometimes not capable of achieving compliance. At the Drumlummon, neither approach was realistic; as such, adsorption media was investigated. Removal of arsenic through adsorption has been well established; but this same technology has not been widely applied to antimony.

Granular ferric hydroxide (GFH) and titanium dioxide media were tested. Titanium dioxide was determined to significantly outperform GFH for antimony removal. Titanium dioxide media allows for longer runtimes between change-outs and results in a lower operating cost. This approach has allowed the Drumlummon to operate in compliance with their arsenic and antimony limits since the installation of titanium dioxide.

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NATIVE TREE SURVIVAL AND HERBACEOUS ESTABLISHMENT ON AN EXPERIMENTALLY RECLAIMED APPALACHIAN COAL MINE[1]

S.C. Koropchak[2*], C.E. Zipper, J.A. Burger and D. M. Evans

Abstract: On a surface coal mine in southern WV, the forestry reclamation approach (FRA) was employed while comparing the effects of substrate type and seeding prescription on survival and growth of native tree species and herbaceous vegetation. Four substrates were used: weathered sandstone (brown), unweathered sandstone/shale mix (gray), mixture of weathered and unweathered rock (mixed), and native topsoil, a mixture of the soil solum and unconsolidated soil parent material (soil). Each replicate was split into two subplots; one seeded with a tree-compatible seeding mixture and one unseeded. Trees were planted in March 2012, measured for initial height in June 2012, and measured for height and survival in late October 2012. Herbaceous groundcover and species richness were measured during the growing season. After one growing season, mean percent survival and growth of planted trees differed among tree species and seeding treatments. There were no interactive effects. There were no differences in tree survival or growth among substrate treatments. Of planted tree species, survival was highest for hawthorn and black cherry (~85%) and lowest for Eastern white pines (25.3%) and shagbark hickory (24.3%). Of the trees which survived the first growing season, hawthorn (22.4 cm) and black cherry (22.2 cm) height in the unseeded treatment increased more than all tree species except white pine (10.8 cm) and gray dogwood (17.3 cm). Unseeded treatments had higher tree survival (70.4%) than seeded treatments (56.4%). Gray and soil treatments had the highest total herbaceous richness and soil treatments had the highest volunteer richness. Seeded treatments had less bare ground and higher mean species richness than unseeded plots. After one growing season, planted trees' survival and growth vary among species and with seeding practice, and herbaceous vegetation cover varies with seeding practice and substrate treatment.

Additional Key Words: Forestry reclamation approach; seeding; tree establishment.

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APPLICATION OF ADVANCED ECOSYSTEM BASED RECLAMATION STUDY FOR A STEEPLY DIPPING OPEN PIT MINE OF INDIA: A CASE STUDY[1]

Pradeep Kumar[2] and Agota Horel

Abstract: Researchers have been striving to develop novel and innovative techniques, for the realization of a holistic, environment friendly and ecosystem-based strategy of reclamation, particularly, in the mining sector. In this work, we study the lay, disposition, seam gradient, prevalent mining method and reclamation technique adopted subsequent to coal winning with reference to the case study of a Coal mine, nestling in the foothills of the Himalayas- an ecologically sensitive zone- in the strategically important north-eastern India, bordering China and Myanmar. The coal from this mine is of very good quality and its GCV ranges up to about 8390 Kcal/kg. The formation exhibits the tertiary stratigraphic sequence. The UVM% ranges from 42.06 – 47.90 and total sulfur varies between 3.4% and 7.2%. The striking feature of this open pit mine is the presence of steeply dipping coal seams- the gradient of the coal seams varying from 18 to 48 deg. We examine the planning and design considerations coupled with the selection of the mining equipment fleet under such stringent duty requirement throughout the life of the mine. Accordingly, we study the strategy for Mine Reclamation and modifications in the reclamation system design adopted for such steeply dipping coal seams so as to ensure a holistic, Ecosystem based Reclamation, subsequent to coal winning, in this ecologically sensitive zone. We examine the modifications made with due regard to slope stability considerations, taking into account the internal angle of friction and cohesion, in the light of the soft and friable strata conditions. On hindsight, we examine the efficacy of such reclamation approach and the design considerations for steep slope stabilization in cases where strata are weak and friable, at the mine planning stage *itself.*

Additional Keywords: Ecosystem based Reclamation, Seam Gradient, Slope Stabilization, Reclamation System Design

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DETERMINATION OF DOMINANT TRACE METAL SEQUESTRATION PROCESSES IN TWO VERTICAL FLOW BIOREACTORS USING MODIFIED TESSIER EXTRACTIONS[1]

J.A. LaBar[2] and R.W. Nairn

Abstract: Vertical flow bioreactors (VFBR) may be employed to remove trace metals from mine drainage through a variety of partitioning mechanisms. Sequential extractions can then be used to obtain an estimate of metal partitioning in VFBR substrates. Substrate samples were collected from two VFBR that had been inundated for approximately 1.5 years as part of a multi-process unit passive treatment system receiving abandoned lead-zinc mine waters. Preserved substrate samples that had been collected prior to construction of the VFBR were also included in this study. Inflow, outflow, and porewater samples were collected from the cells at or near the same time as the substrate samples. Mean inflow and outflow data indicate that cadmium, cobalt, lead, manganese, nickel, and zinc decreased significantly in the VFBR. Modified Tessier extractions were used to determine the water soluble, exchangeable, organic-bound, carbonate-bound, oxide or oxide-bound, and residual fractions of metals in the substrates. Results demonstrate that the VFBR are removing metals through several sequestration processes including: sorption, complexation, concretion, and sedimentation. On average, complexation (represented by the organic-bound fraction) appeared to be the dominant removal process for trace metals in the first year and a half of VFBR operation, with removal as sulfides and/or carbonates also contributing substantially to overall decreases in trace metal concentrations in these VFBR. It is anticipated that removal of trace metals as carbonates and sulfides will become more significant removal processes as the VFBR mature.

Additional Key Words: acid mine drainage, passive treatment, sequential extraction, Mayer Ranch

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THE EIGHT TH YEAR OF THE INTERNATIONAL MINE CLOSURE CONFERENCES: ITS POSITIVE INFLUENCES ON EFFECTIVE MINE CLOSURE, COMPLETION AND RECLAMATION IN AUSTRALIA[1]

H. W.B. Lacy[2]

Abstract. This paper discusses the issue of mine closure and its advance in Australian mining operations and the influence of the International Mine Closure Conferences – now in their 8th Year. Professionals from Academia, Global and Local Mining companies, Consultants and Scientists are now more connected and interactive through this annual international forum. Mine completion ultimately determines what is left behind as a benefit or legacy for future generations. If mine closure and completion are not undertaken in a planned and effective manner, a site may continue to be hazardous, and a source of pollution for many years to come.

Unfortunately, the reputation of the mining industry has been affected by poor examples of mine closure, resulting in long-term environmental impacts and legacy sites. Mine closure planning has been, and in many cases still is, left until near the end of mine life, often leaving little time, financial provision and/or resources for effective closure planning and decommissioning. Current standards for mine rehabilitation and closure are becoming much more stringent, reflecting changing public priorities and the concept of sustainable development. I wish to show how the Mine Closure series is advancing networking in this field, with sharing of knowledge, systems and planning, and is changing legislation and improving mine closure outcomes.

The presentation will also be drawing on images from changes ongoing in mine reclamation in Australia, and an overview of the influences and challenges the Australian industry still has in many areas of mine closure – and it's attempt to address those challenges.

Through this paper, I also wish to hope to suggest and encourage ASMR members to engage in these international forums so they can bring their wealth of knowledge to this international conference. This will be in keeping with the objectives of the ASMR, and as the oldest and most dedicated Society, that I am aware of, residing in a country that has lead been at the forefront of change in this field, has had one of the largest mining industries, has invested heavily in Mine Closure and Reclamation (in part driven by the Acts promulgated in the 1970'and 80's and the CERCLA and Hardrock laws), the Society and its members have a great deal to give to these International Mine Closure Forums.

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DEVELOPMENTS IN MINE CLOSURE AND INTEGRATION WITH OPERATIONS IN AUSTRALIA[1]

H. Lacy[2]

Abstract. This paper discusses the issue of mine closure and its advance in Australian mining operations and the influence of global companies. Mine completion ultimately determines what is left behind as a benefit or legacy for future generations. If mine closure and completion are not undertaken in a planned and effective manner, a site may continue to be hazardous and a source of pollution for many years to come. The overall objective of mine completion is to prevent or minimize adverse long-term environmental, physical, social and economic impacts and to create a stable landform suitable for some agreed subsequent land use.

Unfortunately, the reputation of the mining industry has been affected by poor examples of mine closure, resulting in long-term environmental impacts and legacy sites. Mine closure planning has been, and in many cases still is, left until near the end of mine life, often leaving little time, financial provision and/or resources for effective closure planning and decommissioning. Current standards for mine rehabilitation and closure are becoming much more stringent, reflecting changing public priorities and the concept of sustainable development. I wish to show how the use of advancing systems driven by global parent companies and planning within Australian operations will inevitable improve mine closure outcomes.

The presentation will be drawing on substance from a paper recently published[3] and bringing to this conference an overview of the challenges and concern the Australian industry still has in many areas of mine closure – and attempts to address those challenges.

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[3] AMMOP (2012) 3rd Edition Australian Mining and Metallurgical Practices in Australasia Ed. Rankin, J. Chapter 3, Environment – Developments in Mine Closure and Integration with Operations in Australia. Published 2012. Carlton, Vic. AUSIMM. Ref Lacy H.W.B. (in AMMOP: Ch3. 2012)

PASSIVE AERATION USING A TROMPE[1]

B. R. Leavitt[2], B. J. Page, C. A. Neely, R. M. Mahony, T. P. Danehy, C. F. Denholm, S. L. Busler, M. H. Dunn

Abstract: Mine water aeration is needed at many mine drainage treatment facilities to oxidize ferrous iron or to remove dissolved carbon dioxide. Aeration is typically accomplished through surface diffusion, cascade aeration, mechanical aeration, or in some cases with chemical reagents such as hydrogen peroxide. Using an ancient device known as a Trompe it is now possible to achieve the benefits of mechanical aeration without the need for electricity, motors, or any moving parts. A Trompe-powered aerator was designed and installed at the Curley passive treatment facility in Fayette County Pennsylvania. Water is conveyed through the trompe to generate compressed air. The compressed air generated by the trompe is used to aerate the raw water raising the dissolved oxygen of the water by nearly 3 milligrams per liter. The effect of this aeration is to increase the oxidized iron by about 10%. Recent developments at the site have allowed the treatment effectiveness to be further enhanced with improved system configuration and the installation of additional Trompes.

Additional Key Words: Water Treatment, Mine Drainage, Pre-Aeration, Carbon Dioxide.

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INVESTIGATING SAGEBRUSH RECLAMATION SUCCESS FOR BENTONITE MINED AREAS IN THE BIG HORN BASIN, WY[1]

Z. J. Liesenfeld[2], P.D. Stahl and L.C. King

Abstract: The Big Horn Basin located in north central Wyoming has some of the largest deposits of quality bentonite throughout the world. Historically, reclamation efforts to establish plant communities similar to premine sagebrush (*Artemisia tridentata*) grassland plant communities have been limited due to the absence of shrub regulatory standards and poor response of sagebrush to reclamation efforts on bentonite mine lands. The lack of suitable shrub cover is believed to have a negative effect on sagebrush obligate species, such as the greater sage-grouse (*Centrocercus urophasianus*). The objective of this study is to determine if sagebrush communities are reestablishing on reclaimed bentonite mined lands in the Big Horn Basin under conventional reclamation techniques. Data indicates that sagebrush establishment on reclaimed bentonite lands in the Big Horn Basin has not been successful using conventional methods. At study sites, sagebrush plants were not established in adequate densities on sites seeded within the past 15 years. However, it does appear conventionally reclaimed sites older than 15 years are undergoing natural recolonization of sagebrush to greater densities than found on the younger sites. Within this study, 11 reclaimed and six native reference sites were analyzed throughout the Big Horn Basin. Five sites were reclaimed in the past 15 years, while six were reclaimed more than 15 years ago. The younger sites have a mean sagebrush density of 900 stems hectare^{-1} while the older sites have a mean of 5140 stems hectare^{-1}. Native reference sites have a mean sagebrush density of 10,763 stems hectare^{-1}. Densities of older reclaimed sites are only about half of observed sagebrush densities on native reference sites. These results are interpreted as indicating that conventional methods of sagebrush reestablishment used in bentonite mineland reclamation are ineffective in the short term, 15 years or less. That is, initial seeding efforts during site reclamation result in very little sagebrush establishment. However, over the long term, natural seed dispersal of native sagebrush from undisturbed areas surrounding reclaimed mine sites appears to have resulted in reestablishment of greater densities of sagebrush plants. Included in the final report sagebrush height and canopy cover data are provided to aid in better understanding natural reestablishment rates.

Additional Key Words: *Artemisia tridentata, Centrocercus urophasianus,* conventional reclamation, greater sage-grouse, natural seed dispersal, reclaimed

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USING ISOTOPES TO STUDY COALBED NATURAL GAS CO-PRODUCED WATER AND SOIL INTERACTIONS[1]

K.J. Lilly[2] and G.F. Vance

Abstract: Natural gas production from coalbed natural gas (CBNG) involves water removal to access the energy resource. This water can be an environmental concern. In order to investigate potential environmental consequences, it may be important to use a tracer to study discharged water as it interacts with soils and the atmosphere. A laboratory study was conducted to evaluate stable carbon (C) isotopes of dissolved inorganic C (δ^{13}C-DIC) after contact of CBNG water with soils from the Powder River Basin, WY. A CBNG water sample was mixed with a local soil and allowed to react for one month. Gas and water samples were taken at six different time periods and analyzed for C isotopes and other geochemical proxies like major cations, electrical conductivity, and pH. CBNG water was found to be isotopically and chemically different than surface stream waters after interacting with soils after one month. Results from this study demonstrate that these contrasting δ^{13}C-DIC signatures coupled with standard geochemical measurements can be used to distinguish CBNG produced water from natural stream waters as the waters interact with soils. However, it is important to recognize that the present study was conducted under a closed system and isotope dynamics may be different under open atmosphere conditions in the natural environment where CBNG water is discharged.

Additional Key Words: carbon isotopes, dissolved inorganic carbon

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DEVELOPMENT OF A SPODUMENE (LITHIUM) MINE ON AGRICULTURAL LAND IN THE SOUTHWEST OF WESTERN AUSTRALIA[1]

K Lindbeck[2]* and B Clark[2]

Abstract: It is very unusual for a minesite to be established on agricultural land in Western Australia (WA) as the rural landholder has a veto right over any mineral tenement application that may cover his/her land. A planar pegmatite containing spodumene (lithium and tantalite) has been known to exist for a few decades near Ravensthorpe approximately 500 km southwest of the state capital, Perth. The first stage for the mine is located on cleared cropping and grazing land. The mining company, Galaxy Lithium Australia, overcame the veto by purchasing the property from the owner. A range of environmental studies were completed during the period 2007-2009 and the WA Government gave its approval to proceed with construction in mid-2009. Processing commenced in August 2010.

The approvals system required grant of the mineral title, approval to clear pockets of degraded native vegetation (requiring an offset), approval to construct the plant infrastructure and then approval of an operating licence.

It is proposed by Galaxy to extend the mine (Stage 2) into the adjacent Unallocated Crown Land (UCL – i.e. public land) in approximately two years. This has required completion of additional studies, especially related to diversion of an ephemeral saline creek system and salvaging and relocation of Aboriginal artefacts.

The presentation will briefly outline the approvals process, the studies completed and the current status of the mining operation.

Additional Key Words: Environmental Impact Assessment, closure planning, water management, rehabilitation.

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RUSSIAN THISTLE POPULATION DYNAMICS AT A FORMER COAL MINE IN NORTHERN NEW MEXICO[1]

A. MAIER[2] AND J. WHITE

Abstract: This study evaluated post-reclamation cover changes in Russian thistle (*Salsola kali*) at a former coal mining site near Raton, New Mexico. Relationships between Russian thistle occurrence and perennial grass establishment, precipitation, and percent bare ground were investigated using post-reclamation vegetation data. Russian thistle, or "tumbleweed", is native to Eurasia and now common at disturbed sites throughout the semiarid western United States. Russian thistle is an annual plant that disperses large quantities of seed following stem detachment. This drought tolerant plant grows well in poor quality soils with little organic matter. It is problematic for reclamation because it is considered an invasive plant, and therefore cannot be counted towards New Mexico Minerals and Mining Division vegetation standards of 13% total plant cover with a minimum of six perennial species established within reclaimed areas. Phase I (baseline), II, and III bond release vegetation data must be collected to demonstrate that the reclaimed areas can support designated post-mining land uses, such as wildlife habitat and/or forage for livestock. Bond release data indicate that Russian thistle growth increases in the years immediately following reclamation, but decreases in subsequent years. Russian thistle cover is positively correlated with below-average annual precipitation and percent bare ground. These data suggest that active control of Russian thistle via mechanical treatment or herbicide may not be warranted due to a decline in plant cover over time. Additionally, Russian thistle may serve as a cover crop that aids in perennial plant establishment through enhancement of soil organic matter, increased soil moisture, and reduced topsoil erosion.

Additional Key Words: reclamation, invasive plant species

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NATURAL GAS FIELD RECLAMATION INTEGRATING RECLAMATION SCIENCE, WEED MANAGEMENT, AND MONITORING, WAMSUTTER, WYOMING. - A PRE-FIELD TRIP OVERVIEW[1]

D. Marshall[2], R. Ansotegui, B.Teson, C. Driessen

Abstract: This discussion provides an overview of the Wamsutter Natural Gas Field prior to the conference field trip. Natural gas fields in the Rocky Mountain west are often located in areas with challenging reclamation conditions. To develop energy resources, oil and gas producers must comply with federal, state, and local environmental policies and regulations. A science based approach to reclamation that integrates monitoring, soil management, weed management, and reclamation implementation allows operators to meet these regulatory requirements. The Wamsutter Natural Gas Field in south central Wyoming covers over 500,000 hectares of public and private lands, and contains over 6,000 natural gas wells owned by more than 100 producers. KC Harvey began reclamation activities in 2007 and now manages reclamation on more than 2,000 well pads, pipelines, and other facilities. The Wamsutter Field has extreme challenges for reclamation. Limited soils are derived from naturally saline marine sedimentary bedrock. Thousands of years of leaching produced a thin veneer of suitable soils, and a salt enriched zone below. The limited precipitation (17-23 cm/yr) also limits plant growth. Pressure from invasive plants and wildlife and livestock grazing provide additional challenges.

The science based approach to reclamation in the Wamsutter Field integrates annual reclamation monitoring, reclamation science, soil management, weed management, and reclamation implementation. The program includes pre-construction reclamation planning to minimize degradation of the limited soil resources, field trials of innovative reclamation techniques, development of custom seed mixes, detailed GPS tracking of herbicide applications, soil amendments to address sodic soils, and performance monitoring. The feedback from monitoring allows adapting reclamation procedures. Over the past five years, this has resulted in improved soils salvaged for reclamation, development of seed mixes with higher success rates, more effective weed management, and reduced time to meet reclamation goals.

Additional Key Words: Soil management, sodic, GPS, herbicide, pre-construction

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INTEGRATING GEOMORPHIC RECLAMATION WITH UNDISTURBED AND PREVIOUSLY RECLAIMED AREAS USING A MULTI-PROGRAM COMPUTERIZED DESIGN APPROACH AT McKINLEY MINE[1]

H. McCabe[2], S. Motycka, M. Siemsglusz, Kyle Kutter, R. Spotts, M. Brennan, R. Wade, K.J. Malers, W. Erickson

Abstract: McKinley Mine is a surface coal mine located in western New Mexico. Coal production began in 1962 and ceased in 2009, leaving extensive lengths of final pit and highwalls (11,850 LF), areas of ungraded spoil (793 acres), areas where reclamation had been performed using conventional reconstruction methods (211 acres), and large areas of undisturbed watersheds that contributed stormwater runoff to the disturbed area (891 acres). Under the Clean Water Act's Western Alkaline Coal Mining regulations (Subpart H), reclamation was required to comply with criteria based upon average annual sediment yield from pre-mining undisturbed conditions.

A combination of post-mining topography and hydrologic control structures were designed to reconstruct stable reclaimed watersheds. A multi-computer program design approach integrated MINCOM (mass balance); Natural Regrade (surface topography); SEDCAD and HEC-RAS (hydrologic modeling, sedimentology and structure designs); and RUSLE (slope stability evaluation). The multi-program approach enabled geomorphic topography to tie into watershed slopes and concentrated flow features at adjacent undisturbed and previously reclaimed areas. The use of various hydrologic control structures (unlined and armored channels, drop structures, loose rock check dams, small depressions and sediment control ponds, etc.) provided stable conveyance of concentrated stormwater flow onto, within and from the reclamation.

Draglines and other large mining equipment were used for the bulk materials handling, to rough-shape post-mining topography. Bulldozers, track excavators and haul trucks were used to shape the final surface and construct the hydrologic control structures. Construction of the hydrologic features integrated with the geomorphic topography required attention, but the resulting reclamation will provide more stable long term slopes and subsequent low-maintenance conveyance of stormwater runoff, with natural-looking, varied topography that is conducive to the establishment of permanent diverse vegetation communities.

Additional Key Words: Geomorphic Reconstruction, Stream Reconstruction, Mine Reclamation, GeoRiparian Restoration, Clean Water Act, Western Alkaline Mining Subcategory, dragline reclamation

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SUSTAINING RAPTOR POPULATIONS AT THE NORTH ANTELOPE ROCHELLE MINE IN NORTHEAST WYOMING[1]

Gwyn McKee[2], Paul Griswold, and Marilee O'Rourke

Abstract: Implementation of appropriate mitigation measures can minimize or preclude negative impacts to nesting raptors and other vertebrate species of concern, as well as to business operations. Over the last 32 years, biologists with Thunderbird Wildlife Consulting, Inc. (TWC) have developed, enhanced, implemented, and/or supervised such measures for both active and inactive raptor nests while working with the energy industry in northeast Wyoming, particularly the North Antelope Rochelle Mine and other surface coal operations. Long-term monitoring has enabled biologists to determine important parameters such as home range territory, tolerance for other species, and ability to acclimate to regular human disturbance for multiple raptor pairs and species. This knowledge base has been invaluable when preparing required mitigation plans for agency review and approval. By 2012, TWC had directed the relocation (of both active and inactive nests), creation, or modification of more than 100 nests across seven raptor species. Nesting raptors used the majority of previously active nests after mitigation measures were implemented, with smaller use percentages associated with nests in territories that had been dormant for several years prior to manipulation. The presentation at the ASMR conference will describe specific case histories for at least two nesting raptor species at the North Antelope Rochelle Mine, demonstrating the ability to maintain and manage nesting raptor populations without interrupting normal mine activities.

Additional Key Words: mitigation measures, minimize or preclude negative impacts, important parameters, case histories, maintain and manage nesting raptor populations

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QUANTITATIVE MONITORING IN OIL AND GAS RECLAMATION: WHAT CAN IT DO FOR YOU?[1]

T.J. Minnick[2]

Abstract: There are two main methods of ensuring reclamation of damaged habitats following natural resource extraction: 1) Best Management Practices (BMPs) or 2) performance-based standards. Performance-based standards, as we know from a multitude of industries (e.g., education, health care, coal mining), generate superior outcomes and can have positive impacts for all stakeholders: industry has flexibility in implementation; regulators have clear, unbiased standards to enforce; and the public, whose lands and wildlife were impacted, has better reclamation outcomes. Successful reclamation is likely to result in less public anxiety about impacts to the environment, and thus ensure the industry's continued enjoyment of the use of these natural resources. Within a performance-based standard system, industry experts have the ability to experiment with new techniques and determine superior, cost-effective methods for reclamation under varying and even difficult conditions. Currently at the federal level, the Bureau of Land Management's *Gold Book* merely requires BMPs for reclamation after oil and natural gas extraction. Conversely, the state of Colorado has a performance standard for both interim and final oil and gas reclamation as determined by the Colorado Oil and Gas Conservation Commission (COGCC). These standards require vegetative cover of "at least eighty percent (80%) of pre-disturbance levels or reference areas, excluding noxious weeds." Remarkably, there are no quantitative measurements required to show that these standards have been met; instead, interim reclamation is documented by photographs and final reclamation is verified by visual inspection. As demonstrated within the coal mining industry, standardized, quantitative system for monitoring and reporting results is critical to ensure and document reclamation success. Such a system enables rigorous comparisons of methods, initial conditions, and final outcomes encountered during reclamation. Sharing these analyses throughout the industry, and with regulators and the public, will further enhance reclamation success.

Additional Key Words: Best Management Practices, Colorado Oil and Gas Conservation Commission, Gold Book, Performance-based Standards, Revegetation

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A STUDY ON THE POSSIBILITY OF PASSIVELY TREATING A HEAP LEACH PAD DRAIN DOWN SOLUTION[1]

A.M. Moderski[2], J.J. Gusek, C. Bucknam, C. Hager, and T.R. Wildeman

Abstract. A 20-week bench-scale study was conducted by Golder Associates to determine whether passive treatment could effectively remove weak acid dissociable (WAD) cyanide and NO_3 from the drain down solution emanating from a decommissioned gold heap leach pad. An anaerobic treatment scenario was chosen and three different substrates were chosen. Limestone at 10 % by weight was in all three reactors, two of the reactors had between 80 and 90 % hay/straw, and a third reactor had 45 % hay/straw and 45 % potato mash. These are local agricultural products and by-products. Because the historic concentration of nitrate-N ranged from 142 to 297 mg/L, the flow rate into the reactors was based on the hydraulic retention time needed to remove nitrate-N down to 10 mg/L, and this was determined to be 20 days. All three substrates were effective at removing WAD cyanide and nitrate-N to below 0.04 mg/L and 1.0 mg/L, respectively. In the effluents, other constituents that could be the products of cyanide and nitrate-N degradation were analyzed and only ammonia-N was detected at concentrations from 5 to 10 mg/L. The most recent regulatory limit has been set at 10 mg/L N for the total N in all nitrogen species. Under this limit, the sum of nitrate-N and ammonia-N would be below the 10 mg/L N limit.

Additional Key Words: Anaerobic bioreactor, nitrate, nitrite, WAD cyanide, ammonia.

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HOW FAR HAVE WE COME? A REFLECTION OF REHABILITATION RESEARCH IN QUEENSLAND OVER RECENT DECADES[1]

D. R. Mulligan[2]

Abstract: Given the major advances in most other aspects of technology, one would expect that the conversion of our expanded scientific knowledge into practice would have meant that the quality of our understanding, protection, management and repair of landscapes we disturb through the extraction of mineral wealth and energy requirements, was a matter of course and one on which we could reflect with pride. But is it?

My research journey began in the early-90s with the extensive lateritic bauxite deposits of north Queensland and the expanding central Queensland coalfields, addressing issues of protecting soil organic matter in the topsoil management program at the former, and developing rehabilitation strategies for sodic spoils in the latter. In the mid-90s, a relationship with the Kidston gold mine began with inviting vegetation to grow directly in tailings, but with the longer-term agenda of requiring the material to allow a whole ecosystem to develop and sustain itself. Major research effort to optimize landform design in the open-cut coal industry developed around this time as did interest in the importance of the understory components of native ecosystems. With that recognition, projects were also developed to identify the strategies required to transition re-vegetated landforms into re-vegetated habitats that would encourage and foster re-colonization by key fauna species.

Since a measure of rehabilitation success could be deemed to be how well rehabilitated land remains stable under the pressures of a subsequent disturbance (including, for example, fire), the coalfields began to be challenged by the historically-nominated end land use of grazing, with multidisciplinary research directed towards understanding the risks and better informing the decision-making processes around end land use. Commodity prices and global demand has now also placed parts of the industry in a greater number of areas in conflict with the environmental and social values of protected ecosystems and productive soils supporting high value food crops. The rapid growth of the sector has seen an equally rapid growth of interest in how to effectively monitor both impacts and recovery.

This presentation provides a few reflections on rehabilitation research activities and some contemplations of where the next set of challenges and solutions may be.

Additional Key Words: bauxite, coal, gold, topsoil management, sodic spoils, tailings, ecosystems, fauna habitat, post-mining land use, monitoring, success criteria.

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OFF-THE-GRID AERATION TO ADDRESS NUISANCE CONSTITUENT PRODUCTION FROM SPECIFIC PASSIVE TREATMENT SYSTEM PROCESS UNITS[1]

R.W Nairn[2] and K.A. Strevett

Abstract: Data from hundreds of passive treatment systems demonstrate successful improvement of abandoned mine water quality by decreasing ecotoxic metals concentrations, and increasing alkalinity concentrations and pH. However, certain biologically-based process units may produce excessive concentrations of atypical, non-mine drainage related constituents. These predominately anaerobic units (e.g., vertical flow bioreactors, sulfate-reducing bioreactors, biochemical reactors, vertical flow ponds, etc.) are designed to promote reductive microbial mechanisms (e.g., fermentation and sulfate reduction). Therefore, even if functioning properly from a mine water quality improvement perspective, effluent waters may contain excessive concentrations of biochemical oxygen demand (BOD), sulfide, and nutrients, have low dissolved oxygen concentrations and oxidation-reduction potential, and cause nuisance odor problems. Compounding a general lack of understanding of these issues, these non-mine drainage related water quality constituents are not typically included in most monitoring schemes and system performance evaluations. In this study, nuisance constituent concentrations and mass balances were developed for re-aeration ponds which were enhanced with renewable energy-driven (solar- and wind-powered) re-aeration devices. The devices were evaluated for their ability to effectively enhance re-oxygenation and mixing of the water column downstream of anaerobic process units. The efficacy of two different re-aeration devices (wind- and solar-powered) was evaluated specifically as to their effect on oxygen mass transfer and the rates of sulfide and BOD removal. Both with and without re-aeration, sulfide, BOD and nutrient concentrations exceeded water quality criteria for most sampling location-event pairs. System effluent dissolved oxygen and oxidation-reduction potential data displayed a distinct seasonality based on the biological nature of production. Nuisance constituent production demonstrated an overall decrease as systems aged, and is likely most problematic in the first few growing seasons. However, more robust monitoring schemes, including constituents beyond the typical mine water parameter suite, may be appropriate when anaerobic process units are included in passive treatment systems.

Additional Key Words: Solar power, wind power, renewable energy, hydrogen sulfide, biochemical oxygen demand, nuisance parameters

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LONG-TERM EFFECTS OF ORGANIC AMENDMENTS AND POTENTIAL CARBON SEQUESTRATION IN SOUTHWEST VIRGINIA MINE SOILS[1]

Whitney L. Nash[2], W. Lee Daniels and James A. Burger

Abstract: The use of organic amendments as a means of improving mined land productivity has been extensively studied. Carbon sequestration by mined lands has been also been evaluated recently as a means of offsetting anthropogenic CO_2 emissions. However, obtaining accurate estimates of total C in mine soils is limited by the lack of an effective method for elimination of positive errors due to coal/fossil-C, carbonate-C in coal mine spoils and other analytical complications. The Controlled Overburden Placement Experiment was installed in 1982 in two parts, the Rock Mix (RM) Experiment compares mixes of sandstone (SS) and siltstone (SiS) spoils while the Surface Amendment (SA) Experiment compares a fertilized control (CON), sawdust (SD at 112 Mg ha^{-1}), topsoil (TS–15 cm), and biosolids (BS) applied at 22, 56, 112 and 224 Mg ha^{-1} to a uniform 2:1 SS:SiS spoil. Results reported here are from the SA Experiment under herbaceous vegetation. Whole soil (litter + 0-5 cm–surface soil + 5-25 cm-subsurface soil) C ranged from 30 to 50 Mg ha^{-1} in 2008. Whole soil C in the higher organic amendment plots (B-112, B-224 and SD) was greater than the CON after 26 years; while C levels in the lower biosolids rate (B-22 and B-56) plots were similar to levels in the CON. By applying a correction for geogenic-C in the 1982 original spoils, we quantified net whole soil C-sequestration rates for the 26 yr period. The non-amended CON and TS sequestered C at 0.54 Mg ha^{-1} y^{-1} and 0.87 Mg ha^{-1} y^{-1}, respectively. Carbon sequestration rates for B-22 and B-56 were 0.31 and 0.01 Mg ha^{-1} y^{-1}. Higher rate biosolids and SD treatments lost C at rates of -0.13 (B-112), -0.68 (B-224) and -1.04 (SD) Mg ha^{-1} y^{-1}. In 2008, the bulk of soil mass C was found in the subsurface of all treatments. Surprisingly, the SD plots contained subsurface C-levels similar to the B-224 and were higher than all other treatments. This indicates substantial mobilization of C from the surface layers of the SD and high BS rates and then stabilization and retention of C in the subsurface. Finally, all treatments appeared to approach an estimated C accumulation threshold of 30-35 Mg ha^{-1} indicating a potential limit for mine soil C-sequestration in this particular setting.

Additional Key Words: Carbon sequestration, organic amendments.

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IMPACT OF INOCULATION WITH PLANT MATERIAL ON PLANT DEVELOPMENT; GREENHOUSE TESTS[1]

Conrad Nelson[2], Warren Rider, and Adrian Unc

Abstract: This study tests the hypothesis that employing site-specific native endophytic microbial consortia would lead to microbial consortia more likely to adapt to the local conditions, persist after inoculation, and enhance plant fitness. Three treatments were used to test this hypothesis: Fresh seed (Treatment A), dehulled and surface sterilized seed (Treatment B), and dehulled, surface sterilized seed with container inoculated with 1 gram of ground native plant material (Treatment C). All treatments were carried out in soil conditions representative of coal mine reclamation areas located in northwestern New Mexico. Mining spoil comprised the bottom 13 cm of the planting containers and was overlaid with 23-28 cm of topsoil. Nine plant species commonly used for revegetation at the mine site were considered for inclusion in the study. All tests were carried out in triplicate. Due to differences in germination potential only three of the original nine species were utilized in the study: S. airoides, B. gracilis and P. jamesii produced statistically complete datasets across all treatments and were used for analysis. Plant growth was measured and documented over 5-7 months after which destructive harvesting was conducted to measure root development and soil chemical and functional parameters. Inoculation with site-specific plant material resulted in increased plant height and root growth for S. airoides and was deleterious to growth rates in H. jamesii. Results suggest that while non-specific endophytic inoculation may have an effect, it is highly plant species dependent. Both beneficial and potentially facultative pathogenic microbes likely interact in improving or impeding plant growth.

Additional Key Words: Reclamation, revegetation, topsoil.

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REMEDIATION OF THE MILLTOWN SEDIMENTS IN MONTANA[1]

Dennis Neuman[2], Frank Hons, Terry Moore, Hamid Shahandeh, Richard Loeppert, and Courage Bangira

Abstract: Mining wastes from a century of hard rock mining, milling, and smelter operations in the vicinity of Butte and Anaconda, Montana were captured in sediments behind the Milltown Dam on Montana's Clark Fork River. In 2004, the U.S. EPA mandated the sediments be removed and transported via rail to a designated Waste Management Area near Anaconda Montana. The Waste Management Area is located on the Opportunity Tailings Ponds, a large impoundment containing smelter tailings. By 2009, 2.2 million cubic years of sediment were placed over some 700 acres on the Opportunity Smelter Tailings Ponds to a depth of approximately 60 cm. Initial attempts at direct vegetation of sediments over 2-3 years were unsuccessful. Characterization of the materials indicated that they had a near neutral pH, but were crusted heavily and moderately saline, and had significant concentrations of water-soluble nitrates and metals.

A series of laboratory and greenhouse studies were conducted to determine the best strategy for improving the sediment to support a sustainable vegetative cover. Mineralogical characterization of the materials indicated a mixed mineralogy that is characteristic of the surrounding basin, but also with metal (Fe, Cu, and Zn) sulfides, gypsum, and weatherable silicate phases. In this paper, the results of the greenhouse trials are presented and a strategy for field implementation is identified.

A replicated greenhouse study was initiated in which 60 x 10 cm diameter growth containers were filled with layered soils, sediments, and amended sediments simulating six different potential field treatments, including a local calcareous cover soil, a liming compound (lime kiln dust), and local organic matter sources. Three grass species (smooth brome, Great Basin wild rye, and thickspike wheatgrass) were grown for 100 days. Plants were measured for shoot height, mass and metal concentration, and root depth and mass; and water uptake. Lime kiln dust (LKD) and organic matter additions resulted in increased depth of rooting into sediment. Water-soluble Mn and Zn concentrations were reduced to very low levels by LKD addition, and metal concentrations in the above ground plant tissue were below ranges considered to be phytotoxic. Treatment of sediment with LKD and cover-soiling with a local calcareous borrow source was judged to offer the best opportunity for successful revegetation. In the summer of 2012, a full scale field remediation of the Milltown Dam sediments was initiated based the outcomes of these investigations.

Additional Key Words: Tailings, Metals, Arsenic, Plant Establishment

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PREDICTING TOTAL DISSOLVED SOLIDS RELEASE FROM OVERBURDEN IN APPALACHIAN COAL FIELDS[1]

J. Odenheimer[2], J. Skousen, L. McDonald

Abstract: The Appalachian coal industry has been successful in developing technologies to identify, handle, treat and isolate potentially acid-forming overburden materials during coal mining to reduce or eliminate water quality problems. However, the techniques used to predict acid mine drainage potential have not been tested for total dissolved solids (TDS) prediction; therefore, new techniques may need to be devised. Using current technologies, recommendations to blend acid-forming with alkaline materials can lead to handling plans that actually increase TDS release. Our objective was to develop quick laboratory methods for predicting TDS release from overburden materials in the Appalachian region by comparing two extracting solutions, and one digestion technique to Acid-Base Accounting (ABA) parameters. Forty one overburden samples were collected from surface mines in West Virginia, Virginia, and Kentucky. Ground samples were mixed with a dilute HNO_3 solution, and once again with EDTA solution and shaken for 72 hours to simulate weathering. An additional test using USEPA Method 3051 was performed to provide the upper limit on TDS release. Supernatants were extracted and analyzed for pH, EC, and other selected ions. ABA parameters, which measure sulfur and neutralization potential (NP), were compared to results from our weathering tests. Results showed that predictions of TDS from the ABA were similar to the actual release of constituents in our weathering study. Samples highest in percent sulfur and NP released the highest concentrations of elements, including Fe, Al, and Mn, and Ca, which are primary elements of concern in acid mine drainage. Samples with lower sulfur and NP contents released lower quantities of TDS.

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LEACHING POTENTIALS OF COAL SPOIL: EFFECTS OF ROCK TYPE AND DEGREE OF WEATHERING[1]

Zenah Orndorff[2] and W. Lee Daniels

Abstract: Overburden in the Appalachian coalfields typically consists of interbedded sandstones, siltstones, and shales. These formations may exhibit considerable weathering at relatively shallow depths from the Earth's surface (<30m), appearing as friable brown materials. At greater depths, the majority of the overburden consists of gray unweathered rock. Differences inherent among these sedimentary rock types, such as grain size and mineralogy, in conjunction with degree of weathering, affect water quality as surface runoff or valley fill drainage. Of particular concern are the pH, total dissolved solids (TDS), and metal concentrations in valley fill discharges. The objective of this study was to evaluate pH, TDS elution (measured indirectly by electrical conductance/EC), and TDS composition over time using laboratory leaching columns for 55 diverse spoil materials from several locations throughout the Appalachian coalfields. The bulk raw spoil materials were typically near-neutral to alkaline with saturated paste pH values ranging from 4.5 – 8.5. Saturated paste EC was typically low (mean <1000 uS/cm), with values ranging from 200 – 3800 uS/cm. Most samples contained little or no $CaCO_3$ (as indicated by fizz test) and low total-S (< 0.25%), although a few samples contained up to 1.5% total-S. The spoil materials were leached in columns for 20 weeks (2 leaching events per week) under unsaturated conditions, and the leachates were analyzed for pH, EC, and several ions of concern. Leachate pH typically increased notably over the first few leach events, and most samples equilibrated at pH 7.5 – 8.5 within a month. For all rock types, weathered materials equilibrated at lower pH values (6.5 – 7.0) than their unweathered equivalents. Highly acidic leachate was observed only from black shale. For many samples, EC decreased notably over the first several leaching events, and achieved a relatively steady state within two months. Large initial EC decreases were more commonly observed for sandstone spoils than for finer textured materials. Sandstone spoils typically equilibrated at EC levels <500 uS/cm, while several siltstone/shale samples exceeded this level throughout the 20 week period. For all rock types, weathered materials equilibrated at lower EC values than their unweathered equivalents. The highest EC values were produced by black shales.

Additional Key Words: electrical conductivity, leachate, pH, overburden, total dissolved solids.

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TRANSITIONING FROM CLEAN WATER ACT NATIONWIDE PERMITTING TO INDIVIDUAL PERMITTING[1]

M.P. Owens[2] and C.K. Applegate

Abstract: The Clean Water Act Section 404 requires dredge and fill activities to waters of the United States (WUS) to be permitted through Nationwide Permits (NWP), general, or Individual Permit (IP) administered by the United States Army Corp of Engineers (USACE). Waters of the United States generally are defined as waters; including interstate wetlands, lakes, rivers, streams, impoundments, and their tributaries, which can be used for interstate commerce, recreation, or industrial purposes (United States Code of Federal Regulations Title 40 Section 230.3). Whether a WUS is regulated by the USACE is determined by conducting either a preliminary jurisdictional determination (PJD) or a formal jurisdictional determination. Surface coal mining operations in the Colorado Plateau may unavoidably impact regulated WUS, and the mine operators must decide what is the best permitting approach for their operation, either NWP or IP. BHP Navajo Coal Company was faced with such a permitting decision when its Navajo Mine NWP permit was up for renewal. BNCC reviewed both the jurisdictional determination and permitting options, and decided to utilize a PJD and transition from the NWP to a NWP Section 404 IP for its Navajo Mine operations. BNCC's decision was based on several factors including uncertainty around mining schedule, duration of the permitting process, pending regulatory changes, and streamlining its regulatory compliance and permitting process.

Additional Key Words: Waters of the United States, preliminary jurisdiction determination, jurisdiction determination, and dredge and fill impacts

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SEASONALITY OF IRON REMOVAL WITHIN THE INITIAL OXIDATION CELL OF A PASSIVE TREATMENT SYSTEM[1]

L.R. Oxenford and R. W. Nairn[2]

Abstract: Iron oxidation, hydrolysis and settling are key processes promoted in passive treatment systems to remove iron from influent abandoned mine drainage (AMD). For net alkaline mine waters, initial oxidation cells are typically used to remove and store large amounts of precipitated iron oxyhydroxides; regular monitoring of influent and effluent water quality is considered suitable to determine overall treatment effectiveness. However, detailed analyses of iron removal within specific spatial and depth zones of oxidation cells provide additional information about performance and functionality. The purpose of this study was to investigate iron removal in such a pond with increasing distance and depth from influent AMD (170±17 mg/L at 400-700 L/min flow) with respect to seasonality at the Tar Creek Superfund Site, Oklahoma. Progressive iron removal profiles were constructed via seasonal (January, April, July, and October) sample collection and measurements at 10 locations with increasing distance from the AMD source and three water depths (surface, 0.45 m, 0.9 m, 1.4 m from surface) over a three-year period (2009-2012) for a 0.4-ha U-shaped oxidation pond receiving ferruginous lead-zinc mine drainage. *In-situ* measurements included pH, temperature, specific conductance, dissolved oxygen, and oxidation-reduction potential; turbidity and total alkalinity were measured in the field and water samples were collected for laboratory determination of total and dissolved metals (EPA methods 3015 and 6010), and sulfate (EPA method 300) concentrations. Within the first year of operation, iron removal rates within the oxidation pond averaged approximately 80% (measured at effluent), yet ranged from a maximum of 96% (April 2010) to 43% (January 2010) seasonally. The implications of variability in seasonal iron removal profiles with respect to reporting oxidation cell performance in association with short-term (per sampling event) and long-term (three year study) passive treatment system operation significantly influences management decisions.

Additional Key Words: iron oxidation, lead-zinc mine drainage, net alkaline water, Mayer Ranch

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COAL COMBUSTION BY-PRODUCTS DISPOSAL PRACTICES AT A SURFACE COAL MINE IN NEW MEXICO: LEACHATE AND GROUNDWATER QUALITY STUDY

Cheryl Parker[2], Kara Hart, Ryan Webb, Bruce Thomson, John Stormont, and Mark Stone

Abstract: This study was conducted to determine what impact might occur from CCBs disposed of in an unlined surface coal mine in northwestern New Mexico. CCBs have been buried in this mine since about 1973 and include fly ash, bottom ash and sludge from the flue gas desulfurization process. The objective of this study was to characterize the leachate from fresh and aged CCBs, to investigate the geochemical transformations that occur with time in the buried CCBs, and to determine stratigraphy from monitoring wells to the CCBs.

Samples of CCBs ranging in age from fresh material from a nearby power plant to buried material that is over 30 years old were collected with direct push drilling (Geoprobe ®) and by sonic drilling. The samples were analyzed to determine their physical and hydrologic properties such as density, water content, hydraulic conductivity and soil moisture characteristic curves. Batch leaching tests and unsaturated column leach tests were conducted to determine leachate quality using different leach solutions. The mineralogical characteristics of the materials were determined by scanning electron microscopy (SEM) and X-ray diffraction (XRD).

Chemical analyses of deionized water extracts show elevated concentrations of barium and iron in the buried ash. Unburied ash leachate has higher concentrations of calcium, sodium and sulfate.

The composition of buried CCBs was correlated with depth to determine if it changes as the material ages. Barium and copper showed the largest increase as depth increases.

Mineralogical examination found signs of dissolution of sulfate minerals and silicate microspheres associated with fly ash., Older ash samples showed evidence of secondary mineralization resulting in formation of calcite, quartz and possibly the silicate mineral Mullite.

Columns of CCBs were subjected to leaching by de-ionized water and groundwater collected at the site from the coal seam. The columns were packed to approximately the same bulk density as the undisturbed material and one pore volume was passed through each column per day. The purpose of the columns was to determine the sequence of analytes appearing in the leachate. Leachate results displayed mineral dissolution with barium having the highest leachate concentration.

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A COMPARISON OF DIFFERENT VOLUMES OF BIOCHAR ON ACIDIC SOILS TO INCREASE PLANT GROWTH AND REDUCE SOIL ACIDITY[1]

C.D. Peltz[2]

Abstract: Soil acidity and toxic concentrations of heavy metals are an impediment to effective revegetation and phytostabilization of acid rock and mining affected sites. The carbon rich product of a pyrolysis reaction, biochar has been utilized as a soil amendment in mining affected soils at sites in Colorado, the U.K. and Spain achieving varying degrees of success in facilitating vegetation growth and soil pedogenesis. However, an open question remains regarding the optimal application rate needed to achieve plant germination and growth.

This study examined the effect of three different applications of biochar equivalent to 2.5, 4.7, and 6.5 tons/acre, on several multi-element polluted soils to determine the optimal biochar application rate to achieve greatest plant growth relative application rate. Trials involved a greenhouse study where replicate sets of multi-element polluted soils, biochar and a seed mix of grasses and forbs were placed in a controlled environment for 3 months with vegetation height and soil leachate pH measured weekly and above-ground biomass calculated upon completion.

Results indicate that the greatest overall increase in above ground biomass was achieved by a 4.7 tons/acre application rate. However, the greatest overall relative gain in biomass increase/ton-biochar was found at an application rate of 2.5 tons/acre. When results were separated in two soil pH classes (<pH 4 and >pH 4) the more acidic soils had a maximum relative gain of biomass at the 2.5 tons/acre application rate with the higher pH soils having maximum gain at the 4.7 tons/acre rate.

These results suggest that a biochar amendment on mining affected soils can increase above-ground biomass. However, a determination of optimal an application rates should be made prior to field application and will most likely depend upon the specific soil conditions of the site.

Additional Keywords: Biochar, Soil Remediation, Acidic Soils, Phytostabilization

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A COMBINATION OF ALUMINA REFINING RESIDUE (BAUXSOL ACID B EXTRA(™)) AND BIOCHAR TO REDUCE METAL CONCENTRATIONS IN ACID MINE DRAINAGE[1]

C.D. Peltz[2], C. Zillich, and K.L. Brown*

Abstract: Current acid mine drainage (AMD) treatment technologies, such as lime precipitation, are expensive to operate and often generate large residual waste streams with high disposal costs. Typical passive treatment systems, such as sulfate reducing bioreactors, often have a large footprint and are generally not suitable for high alpine environments. As part of the Abandoned Mine Lands (AML) Program the Bureau of Land Management (BLM) has built and is operating the Eveline Mine Drainage Treatment Vault near Silverton, Colorado to investigate innovative passive treatment technologies for AMD in high alpine environments.

In 2012 BLM explored the potential of combining Bauxsol Acid B Extra(™), a by-product from the alumina refining process, with three different matrix medias, Biochar, porous concrete, and pea gravel. The objective of the trials was to create a treatment system that (1) reduces metal concentrations in effluent waters, (2) reduces operational costs, and (3) does not create a residual, toxic product needing specialized disposal.

Field trials consisted of multiple column tests on continuous-flows of AMD from the Eveline mine. Field measurements of pH and hydraulic conductivity, and laboratory measurements of aqueous chemistry were taken at weekly intervals throughout the trial. Results suggest that the combination of Bauxsol Acid B Extra(™) (30%/vol) and Biochar (70%/vol) achieved optimal results with >95% removal of Cd, Cu, Fe, Mn, and Zn, and >60% removal of Al and Pb, while maintaining adequate hydraulic conductivity.

We conclude that the combination of a Biochar matrix media and Bauxsol Acid B Extra(™), has the potential to reduce metal concentrations in AMD in a passive treatment system while providing the added benefit of utilizing by-products and sequestering carbon in Biochar.

Additional Key Words: passive treatment, high alpine, Silverton, Colorado, porous concrete, pea gravel, metal concentrations, carbon sequestration, Bureau of Land Management

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CHANGES IN SPOIL ELECTRICAL CONDUCTIVITY (EC) AND SODIUM ADSORPTION RATIO (SAR) FOLLOWING IRRIGATION AT A MINE SITE IN NORTHWESTERN NEW MEXICO[1]

Steven Perkins[2], Kent Applegate, Brent Musslewhite, Bruce Buchanan, and Terry H. Brown

Abstract: Successful mine land reclamation is contingent upon a suitable soil/spoil substrate with physicochemical characteristics conducive to vegetation establishment. The objective of this study was to evaluate changes in spoil salinity and sodicity following irrigation to determine if spoil initially unsuitable for vegetation establishment due to EC and SAR characteristics would become suitable following irrigation. In February 2006, a survey was conducted at Navajo Mine in Northwestern New Mexico to determine if the characteristics of recently placed spoil were suitable for vegetation establishment. Results of the survey revealed that 60% of the area was unsuitable according to the Hanson Diagram. In September and October 2006, a subset of 34 sites was sampled from the February sampling area. The sampling involved the collection of 10 cm of topsoil above the topsoil-spoil contact and the collection of spoil material from 0 to 15 cm, 30 to 60 cm, and 60 to 90 cm below the topsoil-spoil contact. At each of the 34 sampling sites, soil moisture monitoring equipment and precipitation gauges were installed. Soil moisture was monitored weekly during the growing season and monthly thereafter. In the spring of 2007, the study area was seeded, mulched, and irrigated. Irrigation was applied during the growing seasons of 2007 and 2008. Topsoil and spoil were re-sampled in the fall of 2008 following the same procedures used in the fall of 2006. Between February 2006 and September-October 2006, changes in EC and SAR were documented that resulted in only 6% of the sites being classified as unsuitable in the 0 to 15 cm layer according to the Hanson Diagram. By the end of the study in 2008, EC-SAR relationships had further improved, and none of the 34 sampling sites were classified as unsuitable in the 0 to 15 cm layer. Results of the study indicate that spoil that may initially be unsuitable for vegetation establishment may become more suitable over time and in response to irrigation.

Additional Key Words: Hanson Diagram, Reclamation, Revegetation

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RESTORING REMNANT HARDWOOD FOREST IMPACTED BY INVASIVE TREE-OF-HEAVEN *(AILANTHUS ALTISSIMA)*[1]

C. M. Peugh[2], J.M. Bauman, and S. M. Byrd

Abstract: Tree-of-heaven (*Ailanthus altissima)* is a fast growing tree native to China. Introduced as an ornamental plant, *A. altissima* has spread throughout North American landscapes, imposing a threat to the biodiversity of native ecosystems. Recommended control methods include basal bark treatments using herbicide with an oil-based carrier around the base of *Ailanthus* stems. Land managers value application methods that maximize efficiency while also reducing environmental impacts when applied over landscape scales. The focus of this study was to assess the efficiency of herbicide concentrations and carriers on the mortality of *A. altissima.* This study was conducted in a 105 hectare hardwood forest at *the Wilds* Conservation Center in Cumberland, Ohio. The forest is directly adjacent to areas mined for coal and reclaimed in the 1980s. Twenty-five plots were established consisting of 732 target trees. Two carriers (AX-IT™ basal oil and diesel fuel) mixed with Garlon® 4 Ultra herbicide were tested at two different concentrations: 1) 10% Garlon® in 90% diesel fuel carrier, 2) 20% Garlon® with 80% diesel carrier, 3) 10% Garlon® with 90% AX-IT™ carrier, and 4) 20% Garlon® with 80% AX-IT™ carrier. Basal bark treatments were applied using a backpack sprayer. After one year, treatments were similar (89-100% mortality) with one exception; the 10% Garlon® in 90% diesel treatment was least effective (69% mortality; $P < 0.0001$). This was more apparent as the DBH increased ($P < 0.0001$). When canopy dieback was compared across treatments, AX-IT™ basal oil remained more effective regardless of the DBH or concentration. Cost comparisons show 10% Garlon® solution in AX-IT™ oil base can be the most economically and ecologically beneficial treatment when applied on a large scale. Long-term monitoring will determine the occurrence of re-sprouts (via seed and root sprouting) and the impact each treatment has on the plant communities within this forest system.

Additional Key Words: Garlon® 4 Ultra, triclopyr, diesel fuel, AX-IT™ basal oil, basal spray, invasive species, herbicide control, allelopathy.

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GREATER SAGE-GROUSE RESPONSE TO BENTONITE MINING IN THE BIGHORN BASIN, WYOMING[1]

A.C. Pratt[2] and J.L. Beck

Abstract: Wyoming contains 70% of the world's bentonite clay deposits, and mines in the Bighorn Basin produce >50% of Wyoming's annual supply. Bentonite is extracted by open-pit mining that leads to disturbance, fragmentation, and loss of sagebrush habitat. These activities may prevent or limit the ability of the sagebrush landscape to provide the space and resources to meet the life history requirements of greater sage-grouse (*Centrocercus urophasianus*). Plans call for mining to increase in sagebrush communities; therefore, our primary study objective is to monitor (for 3 years; 2011–2013) the demographic rates and habitat selection patterns of greater sage-grouse in an area with bentonite mining compared to a reference area without mining. We are monitoring female survival, nest success, and brood survival with radio telemetry. For males, we are attaching bands to estimate survival using mark-recapture techniques. To help guide mining reclamation we are sampling vegetation in microhabitat plots at nests, early-brood (0–5 weeks) locations, and at paired random locations. Preliminary observations during 2011–2012 have revealed some differences in demographic rates and habitat selection between study areas, though not necessarily consistent between different seasons and years. In the future we will evaluate habitat selection at the landscape scale and compare demographic rates of grouse relative to their exposure to mining. We will also experiment with using genetic markers in feathers collected from leks to estimate male survival using mark-recapture models. Our results will help industry and agencies better conserve habitat for sage-grouse in the Bighorn Basin and in areas undergoing bentonite mining.

Additional Key Words: brood, demographic rates, habitat selection, nest, survival

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FITNESS MORE THAN DIVERSITY GUIDES VEGETATIONAL RECOVERY[1]

R. A. Prodgers[2]

Abstract. Three case studies document vegetational recovery that hinged on a single species. Unassisted improvement of cheatgrass-infested revegetation at the Decker Coal Mine (DCM) in southeast Montana hinges upon a single grass, a single cultivar: *Rosana* western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love). Species groupings, or guilds such as "native perennial grasses" or even "cool-season rhizomatous grasses," fail to capture the species-specific nature of the recovery process, in which diversity plays no role. Numerous fields seeded between 1999 and 2002 failed to qualify for Phase 2 bond release, which requires effective seeding, but a sprinkling of seeds established. Years of revegetation-monitoring reports documented sporadic improvement but emphasized the prevalence of annual bromes. Then, in a few short years, incremental improvement was replaced by full-blown transformation. Most of those seedings qualified for Phase 2 bond release for the first time in 2010 because western wheatgrass replaced annual introduced bromes. While present, bunchgrasses (e.g., green needlegrass), sod-formers (e.g., blue grama), and shrubs (e.g., big sagebrush) played no such role. Due to individualistic species responses to environmental conditions (Prodgers, 1988), a dynamic equilibrium is assured, and field appearance will vary through time, but about one decade after seeding, western wheatgrass had supplanted cheatgrass on more than 250 hectares. Western wheatgrass also is pioneering the recovery process on some land at a Clark Fork River Superfund site that was contaminated by heavy metals in irrigation water. In another case study, another strongly rhizomatous grass, this one naturalized (*Agrostis stolonifera* L.), is playing much the same role in smelter-contaminated uplands (historic SO_2 fumigation and heavy metal deposition) near Anaconda, Montana. While a variety of adapted taxa may be desirable, the fitness of a single linchpin species can be far more instrumental in vegetational recovery than a collection of also-rans. That effective taxon may have originated locally or an ocean away.

Additional Key Words: vegetative spread, cheatgrass, western wheatgrass, rhizomes, habitat, adaptations, vegetational development.

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EFFECTIVENESS OF COMMERCIAL COMPOST SOIL AMENDMENT IN MONTANA UPLAND AND RIPARIAN REVEGETATION[1]

R. A. Prodgers[2]

Abstract. When using borrow dirt as cover-soil, revegetation often stagnates or declines in one decade or less, especially in cold, semiarid climates, due to infertility and lack of nutrient cycling. Fresh cover-soil is dirt; *soil* is distinguished by the organisms living in and on it. Compost amendment is intended to speed the conversion of dirt to soil by initiating an incipient soil food web. Compost provides microorganisms capable of degrading a wide variety of organic substances and the carbon and nutrients to sustain them until vascular plants provide fresh substrates and eventually a diverse array of food sources from root exudates to microbial cells. Or so it was thought when the two reclamation projects discussed in this paper began, one a Superfund remediation on Silver Bow Creek and the other waste dump reclamation at the Golden Sunlight Mine. The two projects are on opposite sides of the Continental Divide in southwest Montana. Applying and incorporating compost along Silver Bow Creek was easy; steep slopes at the gold mine limited both application and incorporation. One decade after seeding, microbiological analyses of composted and uncomposted soils failed to demonstrate greater diversity in composted cover-soils at the riparian Superfund site. Neither were short-term microbiological effects of compost amendment detectable at the hard-rock mine. Vascular plant cover likewise did not show a significant difference between composted and uncomposted treatments at the riparian site. This raises the question of whether introduced soil microbes drive revegetation or vice-versa, the vascular plants lead and soil microbiology follows. Soil biology may be one aspect of the recovery process that cannot be expedited using biologically active organic amendment. Thermophilic microorganisms in compost simply may not survive in soils that dry and freeze, or the microbiological activity that matters may be restricted to the rhizosphere. Speccing compost also is discussed.

Additional Key Words: nutrient cycling, soil microbiology, microbial diversity, compost specifications, reverse fertilization.

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TEN YEARS AFTER: THE OPERATION OF THE LUTTRELL BIOCHEMICAL REACTOR[1]

David J. Reisman[2]. Angela K. Frandsen, and David T. Shanight

Abstract: One of the remaining issues regarding biochemical reactors (BCRs) for use in treating mining-influenced water is the longevity of these solid substrate treatment systems and continuous high metal removal efficiency (MRE). Previous papers have predicted the demise of these systems after a few years of treatment as the carbon source for the bacteria is exhausted, or is in the wrong form to sustain the sulfate-reducing bacteria. Other systems have failed for numerous reasons including clogging and plumbing problems which inhibit BCR circulation, while other reactors only partially function with reduced metal precipitation and are in need of repair. The Luttrell BCR is located at a remote location at an altitude of ~7,800 feet (~2377 m) above mean sea level in the Upper Tenmile Mining District near Helena, Montana. This BCR treats leachate from a joint federal repository being filled with mining impacted materials from the Upper Tenmile and Basin Creek superfund sites. This paper presents BCR analytical data that spans almost 10 years, documenting a period in which metal removal efficiencies for contaminants of concern are usually 98 % or higher. The current BCR pilot operation is pre-treatment in a mixed passive-active system where its utilization reduces operational MIW treatment expenses.

Additional Key Words: MIW, acid mine drainage, AMD, sulfate-reducing bacteria, BCR, SRB, mine water treatment, passive treatment, chemical precipitation.

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REHABILITATION OF IRONSTONES OUTCROPS DEGRADED BY IRON MINNING ACTIVITY IN MINAS GERAIS STATE-BRAZIL[1]

Lina A. Lobo de Rezende[2], Luiz E. Dias, Igor R. de Assis, Ramon Braga

Abstract: The properties of the soils and underlying substrates of “canga” (ironstones outcrops) in central Brazil have a number of restrictions for the establishment of plant species and the high specialization of local vegetation contributes to a high rate of endemic adaptations. The close association between the mining of iron and the need for locally adapted vegetation presents a special condition of vulnerability. This study evaluated varied approaches to the rehabilitation "canga" fields considering technical and economic aspects related to the application of topsoil, re-introduction of plants from local sources and their regeneration. We set up a field experiment on one overburden pile of Capão Xavier iron mine (mined by the Vale Company), composed by eight treatments formed from combinations of two thicknesses of “canga” and associated salvaged soils (20 and 40 cm) and four levels of fertilization. In each plot, we planted the same number of seedlings following the same spatial arrangement. The evaluation of the treatments was made at 10 and 42 months after planting for survival of the planted species. There was no significant difference among the average survival of seedlings planted for the different thicknesses of substrate and fertilization levels. The development of programs for ecological restoration of ferruginous fields should therefore consider, among other factors, the complex soil x vegetation mosaic commonly found in natural settings and thus carry out the "canga" material soil reconstruction sequence in order to reproduce this scenario. Furthermore, in view of the possible reduction in the number of plant individuals over time, there must be a satisfactory amount of individual species selected for reintroduction.

Additional Key Words: revegetation, ecological reclamation.

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FOLIAR COVER AND CANOPY COVER RELATIONSHIPS ON THE GOATHILL SUBSIDENCE IN QUESTA NM[1]

Trace Richardson[2], Mark Heil, Bruce A. Buchanan, Derek Heafey

Abstract: In 2012, a forest inventory was conducted to determine how vegetation was responding to subsidence at the Chevron Mining Inc., Questa New Mexico. The objective of this study was to explore the relationship between foliar cover and canopy cover. The study site is comprised of 30 random points within the 29 hectares of the Goathill subsidence portion of the mine. Foliar cover and canopy cover was derived at each of the sites, where three 20 meter transects spaced 5 meters apart, were read at 1 meter gap intervals. Foliar cover, the dependent variable, was determined from gap interval readings, with a .5m by 1m quadrate along the 20 meter transects. Canopy cover, the independent variable, was derived at the same corresponding locations using a densitometer. The Foliar data collected was comprised of a combination of shrub and herbaceous cover. Shrub and herbaceous cover were also explored independently. The analysis conducted determined that there is no relationship between shrub cover and canopy cover. Additionally, the analysis determined that there is an inverse relationship between herbaceous cover and canopy cover with a coefficient value of -0.08, an r-squared value of 0.17, and a p-value of 0.02. The analysis found that there is no significant relationship between foliar cover canopy cover. The data tested implies that canopy cover has a significant inverse relationship to herbaceous cover. However, this relationship was shown to be minimal, explaining only 17% of the variability occurring within herbaceous cover. Although this relationship is meaningful, it is improbable that canopy cover is the primary factor for causing herbaceous cover variability. There are likely several other environmental factors causing the remainder of variability in herbaceous cover.

Additional Key Words: vegetation, densitometer, coefficient value, transect data, herbaceous cover, mine subsidence, regression

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LEAST LIMITING WATER RANGE OF A WASTE OF LAUNDERING BAUXITE AFTER ELEVEN YEARS REVEGETATED[1]

G.C. Rocha[2]; L.A. de O.P. Guimarães; L.E. Dias; I.R. de Assis; S.M. de Faria; L.C. Lemos Neto; and J. Carvalho

Abstract: The washing process from bauxite ore results in production of large quantities of waste. Physical transformations of tailings over time are attributed to organic matter dynamics, the activity of microorganisms, the release of exudates by roots and microbial activity and root growth, factors involved in the structural quality of the waste and that occur at different intensities depending on the doses of fertilizer and lime. Our objective was to study the Least Limiting Water Range (LLWR) of a substrate formed by deposition of tailings bauxite beneficiation after a decade of revegetation. After ten years, the planting of seedlings and application of lime and fertilizers resulted in improvement of the physical attributes of the substrate by offering greater biomass production. The LLWR showed that the waste received planting seedlings and larger doses of fertilizer and lime was less limiting to plant growth, despite showing a narrow LLWR compared with agricultural soils. The value of penetration resistance used in calculating the LLWR (3.5 MPa) was adequate for the type of substrate studied. It is recommended that this value be used not only for substrates formed from waste from bauxite processing, but for areas in process of environmental recovery. A visual evaluation of the study area showed that the plots that received the highest doses of fertilizer and lime and planting seedlings have higher vegetation density and volume of litter, although the assessment of biomass has not been implemented in this study. The LLWR proved to be a sensitive indicator to changes in the physical attributes of the substrates. Therefore, it is an important indicator to evaluate the environmental recovery process, the improvement of soil physical conditions and the sustainability of the process.

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GENETIC DIVERSITY OF BROOK TROUT POPULATIONS IN SEVERAL SUB-WATERSHEDS OF THE WEST BRANCH SUSQUEHANNA RIVER WATERSHED[1]

Shawn M. Rummel[2] and Fred J. Brenner

Abstract: The West Branch Susquehanna River watershed is located in northcentral Pennsylvania. The watershed contains some of the most pristine brook trout (*Salvelinus fontinalis*) habitat in Pennsylvania. However, water quality issues such as abandoned mine drainage (AMD) and acid deposition have contributed to the decline of brook trout in the watershed. Over 20% (1,200 stream miles) of the watershed is impaired by AMD alone. One of the negative consequences of AMD in the watershed is the isolation of brook trout populations and the loss of genetic diversity in these populations. The purpose of this study is to evaluate the genetic diversity of brook trout populations in the West Branch Susquehanna River watershed in Pennsylvania. As part of an ongoing study to locate and evaluate natural re-producing brook trout populations, fin samples were collected and preserved in 70% ethanol for genetic studies of these isolated populations. Results to date indicate that distinct material linages occur in each of these populations suggesting that genetic bottlenecks may exist in these isolated populations. The results of this study will aid management decisions for reconnecting and re-establishing populations of wild brook trout throughout the West Branch Susquehanna River watershed.

Additional Key Words: Water Quality, Abandoned Mine Drainage, Acid Deposition

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SOIL AMENDMENT APPLICATION DURING DROUGHT ON OIL AND GAS SITES IN WYOMING[1]

Brenda Schladweiler[2]

Abstract: Oil and gas development often forms a network of pad, pipeline, and right-of-way disturbances across a landscape. These disturbances are sometimes located on challenging ecological sites for successful reclamation which can be exacerbated during drought periods. These site-specific challenges include extreme soil textures such as clay and sand, as well as chemical issues such as high salinity or sodicity.

Application of soil amendments on oil and gas sites in Wyoming to ameliorate, not only the effects of the physical or chemical issue in the growth medium, but also the impact of drought will be discussed.

Additional Key Words: pads, pipelines, right-of-way, physical, chemical, reclamation

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LONG-TERM COMPARISON OF VEGETATION REFERENCE AREA ON RECLAIMED COAL MINES IN NORTHEASTERN WYOMING[1]

Brenda Schladweiler[2]

Abstract: Baseline vegetation studies have been conducted as part of regulatory permitting requirements for coal mines in northeastern Wyoming since the implementation of requirements from the 1977 Surface Mining Control and Reclamation Act (SMCRA). Vegetation reference areas, control areas, and extended reference areas have been utilized to compare lands within a portion of the mine permit area to be disturbed to those that will likely not be disturbed over the life of the mine. If reference/control areas were not selected prior to disturbance, comparison areas representative of lands that were disturbed are selected post-disturbance; however, the use of this concept is generally limited to non-coal mines in Wyoming.

Depending on the number of baseline studies or sampling programs of reference/control areas associated with interim vegetation monitoring, several years of data are available within coal mines in northeastern Wyoming. The difficulty in comparison of reference/control area data between all coal mines in northeastern Wyoming is variation in vegetation mapping and sampling methodology. Within a given mine, differences between years may vary on the sampling pool, i.e., established reference/control area vs. a newly established reference/control area due to loss of a previously established area from mining operations or if a mine has switched to an extended reference area approach.

Several years of baseline data within reference/control areas are compared for selected coal mines in northeastern Wyoming. Results will be presented.

Additional Key Words: monitoring, reclamation

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EFFECT OF SPOIL TYPE ON THE CHEMICAL AND HYDROLOGIC PROFILES OF EXPERIMENTAL MINE REFORESTATION PLOTS IN EASTERN KENTUCKY[1]

Kenton Sena[2], Christopher Barton, Carmen Agouridis and Richard Warner

Abstract: Mountaintop removal mining has often been linked to flooding and contamination of local headwater streams. It has been speculated that forest loss and grassland reclamation contribute to these issues, but little data is available to support these claims. A series of experimental plots was installed in 2005 on a reclaimed mine site in eastern Kentucky to examine the influence of reforestation and spoil type (gray sandstone, brown sandstone, mixed sandstone/shale) on water quality and quantity. Two years after installation, researchers concluded that water chemistry improved in all spoil types over time, but the brown sandstone treatment exhibited the lowest concentrations of dissolved constituents. Initial hydrologic analysis did not show differences between treatments. In 2012, vegetation differences between treatments are obvious with brown sandstone exhibiting higher tree volume and canopy cover. Water quality analyses suggest that all spoil types have reached a more steady-state discharge pattern and brown sandstone plots continue to exhibit lower dissolved solid concentrations. Brown sandstone plots also exhibit a lower volume of discharge water than the other treatments, which is likely due to enhanced evapotranspiration.

Additional Key Words: water quality, water use, reforestation, spoil type.

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FIELD TRIAL OF A PULSED LIMESTONE DIVERSION WELL[1]

P. L. Sibrell[2], C. Denholm and M. Dunn

Abstract: The use of limestone diversion wells to treat acid mine drainage (AMD) is well-known, but in many cases, acid neutralization is not as complete as would be desired. Reasons for this include channeling of the water through the limestone bed, and the slow reaction rate of the limestone gravel. A new approach to improve the performance of the diversion well was tested in the field at the Jennings Environmental Education Center, near Slippery Rock, PA. In this approach, a finer size distribution of limestone was used so as to allow fluidization of the limestone bed, thus eliminating channeling and increasing particle surface area for faster reaction rates. Also, water flow was regulated through the use of a dosing siphon, so that consistent fluidization of the limestone sand could be achieved. Testing began late in the summer of 2010, and continued through November of 2011. Initial system performance during the 2010 field season was good, with the production of net alkaline water, but hydraulic problems involving air release and limestone sand retention were observed. In the summer of 2011, a finer size of limestone sand was procured for use in the system. This material fluidized more readily, but acid neutralization tapered off after several days. Subsequent observations indicated that the hydraulics of the system was compromised by the formation of iron oxides in the pipe leading to the limestone bed, which affected water distribution and flow through the bed. Although results from the field trial were mixed, it is believed that without the formation of iron oxides and plugging of the pipe, better acid neutralization and treatment would have occurred. Further tests are being considered using a different hydraulic configuration for the limestone sand fluidized bed.

Additional Key Words: acid mine drainage; water treatment; passive treatment

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RECLAMATION OF MINED LAND WITH SWITCHGRASS, MISCANTHUS, AND ARUNDO FOR BIOFUEL PRODUCTION[1]

Jeff Skousen,[2] Travis Keene, Mike Marra, and Brady Gutta

Abstract: Use of biomass to supplement the nation's energy needs for ethanol production and green fuel for power plants has created a demand for growing reliable feedstocks. Switchgrass (*Panicum virgatum* L.), miscanthus (*Miscanthus x giganteus)*, and giant cane (*Arundo donax* L.) are possible biofuel crops because they produce large amounts of biomass over a wide range of growing conditions, including marginal and reclaimed land. West Virginia's climate and large acreage of available reclaimed mine land provide a land base to generate high amounts of biomass for a biofuel industry. The purpose of this study was to determine the yield of three biomass crops on reclaimed mined land in central West Virginia. A 25-year-old reclaimed site near Alton, WV, was prepared using herbicides to eliminate all existing cool-season vegetation on a 5-ha area. Twenty-three plots of 0.4-ha were established. Mine soil samples showed an average pH of 7.5 and adequate supplies of plant nutrients. Two switchgrass varieties (Kanlow and BoMaster) were randomly assigned to 10 plots (five replications) and seeds were drilled into the killed sod at a rate of 11 kg ha^{-1}. Two types of miscanthus (a sterile public clonal variety and a sterile private variety) were randomly assigned to 10 plots and planted with seedling plugs on 0.8-m centers. Giant cane was assigned to three plots and rhizomes were planted on 1.5-m centers. Yield measurements were taken in September the second and third years after planting. Yields for Kanlow switchgrass varied from an average of 4,040 kg ha^{-1} in 2011 to 4,887 kg ha^{-1} in 2012. BoMaster switchgrass was lower at 2,750 kg ha^{-1} in 2011 and 3,981 kg ha^{-1} in 2012. The public variety of miscanthus showed yields 7,500 kg ha^{-1} in 2011, but decreased to an average of 4,905 kg ha^{-1} in 2012. The private miscanthus variety was much greater at 21,880 kg ha^{-1} in 2011, and 15,467 kg ha^{-1} in 2012. Giant cane yields were low with an average yield of 515 kg ha^{-1} in 2012. Survival and growth of giant cane was hindered by weed competition. Target yields for reclaimed lands, as established by the WV Department of Environmental Protection, of 5,000 kg ha^{-1} for switchgrass and 15,000 kg ha^{-1} for miscanthus were not attained with switchgrass and the public variety of miscanthus, but was achieved with the private variety of miscanthus. More time may be needed for these yield goals to be achieved as stands continue to develop over time.

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BENCH-SCALE TREATABILITY TESTING FOR *IN SITU* BIOREMEDIATION OF MINING-INFLUENCED WATER[1]

N.T. Smith[2], N.A. Anton, D.J. Reisman, M.R. Nelson, A.K. Frandsen, R.L. Olsen, W.A. Rosche

Abstract: CDM Smith is completing an in-house bench-scale treatability study for bioremediation of mining-influenced water (MIW), with the eventual goal of completing *in situ* treatment of MIW within abandoned mine workings and groundwater systems. The use of passive or semi-passive treatment (*ex situ* biochemical reactors and wetlands) has received increasing attention over the past decade as a method for remediating MIW, which impacts surface water and groundwater worldwide. However, these methods, while sometimes more cost-effective than active treatment (such as treatment through the addition of hydrated lime), may have limited applicability due to space requirements, flow rates, and seasonality of MIW discharge. *In situ* application of MIW bioremediation has the potential to significantly decrease the amount of space required, treats the contaminant source, minimizes issues with armoring, and alleviates the issue of fluctuating flow that can cause problems for *ex situ* systems. CDM Smith is completing initial treatability testing for three MIW types: two strongly-acidic, high-metal content MIWs, and one near-neutral, moderate metal content MIW. These three MIWs are being tested with seven combinations of readily-attainable, injectable carbon sources: ethanol, polyethylene glycol (antifreeze), beer, ChitoRem®, and methanol (two concentrations of ethanol and antifreeze each). The acidic waters were first incubated with the site soils overnight, and then pretreated in the bottles using sodium hydroxide to elevate the pH to approximately 4.5. The bottles contain approximately 2.5 liters of MIW, 100 grams of site soils, inert media (sand), water incubated with horse manure, and one of the carbon sources. Laboratory measurements of pH, redox, conductivity, dissolved oxygen, ferrous iron, and alkalinity were measured periodically. Results of the testing will be presented, including metal removal, water chemistry, and population characteristics of sulfate-reducing bacteria.

Additional Key Words: SRB

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GEOMORPHIC RECLAMATION OF ABANDONED COAL MINES NEAR RATON, NEW MEXICO DESIGN AND CONSTRUCTION OVERSIGHT[1]

R. Spotts[2], M. Brennan, R. Wade, K.J. Malers, K.E. Carlson and Z. Isaacson

Abstract. In order to address hazards and environmental detriments associated with historic coal mining, the New Mexico Abandoned Mine Land Program contracted with Water & Earth Technologies, Inc. Construction for the Swastika Mine and Dutchman Canyon Reclamation Project took place over a six-month period in 2012. The geomorphic reclamation approach coupled hydrologic and hydraulic engineering analyses with geomorphic design tools to stabilize and reclaim the significantly altered landscape. Coal waste piles, a straightened and incised half-mile-long reach of the Dillon Canyon stream channel, and existing wetland features proved to be challenging design elements of this award winning project. The geomorphic landform accommodated nearly 200,000 cubic yards of coal waste that had been abandoned in unstable piles that were degrading the adjacent stream physically and chemically. The stream reconstruction restored meanders and a functional floodplain to the impaired system. In Dutchman Canyon, road and embankment improvements were designed to allow seepage from closed mine adits to hydrate a constructed salt-tolerant wetland.

In addition to the geomorphic landform and the sinuous stream, a realigned access road was constructed through the narrow valley. Valuable ecological and cultural features including mature trees, wetland areas, utility poles and over two hundred identified archaeological features were preserved. Geomorphic designs were modified as required during construction to accommodate additional archeological discoveries. Geomorphic design was accomplished using Natural Regrade with Geofluv™ to incorporate stable drainage and topographic variety into the reconstructed stream and landform. The design used geomorphic criteria developed from measurements of nearby, undisturbed portions of the valley, mimicking stable landforms and stream characteristics that have developed naturally in response to the topographic relief, soils, vegetation and climate in the project area. The project created an aesthetically pleasing valley with an ecologically rich riparian corridor integrated into a stable landform composed of reclaimed coal waste.

Additional Key Words: Geomorphic Reconstruction, Stream Reconstruction, Mine Reclamation, GeoRiparian Restoration

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EFFECTIVENESS OF MECHANICAL THINNING FOR INCREASING MULE DEER FORAGE IN AN OIL AND GAS DEVELOPMENT REGION[1]

Garrett J. Stephens[2], Mark W. Paschke, and Danielle Bilyeu Johnston

Abstract: Declining Colorado mule deer (*Odocoileus hemionus*) populations have necessitated improved habitat management techniques. In particular, oil and gas development in the Piceance Basin of western Colorado has impacted critical winter range, creating a need for treatments which will increase forage. Pinyon-juniper tree removal is one such treatment, but the best method of tree removal is unclear. Here, we quantify understory responses to pinyon-juniper removal by three different methods: hydro-axing, chaining, and roller-chopping. Twenty-one 0.8 ha plots were treated during the fall of 2011, 7 of each thinning type. Half of each plot was seeded prior to mechanical treatment with a native mix of grasses, shrubs, and forbs. The project targets these main questions: Does mechanical thinning increase forage biomass? Which treatment is most effective? Is seeding in conjunction with thinning necessary for increasing forage biomass? Understory plant data were collected during the summer of 2012 and will be resampled again in 2013. Despite extreme drought conditions during 2012, a seeding effect was seen in annual plant biomass. We observed greater grass biomass in chaining treatments relative to rollerchopping and hydro-axing treatments. This was likely the result of the chaining treatment being less destructive to existing vegetation relative to the other treatments.

Additional Key Words: mastication, restoration, Piceance Basin, pinyon-juniper woodlands

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RECLAIMING MINE LANDS WITH CATTLE GRAZING ON A SOUTHEASTERN ARIZONA MINE SITE[1]

S. Stone[2] and J. Fehmi

Abstract: There has been debate regarding the use of grazing as a tool in ecosystem restoration. Grazing can introduce substantial changes to grassland ecosystems, as grazing affects the structure, function, biotic, and abiotic conditions of the area. Thus, grazing may increase soil compaction and deformation, reduce plant density and biodiversity, and increase runoff and soil erosion. Many of these impacts occur under heavy grazing conditions. Some argue that adaptive grazing management may help to improve biotic and abiotic conditions at a degraded site. Low-intensity, short-duration grazing may increase production of some grasses, enhance the incorporation of litter into the soil, and improve soil fertility. This study aims to improve our understanding of these processes on a severely disturbed mine land. We introduced cattle grazing to an existing reclamation experiment at the Rosemont Copper property in southeastern Arizona. There are two test sites at differing elevations, each containing twenty-four plots (which comprise differing experimental treatments) that were broadcast-seeded with ten native desert grassland species. The cattle were introduced after the winter growing seasons and were managed for short-term, low-intensity grazing on each site. Within each plot, we constructed enclosures to restrict the impact of grazing to a defined area. We then evaluated the differences in vegetative response, macronutrient loads, microbial communities, and slope stability between the grazed and un-grazed areas. Our results may provide a novel reference for the use of grazing as a tool in other desert grassland and mine land reclamation projects. Preliminary results indicate that across experimental treatments, low-intensity, short-duration grazing does not significantly impact seeded grass biomass/density, forb and volunteer species biomass/density, or species diversity; indicating that adaptive grazing may be used to import nutrients to the system without negatively impacting the structure of the plant community on degraded mine sites.

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EVALUATION OF GEOMORPHIC RECLAMATION PERFORMANCE AND MODELS IN THE SOUTHWESTERN UNITED STATES[1]

M. Stone[2], J. Stormont, E. Epp, C. Byrne, S. Rahman, R. Powell, W. Rider, and S. Perkins

Abstract: The objectives of this study are to assess the performance of geomorphic reclamation in the southwestern United States; analyze the effectiveness of the Water Erosion Prediction Project (WEPP) and Soil, Erosion, Discharge by Computer Aided Design (SEDCAD) models in describing watershed processes on geomorphically reclaimed land; and model watershed response to land cover change, climate change, and wildfire. The implementation of geomorphic reclamation is based on the idea that natural landscapes most often evolve over long periods of time under localized conditions. This creates a natural system that minimizes the impact of storm events. In its design, geomorphic reclamation formations are intended to mimic the surrounding natural systems and provide stability to a reclaimed landscape that traditional reclamation does not. This two-year study is being conducted at La Plata Mine in northwestern New Mexico with funding from the Office of Surface Mining. The study provides a unique opportunity for researchers from the University of New Mexico to work in partnership with industry personnel from BHP-Billiton - San Juan Coal Company. The study involves the monitoring and modeling of three catchments: two reclaimed watersheds and one natural watershed adjacent to the reclamation area. Monitoring and modeling of the sites has begun and performance of the La Plata reclamation is being assessed. Catchment basins and v-notch weirs have been installed on or near the sites to measure sediment yield and runoff volumes, respectively. Analysis of the watershed modeling will provide insight into the benefits modeling can have on geomorphic reclamation in the future.

Additional Key Words: sediment yields, process models

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COMPOST RATES FOR REMEDIATING RECLAIMED SALINE SOILS[1]

Calvin Strom[2]

Abstract: Reclaimed soils in the Continental Divide-Creston Junction gas field in southwestern Wyoming present many challenges for reclamationists. Crusting of the soil surface is a common occurrence that limits seedling emergence, which inhibits successful reclamation of these pads. The Wyoming Reclamation and Restoration Center partnered with BP Wamsutter operations center and KC Harvey to examine the effects of municipal solid waste compost (MSC) on soil crusting. Latham Draw 29-2 well pad was selected for the trial. The well pad was divided into four 25-meter strips from north to south. The compost was spread at three rates (26.32, 16.87, 8.4 MT/ha) across the pad.

Soil samples were collected in each grid prior to MSC application. The samples were sent to the lab to determine electrical conductivity (EC), pH, and organic matter (OM) content. The site was seeded in the early March with a mix of forbs and shrubs. Soil crust measurements and soil samples were collected again in July. The soil EC in band 4 pre-compost was 8.4 DS/M; the EC post-compost averaged 4.2 DS/M. Crust thickness in band 4 at the high rate averaged 0.81mm, medium rate 1.78mm, low rate 1.93mm thick and the control was 2.08mm. The EC dropped to an average of 4.22 DS/M and crust thickness was reduced 61% at the high application rate of compost. Other soil properties examined were not significantly impacted (Organic Matter, Microbial biomass) by the addition of compost.

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CASE STUDY: UTILIZING PASTE TECHNOLOGY FOR RECLAMATION OF THE UTE ULAY UPPER TAILINGS IMPOUNDMENTS, LAKE CITY, COLORADO

Tara Tafi[2] and David Lazorchak

Abstract: The Ute Ulay Mining complex, located approximately five miles west of Lake City, Colorado, is an inactive gold, silver, and zinc mining/milling operation that operated from the 1880's until the 1970's, and sporadically into the mid 1990's. During operation, milled tailings were pumped upstream from the mine/mill site in a sluice box and deposited into five tailings impoundments. The tailings impoundments comprised 9,000 yd^3 on 6 acres of public lands managed by the Bureau of Land Management (BLM). Prior to reclamation, windblown tailings from the impoundments exposed the public to potentially harmful dust, the tailings from the lowest pond washed into Henson Creek during high flow, and zinc, lead and cadmium leached into groundwater through the unlined tailings ponds. An additional 4,000 yd^3 of mine and mill wastes from three other BLM sites located along Henson Creek had previously been hauled to the site, and were incorporated into this project. Reclamation of the approximately 13,000 yd^3 of mine and mill waste materials was completed using paste technology. All waste materials were screened and separated on-site, and the fine-grained waste materials were mixed with cement and water to form the paste. The repository was constructed using a layered design, with paste forming the base and cap, and coarse waste materials placed as a middle layer within the enclosing paste. Following repository completion, the site was graded, channels were constructed, groundwater monitoring wells were installed, and six acres were revegetated. Reclamation was completed in October, 2009, with maintenance in 2011. Following three growing seasons, the vegetation community is healthy, with minimal weedy species, and no noxious weeds. The water quality in Henson Creek indicates a slight reduction in zinc and cadmium levels, and metals levels in the groundwater have significantly declined.

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PASSIVE TREATMENT SYSTEMS FOR THE REMOVAL OF SELENIUM: BARREL SUBSTRATE STUDIES, DESIGN, AND FULL-SCALE IMPLEMENTATION[1]

R.C. Thomas[2], M.A. Girts, J.J. Tudini, J.S. Bays, K.B. Jenkins, L.C. Roop, and T. Cook

Abstract: Passive treatment systems have been developed using biochemical reactors (BCRs) and aerobic wetlands for the treatment of selenium in effluents related to coal mining in the state of West Virginia (WV). Barrel studies were conducted to determine the best substrate mix for the BCRs for removing selenium while limiting the discharge of biological oxygen demand (BOD), low dissolved oxygen (DO), excess sulfide, and other secondary parameters typically generated from BCRs. The barrel studies demonstrated that a high-strength BCR substrate mixture can consistently remove selenium below regulatory limits of 4.7 µg/L at a 12-hr hydraulic residence time (HRT), but a 24-hr to 48-hr HRT is recommended for conservative full scale design. During the initial start-up period, BCR substrate mixtures generate elevated concentrations of secondary parameters, but concentrations quickly decrease to a level that can be treated by a downstream aerobic polishing wetland. Based on the results of the barrel studies, three full-scale passive treatment systems have been designed and two have been constructed for two coal companies in Southern WV. One passive treatment system removed selenium below detection limit during the first six months of operation spanning low and high flow conditions. The other passive treatment system received above-average flows during the first three months of operation, but still removed selenium below regulatory limits. This paper presents a compilation of results from the barrel studies and preliminary data from the full scale passive treatment systems.

Additional Key Words: biochemical reactor, constructed treatment wetland.

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PASSIVE TREATMENT SYSTEMS FOR THE REMOVAL OF SELENIUM: SELENIUM REMOVAL MECHANISMS WITH BIOCHEMICAL REACTOR SUBSTRATE[1]

R.C. Thomas[2], J.J. Tudini, J.S. Bays, M.A. Girts, K.B. Jenkins, L.C. Roop, and T. Cook

Abstract: Passive treatment systems have been developed using biochemical reactors (BCRs) for the treatment of selenium in effluents related to coal mining in the state of West Virginia (WV). Three separate barrel studies consisting of four barrels each were conducted at three separate field sites for a total of twelve barrels. The influent selenium at all sites was in the oxidized-form, selenate. The barrel studies demonstrated that a high-strength BCR substrate mixture can consistently remove selenium below regulatory limits of 4.7 µg/L. Vertical profile samples of the substrates were collected from each barrel at different time intervals ranging between three to twelve month. Substrate samples were analyzed for total selenium as well as selenium speciation. Total selenium profiles of the substrate demonstrate that selenium removal occurs rapidly at the influent water – substrate interface. Selenium speciation of substrate samples indicated that in the early stages of selenium removal, the dominant mechanism leading to selenium retention is reduction of selenate to reduced forms of selenium that are weakly adsorbed to the substrate with approximately more than half being attributable to selenite. Highly immobile elemental selenium and/or selenosulfide account for about a quarter of the total selenium retained, while very little metal selenide was found. Using mass balance evaluation methods, the amount of selenium removed from the influent water over time is greater than the selenium retained in the substrate. This difference is attributed to loss due to volatilization.

Additional Key Words: biochemical reactor, constructed treatment wetland.

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MONITORING AND THRESHOLDS FOR IRRIGATED LANDS IN COAL BED METHANE AREAS[1]

Jason Thomas[2]

Abstract: A key environmental concern for coal bed methane (CBM) development in Wyoming over the past fifteen years has been the potential water quality impact to existing irrigated lands and alluvial pasture areas located downstream of produced water discharge points. This challenge has been encountered most prominently within the ephemeral tributary drainages of the Powder River and Tongue River Basins in Northern Wyoming. Potential threats to hay and forage production include elevated salt concentrations and sodium adsorption ratio levels in surface water and groundwater occurring below regulated CBM discharge points. n addition, the added volume of water can lead to surface flooding and elevated groundwater within irrigated areas in these drainages. Given the natural year-to-year variability in crop production within these systems, any recent impacts from CBM water have been difficult to discern. Through its water quality regulatory program, the Wyoming Department of Environmental Quality (WDEQ) is currently initiating a series of irrigation monitoring networks throughout the Powder and Tongue River Basins. This enhanced monitoring covers water chemistry at discharge points, containment reservoirs, downstream surface water stations, as well as down-gradient monitoring wells. In addition, CBM producers in the affected drainages are required to monitor for groundwater elevation in downstream fields, and conduct ongoing soil and crop sampling. The data is to be analyzed by WDEQ and used as feedback for future water management and permitting decisions within these areas.

Additional Key Words: ag protection, sodium bicarbonate, passive irrigation, sodic, saline, carbon isotope.

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A COMPARISON OF THE VEGETATION COMMUNITIES ON GEOMORPHIC AND NON-GEOMORPHIC RECLAIMED MINE LANDS IN NORTHWESTERN NEW MEXICO[1]

J. Voss[2] and T. C. Ramsey

Abstract: Geomorphic reclamation of surface mine lands attempts to create stable land forms that mimic natural areas in key aspects such as meandering drainage channels, slope and aspect diversity, and microhabitat diversity. In theory, geomorphic reclamation should allow for the development of a more diverse plant community as species suited to each of these niches establish themselves where conditions are most favorable.

In 2012, vegetation sampling was conducted in northwestern New Mexico at San Juan Mine on two reclaimed areas. The first area has a geomorphic land form that includes steep slopes and meandering drainage channels. The second area was constructed with a more traditional reclamation land form with few slopes and no meandering drainage structures. This paper presents the results of the vegetation survey and contrasts the vegetation communities of the geomorphic and non-geomorphic areas.

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FIELD DIRECT, A FIELD INSPECTION APPLICATION DESIGNED TO IMPROVE DATA INTEGRITY AND ACCESSIBILITY FOR MANAGEMENT OVERSIGHT[1]

Kari Ward[2]

Abstract: Field observations and inspections are commonplace for reclamation and restorative projects and often involve a variety of stakeholders. Capturing daily site information can often be a difficult or cumbersome task given the site conditions and multiple responsibilities field personnel manage over the duration of a project. Yet, project status, completeness, and effectiveness rely upon recorded field information being shared in a timely manner with the decision makers. The most commonly experienced problems regarding field data collection are illegibility, transcription errors, timely peer review, version control, and accessibility for management oversight.

Project field staff and managers worked with our software development team to create a secure field observation application that captures site-specific content photographs and field data. Through the application, field workers can enter field information into an electronic form stored on a ruggedized, field-friendly tablet. Once the field worker establishes an internet connection, the form and data are uploaded to a centralized database accessible through a web interface where project team members and stakeholders can review the collected information and prepare a report to share with other stakeholders. The application has been tested on multiple environmental sites including, ecological inspections, well pad observations, construction projects, and mine reclamation projects like the York Canyon site.

Project teams working with the application have experienced uniform legibility, a reduction in transcription errors, streamlined observation reporting, and a reduction in the amount of time spent reviewing the information. Reclamation projects are under heavy scrutiny with multiple stakeholders including the site owners, regulatory agencies, and the public. Therefore, the accuracy and completeness of information communicated from the field was paramount. The importance of controlling data security and maintaining all versions of each field record were among the project lessons learned.

Additional Key Words: tools, data collection

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AZURITE MINE – A CERCLA REMOVAL ACTION CASE STUDY[1]

D. G. Wasley[2]

Abstract: The Azurite Mine is an abandoned gold mine in a remote area in the North Cascades. The Site consists of five adits with a total of 11,500 feet of workings. Surface wastes include metals impacted millsite soil, 50,000 cubic yards of pyritic tailings, and 25,000 cubic yards of waste rock with high ARD potential; all situated on steep slopes. The mine is located in a remote high altitude valley that is only accessible 3 months of the year. On behalf of the Forest Service, CES completed a CERCLA Site Inspection (SI) and Removal Action Design. Samples were collected as part of the SI and data gap assessment from tailings, waste rock, soil, and surface water, pore water, and sediment from Mill and Canyon Creeks to assess the impacts of the mine. The Engineering Evaluation/Cost Analysis (EE/CA) was subsequently prepared by the PRP, ASARCO. ASARCO entered into settlement negotiations with the Forest Service, which eventually lead to a monetary settlement to allow completion of the Removal Action. Following the completion of the EE/CA, CES prepare the Removal Design. The design included onsite consolidation and containment of the tailings and waste rock in a lined repository, construction of a retaining wall to stabilize the repository, reconstruction of the existing access road, physical hazard mitigation of several mine openings, and reclamation of disturbed areas.

The Removal Action project began in July 2011 under a design-build contract structure with CES, and was completed at the end of September 2011. The repository was constructed over the existing tailings pile with a final overall slope of 2.5:1, and the liner consisted of a traditional HDPE liner/geomembranes, along with a geogrid and a talus rock cover to blend in with the surrounding area. In addition, a 22-foot, 17-layer retaining wall/stabilized slope was constructed at the toe of the repository. All borrow material was generated onsite because hauling material to the Site was impractical. There will also be ongoing semi-annual inspections to monitor the constructed repository, revegetation, and to collect aquatic samples to assess the success of the Removal Action.

Additional Key Words: Repository, ARD, tailings, waste rock

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ORGANIC MATTER DYNAMICS IN RECLAIMED MINE SOILS[1]

A.F. Wick[2], P.D. Stahl, and W.L. Daniels

Abstract: There is limited information on organic matter accumulation and decomposition across reclaimed mine soil in the United States – especially to the level required for a complete understanding of the variables driving these dynamics. In a compilation of studies from the past 10 years, we identify some of the primary variables driving organic matter dynamics in reclaimed soils across climatic gradients (eastern and western US) and soil type (coarse and fine textured). Typically, the active pool contained 35% of total C in eastern reclaimed soils and 60-70% of total C in western reclaimed soils. Carbon accumulates at a rate of approximately 0.34 Mg C ha^{-1} yr^{-1} (0.22 Mg C ha^{-1} yr^{-1} in protected pools) for one particular eastern reclaimed site. While reclaimed fine textured soils accumulated 0.71 Mg C ha^{-1} yr^{-1} (0.16 Mg C ha^{-1} yr^{-1} in protected pools) and coarse textured soils accumulated 0.17 Mg C ha^{-1} yr^{-1} (0.03 Mg C ha^{-1} yr^{-1} in protected pools) for a series of sites in the western US. In evaluating the data, we conclude that physical protection by soil aggregates and chemical binding of C to fine soil particles are important mechanisms for C accumulation in eastern US reclaimed soils. In contrast, climatic conditions (i.e. low soil moisture and the subsequent effects on microbial dynamics) and soil texture contribute to C accumulation in western US reclaimed soils.

Additional Key Words: southwest Virginia, Powder River Basin, available organic matter, aggregate-protected organic matter.

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RECLAMATION OF TWO COAL MINES IN MONGOLIA: THE EREN MINE AND THE PLANNED TAVAN TOLGOI MINE[1].

S. E. Williams[2], V. Pfannenstiel and A. Jalsrai

Abstract: Mongolia has a long history of a mostly animal products based economy that is rapidly being supplemented by one that is mineral extraction based. A democracy since 1990, Mongolia is developing regulations and an enforcement infrastructure aimed at development by design including reclamation of mining disturbances. Although there is much mining of precious and industrial metal in Mongolia, this paper focuses on reclamation of mines at the Tavan Tolgoi coal deposit in the Mongolian Gobi Desert. This site is compared to other surface mine reclamation scenarios in Mongolia: Baganuur Coal Mine (140 km NE of Ulaanbaatar), Zamaar Gold Mining District (180 to 200 km W of Ulaanbaatar) and Eren Mine (240 km NNW of Ulaanbaatar)). These mine areas are all in grassland/shrub steppe environments and have annual precipitation rates of 250 to 300 mm as well as surface mining scenarios similar to the Northern Great Plains of Western USA. The high desert environments of western Wyoming have similarities to the Gobi (e.g. growing season length and annual precipitation). Information generated from these locations is evaluated to postulate reclamation strategies for the Tavan Tolgoi. The Eren Mine (located in a typical grassland steppe environment having annual precipitation of 300 mm annually) was the first large reclamation project in Mongolia. At the Tavan Tolgoi (desert shrub steppe environment having annual precipitation of <100 mm), soils have low organic carbon, high pH and salts. Baseline environmental, botanic and edaphic information is comparatively given for both sites as well as information on mycorrhizal associations and nitrogen fixing species. Further are descriptions of the reclamation effort at the Eren mine and strategies posed for reclamation at the Tavan Tolgoi. The reclamation efforts at the Eren mine are favorable. Reclamation at Tavan Tolgoi is postulated to be much more difficult.

Additional Key Words: Bulgan Grasslands, Gobi Desert, mycorrhizal fungi, saline and/or sodic soils.

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HARDWOOD TREE GROWTH AFTER EIGHT YEARS ON BROWN AND GRAY MINE SOILS IN WEST VIRGINIA[1]

L. Wilson-Kokes[2], J. Skousen, P. Emerson, C. DeLong, and C. Thomas

Abstract: Surface coal mining in Appalachia disturbs hundreds of hectares of land every year with the removal of valuable and ecologically diverse eastern deciduous forests. After the passage of the Surface Mining Control and Reclamation Act (SMCRA) in 1977, coal mine operators began planting a variety of grasses and legumes as a fast and economical way to re-establish a permanent vegetative cover in order to meet erosion and site stabilization requirements. However, excessive soil compaction has arrested the re-colonization of native hardwood tree species on these reclaimed sites. In an effort to evaluate tree growth on selected spoils and determine the effects of compaction, three 2.8-ha experimental plots were established at Catenary Coal's Samples Mine in Kanawha County, West Virginia. Two plots were constructed of weathered brown sandstone and the third plot was constructed of un-weathered gray sandstone. Half of each plot was compacted while the other half of the plot was left non-compacted. Each plot was hydroseeded with a low competition herbaceous cover and planted with eleven hardwood tree species. Soil chemical properties and tree growth have been measured each year since 2005. After eight growing seasons, average tree volume index was nearly ten times greater for trees grown in the brown sandstone treatments, 3853 cm^3, compared to 407 cm^3 in the gray sandstone treatment. Trees growing on compacted treatments had a lower mean volume index, 2281 cm^3, than trees growing on non-compacted treatments, 3899 cm^3. Average pH of brown sandstone was 5.2 to 5.7 while gray sandstone was 7.9. The gray sandstone has continued to resist breakdown. As a comparison to tree performance on the un-weathered gray sandstone treatment, which appeared to have exceptionally poor tree growth, two other areas on the mine site that were similarly reclaimed in 2005 with un-weathered gray sandstone were measured for chemical properties and mean tree volume index in 2012. One site was compacted while the other site was compacted and then ripped. Average pH was 7.4 on the compacted site and 7.3 on the ripped site while mean tree volume was almost identical at 909 cm^3 and 885 cm^3, respectively. Although slightly higher, no significant differences in mean pH and mean tree volume index were found between the original gray sandstone treatment and the two reclaimed gray sandstone areas. After eight years, brown sandstone has shown significantly greater tree growth and is a more suitable topsoil substitute than the gray sandstone plots on this site.

Additional Key Words: gray sandstone, brown sandstone, tree volume, tree survival

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HIGH RESOLUTION LIDAR AS A BASE FOR DESIGNING GEOMORPHIC RECLAMATION SCHEMES FOR SURFACE MINES IN THE CENTRAL APPALACHIANS

Charles Yuill[2]

Abstract: Recent acquisition of high-resolution LiDAR based topographic data for the mountaintop mining region of West Virginia is facilitating improved understanding of the topographic / hydrologic impacts of approximate original contour as well as mountaintop mining in headwater watersheds in the region. Minor topographic changes that are impacting drainage patterns in small catchments can be identified and the potential impacts of those changes assessed. This paper will examine the changes that have occurred over time in a relatively heavily mined area in Southern West Virginia and demonstrate how high resolution topographic data derived from LiDAR can be utilized to implement varying degrees of geomorphic reclamation alternatives within the context of maintaining. Geomorphic reclamation methods and principles as alternatives to traditional mountaintop backstack / valley fill reclamation are being developed and will be detailed in the paper. Two large mountaintop mine areas will serve as the case studies for the presentation.

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CHEMICAL CONSTITUENTS IN SEDIMENT AND WATER FROM GRAND LAKE O' THE CHEROKEES, OKLAHOMA, DOWNSTREAM FROM THE TRI-STATE LEAD-ZINC MINING DISTRICT[1]

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Abstract: Since completion of the Pensacola Dam in 1940, Grand Lake, Oklahoma, has been the repository for metal contaminants from the historic Tri-State Lead-Zinc Mining District. The purpose of this study was to assess metals concentrations in Grand Lake sediments at several sites where development practices may require dredging. Two Environmental Science and Engineering undergraduate capstone classes at the University of Oklahoma collected sediment and water samples at 17 different locations in 2010 and 2012. Sediment samples were incremented with depth and analyzed for total metals concentrations, TCLP metals (2010 only), moisture content, and organic matter; water samples were analyzed for total and dissolved metals, nutrient concentrations, physicochemical parameters, total alkalinity, and turbidity. Sediment metals concentrations were compared to published Sediment Quality Guidelines (SQG) to determine if concentrations exceeded the TEC or PEC. In an initial lake-wide survey of seven locations in 2010, four sites demonstrated concentrations in individual sediment increments that exceeded the TEC or both the TEC and PEC. All re-composited sediment samples had metals concentrations below RCRA criteria for TCLP metals. In a targeted study of 10 sites in two coves in 2012, 100% of sediment increments exceeded the TEC for Zn and Cd. Zn concentrations also exceeded the PEC in 55% of samples analyzed. Pb concentrations exceeded the TEC in 75 % of all core samples from both studies. The Grand River Dam Authority requires dredging applicants to obtain permits and, in some cases, to analyze and compare sediment metal concentrations to applicable SQG. The data generated by this study indicate the likelihood of substantial metal contamination of sediments in Grand Lake. In both 2010 and 2012, total and dissolved metal concentrations in water did not exceed applicable criteria.

Additional Key Words: Lakes, reservoirs, sediments, Sediment Quality Guidelines, metal mining

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REBUILDING SOILS FOR FOREST RESTORATION ON APPALACHIAN MINED LANDS[1]

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Abstract: The Appalachian region supports the globally significant forests but surface mining for coal has caused forest loss. The Forestry Reclamation Approach (FRA) is a new reclamation method that is being used with the intent of restoring Appalachian native forests on mined lands. In addition to avoidance of soil compaction, selection of mining-disturbed materials for use in constructing mine soils is essential to the FRA reclamation process. This presentation will describe material selection procedures for mine soil construction when rebuilding soils in on Appalachian mined lands for forest restoration, based on a review and synthesis of scientific literature. The low soluble salt contents and slightly to moderately acidic pHs that are characteristic of the region's native soils are important soil properties for successful reforestation. Use of weathered rock spoils to reconstruct mine soils has enabled restoration of native tree productivity comparable to the productivity of native forest sites on some Appalachian mined lands. Native Appalachian soils, however, have higher contents of bioavailable N and P than weathered rock spoils and they contain live seed banks. Our review of scientific research suggests use of salvaged native soils when available as a beneficial soil-construction practice when restoring native forests on mine sites, and that weathered rock spoils are generally superior to unweathered rock spoils when constructing mine soils for this purpose.

Additional Key Words: Reforestation, weathered rock spoils

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