MONDAY, JUNE 6, TECHNICAL SESSIONS			
	WATER QUALITY SESSION 1A MEETING ROOM 1 MODERATOR - KENNET BERTELSEN	LONG TERM RECLAMATION EVALUATION SESSION 1B MEETING ROOM 2 MODERATOR - PIERRE LEMIEUX	RECLAMATION APPROACHES SESSION 1C MEETING ROOM 3 MODERATOR - JOHN HANEY
2:00 p.m. - 2:30 p.m.	Rock Disposal Area Seep Water Treatment At The Jerritt Canyon Mine **by Debbie Johnston**	Reclamation Of The McLaren Tailings Restoring Previously Unusable Area Back To Its Historical Landscape **by Marty Bennett**	Innovative Approach Using GIS to Advance Reclamation and Bond Release **by Rio Franzman**
2:30 p.m. - 3:00 p.m.	A Paired Comparison Study To Evaluate The Effect Of Ionic Strength On Trace Metal Removal Products In A Vertical Flow Bioreactor Substrate **by Julie LaBar (Student)**	Survival And Growth Of Chestnut Backcross Seeds And Seedlings After 8 Years On Surface Mines **by Jeff Skousen**	Bench Scale Hexavalent Chromium Removal With A Biochemical Reactor **by James Gusek and Rado Razafimandrato**
3:00 p.m. - 3:30 p.m.	Got Aluminum? -Removing Suspended Metals With Peat Based Sorption Media **by Paul Eger**	Effects Of Topsoil Substitute Materials, Depth Of Material, And Compaction On The Average Growth Rates Of Hardwood Trees Eleven Years After Reclamation **by Kara Dallaire (Student)**	The Use Of Soil Sampling And Investigations To Improve Reclamation Costs **by James Hartsig**
3:30 P.M. - 4:00 P.M. - BREAK (EXHIBIT HALL)			
	WATER QUALITY SESSION 2A MEETING ROOM 1 MODERATOR - JIM GUSEK	LONG TERM RECLAMATION EVALUATION SESSION 2B MEETING ROOM 2 MODERATOR - MARTY BENNETT	RECLAMATION TECHNOLOGIES SESSION 2C MEETING ROOM 3 MODERATOR - BRENT HARDY
4:00 p.m. - 4:30 p.m.	Acid Mine Drainage Treatment With Dispersed Alkaline Substrate And Limestone Beds **by Paul Eger**	Design Approaches And Lessons Learned For The Durant Canyon Reclamation Project **by Pierre LeMieux**	The Potential Of Biosolids And Other Amendments For Revegetation Of Lead/ Zinc Mine Tailings With Three Biomass Crops: Greenhouse Study **by Mariam Al-Lami (Student)**
4:30 p.m. - 5:00 p.m.	Passive And Active Treatment Of Arsenic And Antimony At A Remote Abandoned Mine Site In Idaho **by Kristina Minchow**	Environmental Control Of Shrub Density Development At The Seneca Ii Mine, 1987-2014, Routt Co. Co **by Vern Pfannenstiel**	Looking At Reclamation In Terms Of Ecological Restoration **by Michael Vice**
5:00 p.m. - 5:30 p.m.	Green Remediation Of Acid Mine Drainage Impacted Water: A Field-Scale Filter Development Using An Industrial Byproduct **by Abhishek RoyChowdhury**	Determination Of Plant Cover In Field Sampling: A Point-Intercept Method For All Strata **by David L. Buckner**	The Holistic Approach To The Design, Monitoring, And Future Performance Assessment Of A Surface Barrier **by Zhuanfang (Fred) Zhang**
5:30 p.m. - 6:00 p.m.	**Water Management TD Business Meeting**	**Forestry and Wildlife TD Business Meeting**	

Tuesday, June 7, 2016

6:30 a.m. – 8:30 a.m. . ..... Breakfast - Grand Ballroom A

6:30 a.m. – 7:30 a.m. ..... Haulin' ASMR - Meet in lobby

7:30 a.m. – 9:00 a.m. ..... Registration - Grand Ballroom Hallway

8:00 a.m. – 4:00 p.m. ..... Technical Tour #1 - Upper Coeur d'Alene Basin Mining Tour (Hosted by CDM Smith). Meet in Lobby

7:30 a.m. – 4:30 p.m. ..... Technical Tour #2 - Land Reclamation in the Inland Empire (Hosted by Rainier Seeds). Meet in Lobby

6:00 p.m. – 10:00 p.m. ..... Social Evening at Chateau Rive

Wednesday, June 8, 2016

6:30 a.m. – 8:30 a.m. . ..... Breakfast - Grand Ballroom A

6:30 a.m. – 7:30 a.m. ..... Haulin' ASMR - Meet in lobby

7:30 a.m. – 8:30 a.m. ..... Living Legends - Meeting Room 5

7:30 a.m. – 8:30 a.m. ..... Wild Women of Reclamation - Meeting Room 6

7:30 a.m. – 5:00 p.m. ..... Registration - Grand Ballroom Hallway

WEDNESDAY, JUNE 8, TECHNICAL SESSIONS			
	WATER QUALITY SESSION 3A MEETING ROOM 1 MODERATOR - STEVE DENT	LONG TERM RECLAMATION EVALUATION SESSION 3B MEETING ROOM 2 MODERATOR - CARL ZIPPER	RECLAMATION TECHNOLOGIES WITH BOMAG SESSION 3C MEETING ROOM 3 MODERATOR - ERNA WATERMAN
8:30 a.m. - 9:00 a.m.	An Appalachian Regional Study To Predict TDS Release From Coal Mine Spoils **by Lee Daniels**	Revegetation Trends And Seeding Lessons At Two Montana Coal Mines Based On 20 Years Of Monitoring **by Richard Prodgers**	Deep Till Method In-Situ Soil Reclamation With A Bomag Recycler **by Erna Waterman**
9:00 a.m. - 9:30 a.m.	Proof Of Concept Bio-Terrace Aluminum Removal At An Abandoned Metal Mine, Idaho **by James Gusek**	Reclamation Practice Influences On The Post-Mining Plant Community At A Virginia Mine Site After Six Years **by Carl E. Zipper**	Composite Sampling - Pre In-Situ Soil Reclamation With A Bomag Recycler **by M. Meadows (Student)**
9:30 a.m. - 10:00 a.m.	Determination Of Hydraulic Retention Time For Passive Treatment System Oxidation Unit Using Rhodamine **by Leah Oxenford (Student)**	Long-Term Study Identifies Avenues For Improving Revegetation Efforts **by Matthew Rinella**	Post In-Situ Soil Reclamation With A Bomag Recycler **by G. Gardner & M. Williams (Students)**
10:00 A.M. - 10:30 A.M. - BREAK (EXHIBIT HALL)			

WEDNESDAY, JUNE 8, TECHNICAL SESSIONS CONTINUED			
	WATER QUALITY SESSION 4A MEETING ROOM 1 MODERATOR - JULIE LABAR	LONG TERM RECLAMATION EVALUATION SESSION 4B MEETING ROOM 2 MODERATOR - DAVID POLSER	MAPPING/GIS SESSION 4C MEETING ROOM 3 MODERATOR - CURT COOVER
10:30 a.m. - 11:00 a.m.	Treatment System Restoration And Power Generation In The Slippery Rock Creek Watershed **by Ryan Mahony**	Mineral Sands Mine Soils In Southeastern Virginia: Comparison Of Physical And Chemical Properties After Eight Years **by Zenah Orndorff**	Ecological Problems In Kazreti, Georgia, Caused By Copper And Gold Mine And Its Reclamation Using GIS Systems **by Marika Avkopashvili**
11:00 a.m. - 11:30 a.m.	Implementation Of Two Passive Treatment Systems In Northern West Virginia **by Cody Neely**	Switchgrass Bioenergy as Silvopasture on Reclaimed Mine Soil **by David Lang**	Blending Historic Mapping With Lidar At Abandoned Mine Sites **by Curt Coover**
11:30 a.m.- 12:00 p.m.	Validating A Method For Determining Specific Conductivity In Mining Wastewater **by Jeffrey Parks**	Natural Processes For The Restoration Of Drastically Disturbed Sites **by David F. Polster**	**TBD**
12:00 P.M. - 1:30 P.M. - LUNCH WITH LEGENDARY COACH BOB GREEN, MT TECH FOOTBALL COACH (GRAND BALLROOM A)			
	WATER QUALITY SESSION 5A MEETING ROOM 1 MODERATOR - ROBERT NAIRN	LONG TERM RECLAMATION EVALUATION SESSION 5B MEETING ROOM 2 MODERATOR - RYAN TOBIAS	DRONES AND UAV'S SESSION 5C MEETING ROOM 3 MODERATOR - MARK DONNER
1:30 p.m. - 2:00 p.m.	TDS Accumulation In An Ohio Creek As It Travels Through A Coal Mining Site **by Jonathan Peterson**	Evaluating The Suitability Of A Reforestation Growth-Medium Prepared By Tractor Pulled Scraper Pans At An East Texas Lignite Surface Mine **by Hannah Angel (Student)**	UAs (Drones) De-Mystified, And How They Can Help Your Mining Reclamation Project **by Josh Schane**
2:00 p.m. - 2:30 p.m.	Comprehensive Watershed Restoration Via Ecological Engineering: The Role Of Passive Treatment **by Robert W. Nairn**	Montana Moonscapes: Mitigating Large-Scale Erosion On Steep Slope Uplands In Roadless Areas Of The Anaconda Superfund Site **by Pedro Marques**	Unmanned Aerial Systems (UAS) – What We Learned in our First Year as a Commercial Operator **by Mark Donner**
2:30 p.m. - 3:00 p.m.	A Review Of The Literature Pertaining To Passive And Hybrid Treatment Systems For Removal Of TDS From Mining Impacted Waters **by Zachary E. Kemak(student)**	Underground Mine Subsidence Evaluation, Closure, And Risk Management **by Tyrel Wilson**	**Geotechnical and Soils TD Business Meeting**
3:00 P.M. - 3:30 P.M. - BREAK (EXHIBIT HALL)			

WEDNESDAY, JUNE 8, TECHNICAL SESSIONS CONTINUED			
	WATER QUALITY SESSION 6A MEETING ROOM 1 MODERATOR - TYLER CHATRIAND	RECLAMATION IN CHALLENGING ENVIRONMENTS SESSION 6B MEETING ROOM 2 MODERATOR - STUART JENNINGS	INTERNATIONAL RECLAMATION SESSION 6C MEETING ROOM 3 MODERATOR - DAVE ENOS
3:30 p.m. - 4:00 p.m.	Long-Term Effectiveness Of Three Passive Systems Treating Acidic, High-Metal, Abandoned Coal Mine Discharges Near De Sale, Pennsylvania **by Cliff Denholm**	Rethinking Arsenic Reclamation Of A "Hellafund" Site, Montana **by Scott Robinson (Student)**	Patches: Optimizing The Ecological Benefits Of Different Reclamation Soils Across The Landscape In The Alberta Mineable Oil Sands Region **by Brad Pinno**
4:00 p.m. - 4:30 p.m.	Proof of Concept AMD Passive Bioremediation At An Abandoned Mine, Idaho **by David Jenkins**	The Spenceville Copper Mine Reclamation **by William J. Walker**	Succession Of Algae, Moss, And Herbaceous Flora During 29 Years In Prairie Opencast Coal Mine, Inner Mongolia, China **by Xiang Fan (Student)**
4:30 p.m. - 5:00 p.m.	Biochemical Reactors For Hard Rock Mining-Influenced Water: Overview Of Treatability Studies And Lessons Learned For Implementation **by Nicholas Anton**	Restoration In Challenging Northern Climates **by Alex Zimmerman**	Revegetation of Jharia Coalfield Using Remote Sensing, Based On Thermal Infra-Red Data: A Case Study **by Pradeep Kumar**
5:00 p.m. - 5:30 p.m.	Unexpected Relationships between Methylmercury Enrichment in Fresh Waterbodies and Food-Web Uptake **by Stephen Dent**	Interstate-Callahan Upper and Lower Rock Dumps Remedial Action Construction Project **by Tony Wesche**	**Land Use TD Business Meeting**
5:30 p.m. - 6:00 p.m.		**International Tailings TD Meeting**	
5:30 p.m. - 7:00 p.m.	POSTER SESSION SOCIAL - GRAND BALLROOM A		

Thursday, June 8, 2016

6:30 a.m. – 7:30 a.m. .....Haulin' ASMR - Meet in lobby

6:30 a.m. – 8:00 a.m. . .....Breakfast - On Your Own

7:30 a.m. – 12:00 p.m. .....Registration - Grand Ballroom Hallway

THURSDAY, JUNE 9, TECHNICAL SESSIONS			
	ECOLOGICAL IMPLICATIONS OF RECLAMATION SESSION 7A MEETING ROOM 1 MODERATOR - ROBERT PAL	AML CASE STUDIES SESSION 7B MEETING ROOM 2 MODERATOR - DEVIN CLARY	INTERNATIONAL RECLAMATION SESSION 7C MEETING ROOM 3 MODERATOR - JOE FRIEDLANDER
8:30 a.m. - 9:00 a.m.	Compaction Impacting Hydrology And Tree Growth On A Demonstration Mine In The Western Gulf **by Cassidy Comer (Student)**	East Fork Ninemile Waste Consolidation Area Site Selection, Design And Initial Construction **by Cody J. Lechleitner**	Effects Of Landscape Transitions Due To Underground Coal Mining On Ecosystem Services In High Groundwater Table And Underground Coal Mining Area: A Case Study Of Yanzhou Coalfield **by Wu Xiao**
9:00 a.m. - 9:30 a.m.	Surface Mine To Biomass Farm: Growing Shrub Willows (Salix Spp.) In Northeastern West Virginia - First Year Results **by Bart Caterino (Student)**	Revegetation Of The Forest Rose Mine In Western Montana **by Leonard Ballek**	Integrated Approaches Of Water And Solid Waste Management In Mining Reclamation Of Coimolache Mining Company-Peru by Alfredo Sagástegui
9:30 a.m.- 10:00 a.m.	The Effectiveness Of Native Seed Dispersal Islands In Reclaimed Mine Lands Dominated By Eurasian Grasses **by Robert W. Pal**	Removal Action At The Monte Cristo Mining Area **by Ryan Tobias**	Innovations Of Land Reclamation And Ecological Restoration In Coal Mining Areas In China **by Zhenqi Hu**
10:00 A.M. - 10:30 A.M. - BREAK (EXHIBIT HALL)			
	REVEGETATION CHALLENGES SESSION 8A MEETING ROOM 1 MODERATOR - JENNIFER FRANKLIN	HEAVY METALS CHARACTERIZATION AND REMEDIATION SESSION 8B MEETING ROOM 2 MODERATOR - KERI PRITCHETT	MINE CLOSURE AND RECLAMATION SESSION 8C MEETING ROOM 3 MODERATOR - JR SUGALSKI
10:30 a.m. - 11:00 a.m.	Improved Methods Of Assessing Plant Species Diversity On Mine Reclamation Sites: A 10-Year Update **by David L. Buckner**	Acid Soil Remediation And Revegetation Of Metal Contaminated Pastures, Deer Lodge, Montana **by Stuart Jennings**	Mining Reclamation Through Service-Learning: Case Studies From Wisconsin **by Yari Johnson**
11:00 a.m. - 11:30 a.m.	Evaluation Of Small Tree And Shrub Plantings On Reclaimed Surface Mines In West Virginia **by Alexis Monteleone (Student)**	Update To Tribal-Led Remedial Action At The Tar Creek Superfund Site **by Craig Kreman**	True North Mine Reclamation Project **by Mark Huffington**

THURSDAY, JUNE 9, TECHNICAL SESSIONS CONTINUED			
11:30 a.m. - 12:00 p.m.	Ripping And Native Seeding Treatments Influence On Vegetation Composition Of Compacted Tailings **by Jennifer Franklin**	Reducing Fresh Water Consumption in Hydraulic Fracturing By Using Acid Mine Drainage As A Make-Up Fluid **by Eric Cavazza**	Cost Effective Plans for Successful Mine Closure – Recent Case Studies **by Marc S. Theisen**
12:00 P.M. - 1:30 P.M. - LUNCH AND PRESENTATION AWARDS			
	RESTORATION AND REVEGETATION SESSION 9A MEETING ROOM 1 MODERATOR - LEAH OXENFORD	RECLAMATION IN CHALLENGING ENVIRONMENTS SESSION 9B MEETING ROOM 2 MODERATOR - PETE STAHL	TREATMENT AND WETLANDS SESSION 9C MEETING ROOM 3 MODERATOR - BERNARD KRONSCHNABEL
1:30 p.m. - 2:00 p.m.	Advanced Planning And Measurable Outcomes: Restoration Success In Southern Colorado **by David Chenoweth**	Developing A Conceptual Site Model In A Watershed With Multiple Mine Waste Dumps, Bunker Hill Superfund Site, East Fork Ninemile Basin **by Erik Naylor**	Trompe Design, Construction And Performance **by Timothy P. Danehy**
2:00 p.m. - 2:30 p.m.	What's So Great About Beavers? **By Susan Firor**	Coal Mine Reclamation Costs And Local Economic Impacts In The Powder River Basin In Wyoming **by Roger Coupal**	Remediation of Acid Mine Drainage using a Sulfate-reducing Bioreactor at the Tab-Simco Passive Treatment System – An Update **by Paul Behum**
2:30 p.m. - 3:00 p.m.	Novel Capping and Revegetation of an Abandoned Mercury Mine, California **by David Jenkins**	Monitoring The Behavior Of Sludge In The Vadose Zone **by Michele Coleman**	Case Study: Baird Wetland Mitigation **by Shaun Busler**
3:00 p.m. - 3:30 p.m.	Passive Biological Treatment Approaches To Reduce Conductivity In Waters Affected By Mine Drainage: Key Challenges & Research Needs **by Bill Strosnider**	Streamlining The Reclamation Monitoring and Reporting Process: A Digital Reclamation Monitoring Tool **by Nathan J. Wojcik**	The Relationship Between Student Service Learning And Technical Assistance In Mine Water Reclamation **by Kelsea Palmer**
3:30 p.m. - 4:00 p.m.	**Ecology TD Business Meeting**	Heavy Metal Characterization And Source Identification For Grove Gulch In Butte, Mt **by Raja Nagisetty**	
NEC WRAP UP MEETING 4:00 PM (MEETING ROOM 5)			

POSTER SESSION AND MIXER

Wednesday, June 8th, 5:30 to 7:00 PM

The Poster Session will be held in Grand Ballroom A on Wednesday evening June 8th, along with a Social Mixer including refreshments. Posters will be displayed on easels provided. Below is a list of the abstracts that have been accepted for the Poster Session.

POSTER SESSION - GRAND BALLROOM A
Hydraulically Isolating An Existing Repository And Potentially Increasing Capacity by **Kara M. Beaudoin**
Metal Recovery Using Biogenic Sulfide From Acid Mine Drainage **by Sangwoo Ji**
Effect Of Different Forest Age On Soil Enzyme Activities And Microbial Diversity On Surface Mine Reclamation In Antaibao **by Jinchuan Li**
The Physiological Characteristics To Estimate Species Potential As Mine Reclamation Ground Covers **by Eddy Nurtjahya**
Interim Reclamation: The Benefits Of Temporary Reforestation For Meeting Final Reclamation Goals **by Brad Pinno et al.**
Interactive Effects Between Lime, Organic Matter, And Bacteria In The Establishment Of Leymus Cinereus In Mine Tailings **by Deicy Sánchez**
Recovery Rate And Purity Of Some Dissolved Metals In Mine Drainage From Abandoned Coal Mine **by Gil-Jae**
Fluorescent Dye Tracing In Abandoned Mines For Adit Discharge Source Control **by Chapin Storrar**
Salix Spp. As A Biomass Crop: Investigating Its Potential On Mined Lands And The Use Of Biochar As A Soil Amendment **by Heather Nobert (Student)**
Design And Construction Challenges For The Southeast Commerce Passive Treatment System **by Bryan J. Page (Student)**
Open Limestone Channel Performance For Aluminum-Rich Acid Mine Drainage **by Charles Spellman (Student)**
Contaminant And Treatment Dynamics In The Greater Rio Juckucha Watershed **by Hannah Patton (Student)**
Open Limestone Channels For Acid Mine Drainage Treatment: Effects Of Agitation On PH Increase **by Swayer Rensel (Student)**
Hydraulic And Biological Maintenance Challenges And Solutions In An Aging Passive Treatment System **by Nicholas Shepherd (Student)**
Geochemistry And Biota Of Bolivian Hypersaline Lakes **by Rachel Wagner and Stefan Long (student)**
Evaluating The Suitability Of A Reforestation Growth-Medium Prepared By Tractor Pulled Scraper Pans At An East Texas Lignite Surface Mine **by Hannah Angel (Student)**
Lab Scale Batch Weathered Limestone Testing To Determine System Sizing **by Andrew Hollern (Student)**
A Gis Model To Guide Revegetation Efforts On Reclaimed Mine Lands **by Mark Mariano (Student)**
Soil Conditions Promoting Long-Term Reforestation Of Appalachian Forests **by Jenise Bauman (Student)**
The Institutional Context of Reclamation: Changing Landscapes of Energy **by Kathryn Bills-Walsh**
Mechanical Suppression of Grasses to Reduce Competition with Wyoming Big Sagebrush (Artemisia Tridentata) Seedlings in a Fire Disturbed Landscape by **Amy P. Jacobs (Student)**
Insect Response to Reclaimed Well Pads with Different Vegetative Characteristics in a Semi-Arid Natural Gas Field **by Michael F. Curran (Student) and Peter D. Stahl**
Georeferencing of American Society of Mining and Reclamation Proceedings: Preliminary Trend Analysis **by Ashley Rovder, Staci Wolfe, Stefan Long, David Madl, Peter Smyntek, Rachel Wagner, William Strosnider**

THE POTENTIAL OF BIOSOLIDS AND OTHER AMENDMENTS FOR REVEGETATION OF LEAD/ZINC MINE TAILINGS WITH THREE BIOMASS CROPS: GREENHOUSE STUDY

Mariam Al-Lami* and Joel Burken

Reclamation of abandoned mine tailings is necessary to reduce environmental risks associated with tailings, and also for beneficial use of large degraded land. Revegetation is a cost effective approach to stabilize the bare surface of tailings pond and control the wind dispersion and water erosion of tailings. However, establishing a vegetative cover on tailings is challenging due to lack of essential nutrients and poor soil structure. Hence, adding nutrient-rich organic amendments should be considered. In this study, tailings were collected from DOE RUN Mine 28 tailings site, Viburnum, MO, U.S. Physicochemical analysis of tailings indicated a very low organic matter content, slightly alkaline pH, and elevated Pb and Zn content. In 2012, miscanthus was planted in these tailings by DOE RUN in a test plot of 4.5 hectares with no amendment application, however; very poor performance of miscanthus was recorded. Therefore, a pot experiment was conducted by amending tailings with two levels of biosolids (BS) (equivalent to 60 and 100 dry Mg ha^{-1}) alone or combined with other amendments: biochar (BC), humic substances (HS), and arbuscular mycorrhiza fungi (AMF), to grow willows, poplars, and miscanthus. Each treatment and plant species was replicated 6 times. The plants were harvested after 6 months of growth. After collecting the aboveground biomass, roots were collected for biomass and fine root tips were collected for AMF colonization estimation. Moist soil samples were collected for dehydrogenase activity (DHA) testing to measure microbial enzyme activities, which are considered effective indicators of soil quality. BS application resulted in a significant increase in biomass compared to control (unamended tailings) for the three species. BS+HS treatment further increased willows biomass (>22 fold) compared to control, while BS+AMF increased miscanthus biomass (>50 fold). Soil DHA increased significantly in all treatments compared to control. AMF was observed on roots with high infection rates in all treatments except the control.

Additional Key Words: Pb/Zn mine tailings, biomass crops, biosolids, biochar, humic substances, AMF.

Evaluating the Suitability of a Reforestation Growth Medium Prepared by Tractor Pulled Scraper Pans at an East Texas Lignite Surface Mine[1]

H.Z. Angel[2*], H.M. Williams, and J.P. Stovall

Abstract: Since 1974, Luminant has planted over 37 million trees on its reclaimed lignite surface mine operations in east Texas. For decades, the use of improved reclamation techniques on Luminant's mined lands have resulted in quality reclamation with over 31,160 hectares reforested to productivity levels similar to that found on undisturbed lands. Development of new reclamation methodologies offers opportunities to improve productivity potential of planted trees at Luminant's Martin Lake Oak Hill Mine in east Texas. Two sites reclaimed using different haulback methodologies (truck-shovel method and scraper pan method) will be sampled to determine the effects of equipment use on soil physical and chemical properties, particularly soil bulk density. The conventional haulback or 'truck-shovel' reclamation method uses haul trucks (loaded by a hydraulic backhoe) for the selective transport and placement of oxidized overburden to serve as the reforestation growth medium. Overburden transport and placement can also be accomplished using tractor pulled scraper pans; however, there is a lack of information regarding the effects of scraper pans on mine soil compaction and tree growth. To address the potential compacting effects of scraper pans, four soil tillage techniques (n=5) were implemented and planted with loblolly pine (*Pinus taeda*) seedlings. Tillage treatments include: 1) disking (30-35 cm depth); 2) ripping (90 cm depth) and disking (30-35 cm depth); 3) cross-ripping (90 cm depth) and disking (30-35 cm depth); and, 4) no tillage (control). First year growth and survival of seedlings will be sampled next fall to determine response of vegetation to treatments. At each reclamation method site, soil test pits will be used to investigate soil physical and chemical properties at three depths (0-30, 30-60, 60-90 cm). Results will be presented for infiltration rates and soil strength at the truck-shovel site and biomass of winter cover crop at the scraper pan site.

Additional Key Words: Reclamation, mining, soil bulk density, surface tillage, subsurface tillage

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1. Oral and poster presentation at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4 – 9, 2016. Published by ASMR; 1305 Weathervane Dr., Champaign, IL 61821.

2. Hannah Z. Angel* (presenter), Graduate Research Assistant; Hans M. Williams, Interim Dean and Nelson Distinguished Professor; and, Jeremy P. Stovall, Associate Professor. All authors located at Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, TX 75962.

Biochemical Reactors for Hard Rock Mining-Influenced Water: Overview of Treatability Studies and Lessons Learned for Implementation

N.R. Anton*, N.T. Smith, A.K. Frandsen, K. Saller, D.J. Reisman, R.L. Olsen

Abstract: CDM Smith has recently completed several treatability studies evaluating the use of passive biochemical reactor (BCR) treatment methods (anaerobic sulfate reduction process) for mining-influenced water (MIW) at sites in Montana, Idaho, Oregon, and California. The scope of studies has included laboratory bench/column testing and pilot-scale field testing to determine the efficacy of treatments, resolve unknowns and issues leading to passive treatment system failure or lack of long-term efficiency, and provide data for feasibility studies and design. MIW types tested ranged from highly acidic and metal rich waters to more near-neutral, lower metal, and low-sulfate waters. Studies involved evaluation of pre-treatment methods to reduce metal loading and increase pH and alkalinity, BCR treatments, post-treatment methods to increase dissolved oxygen and reduce nutrients, sulfate addition methods for low-sulfate MIW types, and effects of lower temperature, increased oxygen, and increased seasonal metal loading. Ninety to greater than 99 percent removal of cadmium, copper, lead, iron, nickel, and zinc have been observed that correlates with measurable sulfate reduction, sulfide and alkalinity generation, and oxidation-reduction potential below approximately -150 mV. A minimum influent sulfate concentration of around 100 mg/L appears to be necessary to maintain sufficient sulfate reduction for metal removal. All of these studies have provided a breadth of information regarding treatment efficiencies for various water types, treatment approaches, and flow rates, and demonstrated the need for bench and pilot-scale studies, utilizing metal loading and volumetric sulfate reduction rates in design, pre-and-post treatment methods to achieve water quality standards and increase system longevity, and sulfate amendment for low-sulfate MIW types. These studies were a step forward toward resolving key issues for developing successful MIW treatment practices and remediating site waters, made us aware of new problems to tackle and resolve, and expanded our current state of knowledge and experience in this developing science.

Nicholas R. Anton, PE, Environmental Engineer, CDM Smith, Helena, MT 59601; Nathan T. Smith, Sr. Project Manager, CDM Smith, Denver, CO 80202; Angela K. Frandsen, PE, Environmental Engineer, CDM Smith, Helena, MT 59601; David J. Reisman, Sr. Environmental Scientist, CDM Smith, Cincinnati, OH 45249; Kevin Saller, Environmental Engineer, CDM Smith, Denver, CO 80202; Roger L. Olsen, Ph.D., BCES, Sr. Vice President, CDM Smith, Denver, CO 80202.

Ecological Problems in Kazreti, Georgia, Caused by Copper and Gold Mine and its Reclamation Using GIS System

M. Avkopashvili and T. Hartshorn[1]

This paper is about RMG Gold and Copper open-pit mine which is situated in Kazreti, Georgia. Sakdrisi-kachagiani site is one of the oldest gold mine complexes in Europe. Scientists dated it to the early 3rd millennium BC.[2]

In this paper we will discuss ecological problems in Kazreti, caused by mining and find out how dangerous is water, soil, and air pollution caused by heavy metals, including Cu, Cd, and Zn, for the local population.[3] The most important focus of our research is to develop suitable reclamation methodologies for the RMG Gold Mine. Geographic Information Systems (GIS) techniques were applied to the dataset to create elemental spatial distribution maps, three-dimensional images, and interpretive hazard maps of the pollutants in the study area. Immediate action to remediate the contaminated topsoil is recommended to safeguard the health of people who live near the mine.

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1 Marika Avkopashvili, PhD student at Ivane Javakhishvili Tbilisi State University. Georgia. Tony Hartshorn, Professor, Land Resources and Environmental Sciences, Montana State University. Bozeman, MT 59717.

2 Thomas Stollner (Deutsches Bergbau-Museum Bochum), Irina Gambashidze (Georgian National Museum). "The Gold Mine of Sakdrisi and Earliest Mining and Metallurgy in the Transcaucasus and the Kura-Valley System". Parzinger, Hermann (2013). "Position to Sakdrisi Gold Mining Complex".

3 Bulletin of Georgian National Academy of Sciences. 2007 Peter Felix-Henningsen, Tengiz F. Urushadze, Eliso I. Narimanidze, Lars-Christoffer Wichmann, Dietrich Steffens, Besik B. Kalandadze. "Heavy Metal Pollution of Soils and Food Crops Due to Mining Wastes in the Mashavera River Valley".

Revegetation of the Forest Rose Mine in Western Montana [1]

L.J. Ballek, K. Houck, D. Clary [2]

Abstract: The Forest Rose Mine site is an abandoned silver and lead mine located within the Beaverhead-Deerlodge National Forest and on private property in Granite County, MT. Herrera worked with the Montana Department of Environmental Quality (DEQ) and in conjunction with the United States Forest Service (USFS) to characterize the waste onsite, develop a site inspection plan to investigate human health and environmental exposures, reduce the mobility of these contaminants, and mitigate impacts to Dunkleberg Creek and the environment. Herrera's design included widening and surfacing the access road to allow for equipment to access the site, off-site removal of mining structures, removal of tailings and waste rock and placement in a repository on USFS administered lands, regrading and reconstructing a portion of Dunkleberg Creek as a step pool system for grade control and fish passage, backfilling and regrading open adits, capping the repository, and revegetating the mine site and repository. Construction activities were completed by September 1, 2013. Successful revegetation was critical to protect the new creek channel and raw slopes of the reclaimed mine site, as well as ensuring long term stability of the repository. Willows were planted along the stream channel in the reclaimed mine site and the reclaimed mine site, repository area, and turnouts on the road were seeded by October 11, 2013. Revegetation methods used, results of revegetation monitoring, and lessons learned will be discussed.

Additional Key Words: seed mixes, hydroseeding, soil amendments, tree protectors, straw wattles, woody debris, weed issues

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1 Oral paper presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4 - 9, 2016. Published by ASMR; 1305 Weathervane Dr., Champaign, IL 61821.

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Soil Conditions Promoting Long-Term Reforestation of Appalachian Forests[1]

J. M. Bauman, R. Brisbin[2*], J. Adamson, and E. T. Cline

Abstract: The Appalachian Regional Reforestation Initiative outlines planting methods that include preparation of a deep-rooting zone for healthy tree establishment (> 1 m deep). Continued monitoring may show that soil-ripping has pronounced effects in later years. However, little is known about the interactions of heavy metals, plant tissue, and the soil rhizosphere in reclaimed coal mined soils. This study examined soil samples, plant tissue, and mycorrhizal root colonization on hybrid chestnut (*Castanea dentata* × *C. mollissima*) that were planted in 2007 on a reclaimed coal mine site under various treatments: 1) deep-ripped to 1 m depth, 2) plowed and disked to 30 cm depth, 3) combination of the two treatment methods, and 4) untreated control plots. Chestnut trees were measured (n=95), plant leaves, flowers, and roots were collected (n = 52), and soil was extracted from the rhizosphere (n = 25). Soil and tissue were analyzed for metals (Ag, Al, As, Cd, Cu, Mn, Pb, S, and Zn) using inductively coupled plasma-mass spectrometry. Mycorrhizal colonization was quantified and genera determined by DNA sequencing. Results illustrate that tree height and % mycorrhiza were significantly different when compared to controls ($P < 0.0001$ and $P = 0.03$). When height and % mycorrhiza were regressed with soil metals, no trends existed. Further, when soil and foliage were compared among treatments, no differences in metal concentrations were detected. Some metal accumulation was noted within tissues of hybrid chestnut; however, this did not appear to impact growth. No differences were noted with regard to soil metals and mycorrhizal fungal community; community included native fungal species that are commonly associated with adjacent forest trees. After eight years, soil preparation methods do not impact hybrid chestnut or modify the soil rhizosphere due to interactions with heavy metals associated with coal mining.

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Hydraulically Isolating an Existing Repository and Potentially Increasing Capacity[1]

Kara M. Beaudoin, P.E.*, Cody J. Lechleitner, P.E.[2]

On behalf of the Successor Coeur d'Alene Custodial and Work Trust (CDA Trust), CDM Smith completed an alternatives assessment to address discharge (metals loading to surface water) from an existing mine waste repository. The alternatives assessment was completed as part of the remedial design and utilizes an adaptive management approach provided in the Record of Decision (ROD) to improve the cost-effectiveness and performance of the selected remedy. The alternatives assessment also included innovative approaches to potentially create additional clean borrow material and/or waste consolidation capacity needed for other remedial actions in Canyon Creek.

In 1996, the Silver Valley Natural Resource Trust (SVNRT) constructed a repository to consolidate mine waste/tailings removed from Canyon Creek alluvium; the material represented significant metals loading (zinc and lead) to surface water and groundwater in the watershed. After repository construction was completed, seeps appeared along the toe of the repository. Subsequent sampling of the seeps and downgradient monitoring wells indicated that the waste in the repository was not hydraulically isolated from groundwater and the repository itself had become a significant loader of zinc to Canyon Creek. The selected remedy presented in the ROD identified capture, conveyance, and long-term water treatment of the repository seep. As part of an adaptive management approach, an alternatives assessment was conducted focusing on solving the loading issue from the existing waste in the SVNRT Repository and potentially creating additional clean borrow material and/or waste consolidation capacity needed for other remedial actions in Canyon Creek. The assessment will likely result in a remedial design approach that achieves significant cost savings and improved long-term performance compared to the selected remedy.

Additional Key Words: mine waste, metals loading, Superfund, seeps, repository.

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Remediation of Acid Mine Drainage using a Sulfate-reducing Bioreactor at the Tab-Simco Passive Treatment System – An Update[1]

Paul T. Behum,[2] Angie Mick,[3] Krystal Pankey,[3] and Lilianna Lefticariu[4]

Tab-Simco is an abandoned coal mine located southeast of Carbondale in Jackson County, Illinois. Underground mining of two coal beds of the Pennsylvanian age Spoon Formation occurred between 1890 and 1955; surface coal mining re-affected the area in the 1960's and 1970's. Two acidic mine drainage (AMD) seepage areas were investigated at the Tab-Simco site between 2003 and 2006 by the Office of Surface Mining in cooperation with Illinois Department of Natural Resources, Office of Mines and Minerals (OMM). AMD seepage from the mine workings were coalesced at two flume structures and measured about 35,000 gallons per day. This AMD created a large "kill zone" of dead vegetation and resulted in a significant aquatic impact on nearby Sycamore creek. To abate the larger of the two seeps a passive-type treatment system was constructed in 2007 by the Illinois Department of Natural Resources, Office of Mines and Minerals (OMM). The principle technology employed is a 0.75-acre sulfate-reducing bioreactor, which is one of the first full scale system employed for coal mine drainage treatment in the US. A series of oxidation cells follow the bioreactor unit to precipitate most of the remaining metals. Over 8 years of operation approximately 98.6 percent of the iron, 98.8 percent of the aluminum, and 47.5 percent of the sulfate was removed (calculated from median contaminant values converted to mass basis using median discharge values). Significant removal was also observed for trace metals nickel (96.4%), zinc (95.9%) and cobalt (82.1%). From 2010 to 2012 there was a decline in the bioreactor outlet alkalinity from >400 to <130 mg/L calcium carbonate equivalent, which led to a decline in discharge water quality. To improve treatment OMM replaced the compost media in the fall of 2013 at a considerable cost. Since then the bioreactor-based system has again performed at a high rate despite a decline in the inlet water quality. As of September, 2015 the Tab-Simco passive treatment system was discharging net alkaline water (net non-Mn acidity = -92 mg/L). This paper is an update to a 2012 presentation.

Additional Key Words: Low-pH iron oxidation and passive treatment.

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Reclamation of the McLaren Tailings Restoring Previously Unusable Area back to its Historical Landscape[1]

M. Bennett[2] and T. Henderson

Abstract: In late 1960, Soda Butte Creek was considered the most polluted stream entering Yellowstone National Park. Significant portions of this pollution were coming from the McLaren Tailings impoundment, constructed in the historic channel and floodplain of Soda Butte Creek from 1934 to 1953. The site is located in the New World Mining District near the community of Cooke City, Montana, in an isolated alpine area characterized by short growing seasons, large winter snow accumulations, rapid spring runoff, and dynamic groundwater fluctuations. The Montana Department of Environmental Quality (DEQ) contracted Pioneer Technical Services Inc. (Pioneer) to complete an Engineering Evaluation/Cost Analysis (EE/CA) for the site in 2000 additional site investigations were completed in 2007/2008. Based on the site investigation, groundwater/surface water modeling, soil stability analysis, and sediment transport modeling results, Pioneer developed a remedial design to stabilize/remove 191,140 cubic meters of mine tailings, mine wastes, and impacted soils; construct an on-site repository, a site-wide dewatering system and water treatment system, 1,219 linear meters of storm water conveyance channels and infiltration systems; reconstruct 610 linear meters of Soda Butte Creek and Miller Creek; and revegetate 10 hectares. The project turned a previously unusable area back to its historical landscape while cleaning up the contaminated Soda Butte Creek, preserving an important fishery and natural resources of Yellowstone National Park. The DEQ awarded the construction contract in April 2010, construction began June 2010, with a completion date of fall 2015. Given the flexibility built into Pioneer's design, DEQ's receptiveness to value engineering, and the consistent diligence of the contractor (Knife River-Yellowstone Division) the McLaren project was completed one year ahead of schedule and $2.5 M under budget.

Additional Key Words: Yellowstone National Park, Cooke City Montana, New World Mining District, Mine Tailings, Stream Channel Construction, Dewatering System, Water Treatment.

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The Institutional Context of Reclamation: Changing Landscapes of Energy

K. Bills Walsh[1]

Abstract: Communities that experience rapid oil and gas development are susceptible to a variety of environmental and socioeconomic impacts. Considering the typical boom-bust dynamics experienced by resource-dependent locales, a community that once had a vibrant oil and gas centered economy will eventually see a drastic slow down or halt to operations due to resource exhaustion, price volatility or otherwise. In light of this pattern, there is a need to mitigate potential impacts through carefully crafted policy. Policies pertaining to resource extraction are enacted at all scales: federal, state and local. This poster will provide the institutional context of reclamation by synthesizing existing federal, state, and local policies around reclamation of oil and gas landscapes in three states in the U.S. West. In doing so, a comprehensive view of required reclamation will be portrayed. Oftentimes such information is found in disparate locations resulting in a muddled understanding of how much, and the type of reclamation that is mandated. Additionally, assembling all reclamation policies pertaining to the oil and gas industry allows questions, omissions, and concerns to become apparent. Reclamation policy of oil and gas landscapes in three U.S. states will be presented, and achievements and implications will be identified.

Keywords: reclamation, oil and gas, policy, land use.

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Improved Methods of Assessing Plant Species Diversity on Mine Reclamation Sites: A 10-year Update [1]

D.L. Buckner [2]

The practicality of evaluating species diversity on reclaimed lands has been limited by the ecological reality that species richness or diversity are attributes that tend to develop on time scales even longer than the ten-year liability period prescribed by SMCRA (on drier sites). Original simplistic application of Shannon-Wiener indices or use of life form "recipes" that were applied after the inception of SMCRA requirements had proven inadequate. At the 2006 ASMR annual meeting, several alternative methods of making these evaluations that had been developed a few years earlier were presented. These methods are designed to use current year's data to project forward a view of the slow progression of integration of additional species and life forms into the developing plant community. Because species richness is substantially variable from year to year in response to varying environmental conditions, these methods make comparative reference to conditions in un-mined vegetation. The application of these techniques has been undertaken at several surface coal mines in the western U.S. over that past ten years including several approved bond-release applications. These examples of the use of these alternative tests of species diversity will be examined to demonstrate their use.

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2. David L. Buckner, Senior Plant Ecologist, ESCO Associates, Inc.

Determination of Plant Cover in Field Sampling: A point-intercept method for all strata [1]

D.L. Buckner [2]

Determination of cover by plants under field conditions is a very common need in applied plant ecology and especially in evaluation of revegetation success. While guesses using “ocular estimation” have been prevalent for many decades, the close scrutiny given to cover data in the context of regulatory/permitting requirements and statistical evaluation has rendered ocular estimates largely useless due to very high variability between observers. Use of point-intercept methods in which data are collected using hit or miss tallies of objectively projected points is widely recognized as preferable. However, even within the methods of cover determination that can be categorized as point-intercept, there is wide variability in objectivity. The very common use of dropped pin flags along transects is an example of a method in which the procedural differences between different observers and the inherent inapplicability to any vegetation that is not prostrate on the ground nearly nullifies the advantage of point-intercept sampling. Most point –intercept methods are unable to equitably apply sound hit tallies to vegetation with multiple strata, especially to strata above waist- or chest-height. The optical device demonstrated in this talk has been developed during field sampling over the past 40+ years to allow equitable tally of hits from tree-tops to ground layer plants. In addition, the optical points are solidly projected to allow careful tally of hit or miss (as compared to what can be done with pin flags in flight, for example).

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2. David L. Buckner, Senior Plant Ecologist, ESCO Associates, Inc.

CASE STUDY: BAIRD WETLAND MITIGATION [1]

S. L. Busler[2], Y. Sheykhet, D. A. Guy, T. P. Danehy, R. M. Mahony, C. F. Denholm, C. A. Neely, M. H. Dunn

Abstract: The Baird Mine is an active quarry in the Vanport limestone located in western Pennsylvania (PA). The mine permit was originally issued in 1997; however, permitting efforts were later expanded due to the presence of 6.7 acres of wetlands and to potential conflicts with the *Sistrurus catenatus* (Eastern Massasauga Rattlesnake). *Sistrurus catenatus* is within the vicinity of the mine site according to the PA Natural Diversity Index, a database identifying resources of special concern. Requiring both wetland and upland habitats to survive, *Sistrurus catenatus* forms a symbiotic relationship with terrestrial crayfish, using the crayfish burrows to hibernate during the winter, while moving to drier uplands during the summer months. Of the wetlands to be affected, 5.9 acres were created by drainage from abandoned bituminous coal mining activities. Prior to the federal Surface Mining Control and Reclamation Act of 1977, a surface coal mine was operated upgradient from the Baird Mine site. Acidic drainage with low metal concentrations, issuing from an unreclaimed highwall, was intercepted by an old sediment pond which disseminated the drainage along the hillside creating a large, sloped wetland. This wetland was dominated by *Typha latifolia* and species of *Sphagnum* moss. Because of the proximity of the *Sistrurus catenatus*, the PA Department of Environmental Protection required a 2:1 (area-based) wetland mitigation. The mine is currently owned and operated by Allegheny Mineral Corporation, and three onsite wetlands, totaling 13.6 acres, have been constructed. The wetlands were created to maximize potential use by the *Sistrurus catenatus* and to establish a wetland community with diverse flora and fauna. Several reclamation techniques were used to construct the wetlands including the use of microtopography, deep pools, seeding, live stakes, snags, woody debris, and the creation of snake hibernacula. In the fall of 2015, as a small-scale experiment to compare the effectiveness of seeding, a native, obligate wetland seed mixture was used to vegetate one wetland while another was not seeded to allow vegetation by volunteer species. Monitoring will continue for five years or until the wetlands meet functional expectations.

Additional Key Words: Wetland Mitigation, Endangered Species, Eastern Massasauga Rattlesnake, Terrestrial Crayfish, Revegetation, Mine Land Reclamation, Live Stakes

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2. Shaun L. Busler, GISP, Biologist; Dan A. Guy, Geologist; Tim P. Danehy, QEP; Ryan M. Mahony, Environmental Scientist; Cliff F. Denholm, Environmental Scientist; Cody A. Neely, EIT, Environmental Engineer; and Margaret H. Dunn, PG. BioMost, Inc., 434 Spring Street Ext., Mars PA 16046 and Yan Sheykhet, Engineer, Allegheny Mineral Corporation, One Glade Park East, P.O. Box 1022, Kittanning, PA 16201.

Surface Mine to Biomass Farm: Growing Shrub Willows (*Salix spp.*) in Northeastern West Virginia - First Year Results[1]

Bart Caterino*[2], Jamie Schuler, Shawn Grushecky, Jeff Skousen

Abstract: Shrub willow (*Salix spp*.) has been a focus of international efforts to develop renewable alternatives for fossil fuels and to sequester carbon from earth's atmosphere. One area of interest has been to plant and cultivate willow on reclaimed mine lands. West Virginia's coalfields provide significant acreage for incorporating willow cultivation into reclamation. The objective of this study was to develop silvicultural treatments to overcome the most common properties of mine soils in Appalachia: high rock fragment content that often causes difficult planting, reduced nutrient availability, and low water-holding capacity. Cuttings of three shrub willow clones were planted with six planting/fertilizer treatments. The treatments compared a horizontal planting method to traditional vertical planting of cuttings, and no fertilization to controlled release and traditional fertilizer at a rate of 125 kg ha^{-1}. Following the first growing season, few treatment effects were detected. Clones clearly differed in survival and volume production but the influence of fertilizer treatments was unclear. Horizontal planting was not successful in overcoming rocky planting conditions. Survival, height, and diameter were 28, 22, and 23% lower for horizontally-planted cuttings relative to vertically planted cuttings, respectively. Response to fertilizer varied by clone. Results of this study will be used to direct future establishment practices on reclaimed mine soils in West Virginia.

Additional Key Words: reclamation, revegetation, short rotation coppice, planting methods

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Reducing Fresh Water Consumption in Hydraulic Fracturing by using Acid Mine Drainage as a Make-up Fluid[1]

E. E. Cavazza, P.E.[2], R. L. Beam, P.G., and M. P. Cavazza

Pennsylvania's rich coal mining history and subsequent legacy of acid mine drainage (AMD) discharges has resulted in over 5,500 miles of impaired streams. During the last ten years significant development of unconventional gas reserves contained in the Marcellus, Utica, and Devonian shale plays within the state has occurred. Drilling and hydraulic fracturing (fracking) operations require 5-7 million gallons of water per well. About 30% of the injected water typically returns to the surface as flowback which operators recycle for future well development. Consequently, make-up fluid is needed to replace the lost water, and fresh water has typically been used. Significant interest has recently developed in utilizing AMD instead of fresh water sources. For AMD to be successful as a make-up fluid, problematic dissolved constituents such as sulfate require some type of removal mechanism prior to re-injection. Elevated concentrations of dissolved barium and strontium in flowback waters may provide a viable mechanism for sulfate removal via precipitation reactions.

For this research, eight AMD discharges of varying quality and two flowback sources from recently fracked wells were sampled and analyzed. The samples were evaluated to identify undesirable constituents in each and potential mechanisms for removal. Mix ratios for each combination were developed, prepared, and analyzed using molar equivalents of known constituents and anticipated reactions. The lab analyses were used to develop a geochemical model to estimate the ideal mixing proportions of AMD to flowback, and additional sampling was performed to evaluate the kinetics of the reactions to determine real world applicability.

Comingling AMD with flowback water results in mutually beneficial reactions facilitating the removal of undesirable dissolved constituents from both sources. This could reduce the demand for freshwater sources of water for hydraulic fracturing operations, improve stream quality, and reduce the quantity of chemical additives needed to prevent down-hole scale formation. There is significant drilling activity near the AMD discharges being investigated, and the Pennsylvania Department of Environmental Protection is working with several partners to apply the results of this research in a field scale demonstration project.

Additional Key Words: Water Management/ARD, Abandoned Mine Lands (AML)

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Advanced Planning and Measurable Outcomes: Restoration Success in Southern Colorado

D.R. Chenoweth* and J.W. Schneider

In the 1970's reclamation was performed along a pipeline alignment which runs adjacent to the now constructed Southern Delivery System (SDS) in Colorado Springs, CO. The revegetation and stabilization of the 1970's alignment was slow and created not only environmental problems but also aesthetic problems for the surrounding landowners. As a result of these prior efforts, land owners in the area became reluctant to have additional disturbances to their land. As plans were being unveiled for the SDS pipeline, the surrounding landowners made sure to voice their expectations. The SDS team heard the public's voice and in turn developed a sophisticated reclamation program.

In order to address stakeholder's concerns as the SDS project moved forward, CSU developed an innovative and science based reclamation program for the SDS alignment. The reclamation program that CSU developed had 7 key features.

- Involvement of environmental consultants and professionals.
- Establishment and analysis of revegetation test plots.
- Soil analysis.
- Establishing pre-construction baseline vegetation surveys.
- Pre-qualified contractors.
- Budget development.
- Public education.

In 2012 Western States Reclamation, Inc (WSRI) was awarded the construction of the project based on a technical and price proposal. A key element to WSRI's proposal was an engineered temporary irrigation system. Other aspects were WSRI's ability to provide an in-house environmental team to conduct soil, vegetation and stormwater quality monitoring.

As the 3 year maintenance and monitoring period comes to a close in 2015 WSRI is confident in meeting the 90% pre-disturbance re-establishment goal.

It is the team's belief that a program designed similar to the one established for the SDS could benefit many restoration projects. The team didn't take an off-the-shelf specification and apply it to a project. They took the necessary steps to calculate what the project needed to complete reclamation successfully the first time.

Monitoring the Behavior of Sludge in the Vadose Zone[1]

M. Coleman[2]*, K. E. Butler,

Abstract: The Fire Road Mine coal mine in eastern Canada has been a source of acid mine drainage since the mid 1980's. Lime neutralization treatment has been ongoing. Placement of the resulting sludge back onto and into the backfilled mine site may be a factor in reducing the mine water acidity.

Apparent conductivity and electrical resistivity surveys have been instrumental in identifying the locations of highly conductive mine water and what we are postulating is the treatment sludge which hopefully settled out in the vadose zone during disposal. However, the conductivities of these zones vary across the site. And some areas thought to hold sludge have become less conductive over time. So does the sludge dry out and become less conductive? Does the sludge continue to migrate through the vadose zone? Excavations in the early 1990's indicated that the sludge only dried out near the surface but remained moist at depth.

To investigate these questions, apparent conductivity and electrical resistivity surveys will be re-acquired in areas that haven't been surveyed or received sludge deposition for more than a decade. Then, test pits will be used to allow in-situ measurements of electrical resistivity and sampling for water content in areas where sludge is present or absent. These data will be compared to the conductivity/resistivity survey results acquired on surface.

This information would be beneficial to determining the behaviour of the sludge in the vadose zone and hopefully establish whether the benefits of sludge in this zone are temporary or long term. This would be useful information for determining sludge depositional locations in the future so as to possibly have a more targeted but larger impact on localized mine water characteristics. Improving the mine water chemistry to "zero lime demand" is the ultimate goal for mine water treatment at this mine.

Additional Key Words: conductivity, resistivity, lime neutralization sludge deposition, acid mine water, acidity, coal mining, waste rock test pits

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COMPACTION IMPACTING HYDROLOGY AND TREE GROWTH ON A DEMONSTRATION MINE IN THE WESTERN GULF[1]

C.L. Comer[2], J.P. Stovall, M.W. McBroom, H.M. Williams, and Y. Zhang.

Abstract: Reclaimed mine sites and their high soil compaction rates show a decrease in productivity for tree growth in forested communities through Appalachia. The Forest Reclamation Approach (FRA) has been used in this region to increase reclamation success of their forests through proper soil management practices ideal for native trees. By creating a growth medium with low bulk density and ample depth, trees are able to flourish on post mined sites. In the West Gulf, this research is unavailable and conventional pan scraper practices are currently in use on lignite coal strip mines. The Office of Surface Mining Reclamation and Enforcement has partnered with Stephen F. Austin State University to create a demonstration and research site to examine the possibility of increasing productivity on post mined sites by adapting the FRA to this new region. A demonstration area has been established in east Texas with three treatments (conventional pan scraper practices, FRA dozer push-up technique, and an un-mined control) as a randomized complete block design (n=3). Each 0.8 hectare plot was planted with genetically improved loblolly pine in winter 2015-16. Hydrologic modeling will be done to determine the effects of the FRA on water quality and quantity in the Gulf along with analyzing seedling survival and growth under varying levels of soil compaction. This study is in its preliminary stages, but has great promise for reclamation practices to be used in the future.

Additional Key Words: loblolly pine, *Pinus taeda*, forestry reclamation approach, hydrology, coal mine

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Blending Historic Mapping with Lidar at Abandoned Mine Sites[1]

C. Coover[2]

Abstract: Investigation of abandoned mines involves gathering available information and matching it to current conditions. Often, historical information is difficult to interpret or properly locate due to poor documentation or illegible notations. Combining historical and current aerial photography with Lidar can reveal landmarks which aid the geolocation of old maps. At the Barker-Hughesville Mining District NPL site in Montana, mine surveys from 1881 through 1927 and workings maps from 1930 through 1953 were available along with short descriptions of mines from state and federal safety inspectors and geologists. Some of these were not locatable on a map until Lidar topography was obtained. Aerial photography showed the larger waste rock piles, but trees obscured many smaller features. The Lidar was able to remove the vegetative cover and reveal waste rock piles only a few feet across and allowed alignment of historical maps. Many additional features such as shafts, prospects, and roads were identified which were not seen during site visits due to the vegetation. At this site, Lidar was a very useful tool for documenting the extent of workings and features that would have not otherwise been found.

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Coal Mine Reclamation Costs and Local Economic Impacts in the Powder River Basin in Wyoming

Abby Perry,[1] Kristiana Hansen[2], Roger Coupal[3]

The Powder River Basin in Wyoming is the largest coal producing region in the United States producing 41% of the nation's coal for electricity production. As of 2014 there are over 44,000 acres involved in active mining operations in the State, a four-fold increase since 1999. The Surface Mining Control and Reclamation Act requires that mines maintain an ongoing reclamation effort as coal production is processed. In this study we estimate costs associated with coal mine reclamation by mine size from their annual reports submitted to Wyoming Department of Environmental Quality and through interviews. We then use the cost estimates to estimate economic impacts of reclamation activities in the Powder River Basin using a modified IMPLAN model calibrated for the Powder River Basin Economy in Wyoming.

Results suggest that there are considerable differences in mine reclamation costs within a particular region. Economies of scale are an important factor in determining costs. Reclamation cost components at large mines can be quite different relative to similar categories in small mines due in part to variations in topsoil haul distance (and cost). Larger mines have predictably higher overall costs but the cost per acre under reclamation is lower. Re-vegetation activities for large mines are estimated at $300 per acre and are 72 percent of small mine costs on a per-acre basis. The same is true for the area bond. Large mines have 29 percent lower area bond costs on a per acre basis than small mines.

Economic impacts of reclamation activities on the Powder River Basin economy are estimated based upon reclamation costs. The activities generated 926 direct jobs with a total of 1,594 total jobs, and $45.7 million in direct labor income and $72.1 million in total labor income.

Keywords: Reclamation Costs, Economic Development, Environmental Bonding, Phase Bonding.

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Insect Response to Reclaimed Well Pads with Different Vegetative Characteristics in a Semi-Arid Natural Gas Field[1]

Michael F. Curran[2] and Peter D. Stahl

Abstract: Although they provide multiple ecosystem services and have been shown to be critical players to reclamation projects, insects have not received a lot of attention in restoration ecology studies compared to other aspects of the field. While it has been estimated over 70% of forb species require an animal pollinator to successfully reproduce, emphasis on reestablishment of forb species to drastically disturbed lands in arid environments has only recently become a topic of high concern. In addition to benefitting success of flowering species on reclaimed sites, insects also play important roles in tri-trophic interactions and are critical food sources to many bird, rodent, reptile and amphibian species. In summer of 2015, a variety of well pads in the Pinedale Anticline natural gas field (Pinedale, WY) with different vegetation characteristics were sampled for insects and compared to each other and to adjacent 'reference' communities. Insect abundance and taxa richness were both significantly affected by vegetation characteristics on different well pads, and although reference vegetation communities chosen were similar in terms of vegetation characteristics, more insects appeared in reference communities near well pads with a strong forb component than those adjacent to less diversely vegetated well pads. A novel method taken to compare vegetation communities will be demonstrated, results of insect sampling will be shown, and implications of our findings will be discussed.

Additional Keywords: ecosystem services, forbs, plant-insect interactions, pollinators

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Release of Nutrients from Weathering in Mine Soils of Different Ages[1]

Kara Dallaire[2], and Jeff Skousen,

Abstract: Due to the steep terrain in the Appalachian region, stripping and stockpiling topsoil during mine construction is not always possible. As a result, coal mine operator are often left with brown and gray sandstone to use as topsoil replacement materials for reclamation. Brown sandstone is more weathered than gray sandstone and considered to be a more suitable topsoil substitute for reforestation. The properties that make brown sandstone more suitable than gray sandstone include lower pH, lower electrical conductivity, and lower coarse fragments. However, little information is available on the long term favorability of brown sandstone and if it over time will continue to have soil properties desirable for tree growth. There is also little information on how gray sandstone weathers over time and if gray sandstone will become more favorable to tree growth as it is weathered. This study was established to evaluate nutrient release from brown and gray sandstone over time. Different-aged reclaimed and abandoned areas with gray and brown sandstone at the surface were located around the Birch River Mine in West Virginia. Mine soils of 9, 20, and 45 years since disturbance were sampled as well as a native forest soil to determine the extractable amounts of elements in these spoils. BCR sequential extraction were performed on these samples. Nutrient availability for brown and gray sandstone was found to be highest at age 20. For P, Ca, Mg, Zn nutrient availability was found to be similar or even higher than the forest soils at age 20. Most elements decreased from age 20 to age 45 in both mine soils. By age 45, pH and organic matter content in the brown and gray sandstone were at similar levels to the forest soil.

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[1] Oral paper will be presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA ***Reclaiming the West*** June 4-9, 2016.

[2] Kara Dallaire (Graduate Student) and Jeff Skousen (Professor), Division of Plant and Soil Science, West Virginia University, Morgantown, WV 26505.

TROMPE DESIGN, CONSTRUCTION, AND PERFORMANCE[1]

T. P. Danehy[2], K. J. Palmer[3], R. M. Mahony, C. A. Neely, D. A. Guy,
C. F. Denholm, M. H. Dunn, B. R. Leavitt[4]

Abstract: Hydraulic air compressor technology known as a trompe, originally developed in conjunction with iron making in seventeenth-century Italy was subsequently used to power pneumatic mining equipment in the Americas near the end of the nineteenth century. This technology has been resurrected as a source of "off grid" compressed air used at mine drainage treatment sites. Mr. Bruce Leavitt, PE, PG, formerly of Washington, Pennsylvania, USA developed trompe designs assembled from commonly available low-cost materials and conducted research on trompes constructed of 50 mm (2 in), 80 mm (3 in) and 100 mm (4 in) schedule 40 polyvinyl chloride plastic pipe. These field tests demonstrated that about 9 L s^{-1} (140 gpm) of water can compress up to 170 L m^{-1} (6 ft^3 m^{-1}) of free air with a device that has no moving parts and requires no outside power inputs. As a furtherance of Mr. Leavitt's work, two, large-scale trompe systems have recently been constructed at the Rock Tunnel and Tanoma treatment sites in Pennsylvania. These systems are constructed with three 250 mm (10 in) trompes operating in parallel designed to utilize a total of 189 L s^{-1} (3,000 gpm) of water and compress up to about 1,600 L m^{-1} (56 ft^3 m^{-1}) of free air. The compressed air generated at the Rock Tunnel and Tanoma systems is used to aerate iron-laden alkaline coal mine drainage in order to enhance iron oxidation by decreasing dissolved carbon dioxide and increasing dissolved oxygen. Aspects of the research conducted on the smaller trompes as well as the scaling, design, construction, installation, and performance of the larger trompe systems will be presented.

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

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An Appalachian Regional Study to Predict TDS Release from Coal Mine Spoils[1]

W.L. Daniels[2], Z.W. Orndorff, C.E. Zipper, J. Skousen, C. Barton, and M. Beck

Abstract. Appalachian USA surface coal mines face significant public and regulatory pressure to reduce total dissolved solids (TDS) and associated levels of specific conductance (SC) in discharge waters, primarily due to effects on sensitive macroinvertebrates. Relatively low levels of SC (300 to 500 µS cm^{-1}) have been proposed as regulatory benchmarks for instream water quality while discharge levels from active coal mines in the region frequently exceed 1000 µs cm^{-1}. The primary objectives of this study were to (a) determine the relative effect of rock type and weathering status on SC leaching potentials for a wide range of regional mine spoils; (b) to relate the laboratory column SC to actual observed field levels; and (c) determine the most effective rapid lab analyses for SC prediction. We correlated laboratory unsaturated column leaching results for 39 overburden materials with a range of rapid static lab procedures such as total-S, saturated paste SC, and neutralization potential (NP). We also compared laboratory column leaching data with available field leaching and fill discharge SC data sets. This study reconfirmed that leachate SC is strongly related to rock type and extent of pre-disturbance weathering, with fine-textured and non-weathered strata posing increased TDS release risk. High-S black shales pose the highest TDS risk. The column technique generates a similar range and overall SC decay response to field observations within 5 to 10 lab leaching cycles (2.54 cm each), while actual reduction in SC in the field occurs over years to decades. Initial peak SC can be reliably predicted ($R^2 > 0.850$; $p < 0.001$) by simple lab saturated paste or 1:2 soil:water SC procedures, but predictions of longer-term SC levels are less reliable and deserve further study. Overall TDS release risk can be accurately predicted by a combination of rock type + S content, weathering extent, and simple saturated paste or 1:2 soil:water SC lab measurements.

Additional Key Words: Reclamation, soluble salts, mountaintop mining, valley fills.

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[2] W. Lee Daniels, Professor, Zenah W. Orndorff, Senior Research Associate, Carl Zipper, Professor and Mike Beck, Senior Research Associate, Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg, VA, 24061. Jeff Skousen, Professor, Div. of Plant & Soil Sciences, West Virginia University, Morgantown, WV, 26506. Chris Barton, Professor, Forestry, University of Kentucky, Lexington, KY, 40546.

Long-term Effectiveness of Three Passive Systems Treating Acidic, High-metal, Abandoned Coal Mine Discharges near De Sale, Pennsylvania[1]

C. F. Denholm*[2], T. P. Danehy[2], M. H. Dunn[2], S. L. Busler[2], C. A. Neely[2], R. M. Mahony[2], and D. A. Guy[2]

Abstract: The De Sale 1, 2, and 3 passive systems were constructed through a public-private partnership effort of the Slippery Rock Watershed Coalition between 2000 and 2002 to treat three separate acidic, high-metal, coal mine discharges emanating from surface mines in the headwaters of Seaton Creek, a sub-watershed of Slippery Rock Creek near De Sale, Pennsylvania. This case study highlights the successful long-term effectiveness of these treatment systems that are now between 14 and 16 years old and that have needed relatively little maintenance in comparison with traditional chemical-based systems. In addition, the combined impact of these systems and land reclamation projects have dramatically improved Seaton Creek, which once had been identified as the most heavily polluted major tributary of Slippery Rock Creek, but now has fish living in the stream and is almost able to be removed from the 303(d) list. The De Sale 1 discharge is on average 50 gpm, pH 4.1, 319 mg/L hot acidity, 82 mg/L Fe, 55 mg/L Mn, and 12 mg/L Al. The De Sale 2 discharge is on average 80 gpm, pH 3.3, 257 mg/L hot acidity, 26 mg/L Fe, 84 mg/L Mn, and 23 mg/L Al. The De Sale 3 discharge is on average 13 gpm, pH 3.1, 509 mg/L hot acidity, 107 mg/L Fe, 107 mg/L Mn, and 29 mg/L Al.

Additional Key Words: AMD, Slippery Rock Watershed Coalition, vertical flow ponds

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Unexpected Relationships between Methylmercury Enrichment in Fresh Waterbodies and Food-Web Uptake

Stephen R. Dent, PhD., Andy Greazel, Eric Blischke, CDM Smith; John Hillenbrand, EPA

The accumulation of methylmercury (MeHg) in fish tissue at concentrations above health-based thresholds is a widespread concern in the United States. State and federal agencies have increased their focus on watersheds impacted by anthropogenic mercury releases, with nearly 40 percent of U.S. river miles under a fish consumption advisory. MeHg is an organic bioavailable form of mercury that accumulates in fish tissue through trophic transfer. The conceptual model for mercury transformation and subsequent food-web uptake is as follows: (1) Anthropogenic inorganic mercury (Hg II) partitions onto a wide variety of mobile organic and inorganic complexes, colloids, and particulates that eventually settle out in sediment beds; (2) Hg(II) is transformed into MeHg by a variety of ubiquitous anaerobic bacteria, most notably sulfate-reducing bacteria, in stagnant anaerobic bottom water and sediments; (3) MeHg enriches in quiescent bottom waters; and (4) MeHg enrichment results in exposure to the base of the food web (i.e., algae) and subsequently biomagnifies through the trophic levels of the food web. This biomagnification phenomenon can result in seemingly harmless levels of MeHg in water (< 1 part per thousand) concentrate to potentially toxic levels of MeHg in fish tissue (> 300 parts per billion). Uncertainties persist as to the specific mechanisms that influence the production of MeHg and subsequent transfer of MeHg into the base of the food web. While some evaluations have shown a positive linear relationship between hypolimnetic mercury enrichment and zooplankton/fish body burden, others have observed an inverse relationship.

As part of the Klau/Buena Vista Mines (KBVM) Superfund Site watershed assessment of Las Tablas Creek, EPA and CDM Smith developed and implemented an innovative approach for assessing the biogeochemical cycle of mercury in Las Tablas Creek Ranch Reservoir (LTCRR). LTCRR is a small reservoir in the lower reaches of the Las Tablas Creek watershed. Mercury contaminated run-off from KBVM is transported downstream via Las Tablas Creek to LTCRR before entering a large water supply reservoir, Lake Nacimiento.

The purpose of the assessment was to evaluate the connectivity between mercury and the food web in the reservoir to support the evaluation of remedial options as part of the KBVM Superfund Site cleanup. A key component of this assessment is monitoring water column MeHg with trophic level 2 organism (large body zooplankton) body burden. Zooplankton were selected for the assessment instead of fish due to their rapid response to aquatic conditions and short life span as well as their ease of sample collection. Water column and zooplankton samples were collected, using trace mercury sampling and handling techniques, once in the wet season several days after a significant rain event (well mixed) and then once in the dry season when flow to and from the reservoir had ceased (stagnant). As anticipated, MeHg enrichment in the bottom water of the reservoir increased by over an order of magnitude from the wet to the dry seasons. However, MeHg in zooplankton decreased by 60 percent despite the increase in MeHg in the water. These observations are opposite of what is predicted by the conceptual model.

This presentation will discuss potential mechanisms that may account for this observed inverse relationship such as competition from mercury ligands (metal colloids, aromatic dissolved organic carbon, and sulfide) as well as algal bloom biodilution. Other case studies that have observed both positive and inverse relationships between MeHg water column enrichment and food-web uptake will also be discussed. Results from this and other studies illustrate the challenges of tracking mercury through the aquatic ecosystem and provide insight on using a multi-parameter approach for identifying strategies to ameliorate food-web uptake.

UNMANNED AERIAL SYSTEMS (UAS) – WHAT WE LEARNED IN OUR FIRST YEARS AS A COMMERCIAL OPERATOR[1]

M.R. Donner[2] and D.C. Mummert

Abstract: Unmanned Aerial Systems (UAS), commonly referred to as drones, are changing how we view and interact with our world, and spurring a renaissance technology development. They offer technical professionals new perspectives to solve the problems and challenges encountered every day. Not only can UAS replace many time-consuming and dangerous data collection tasks, they also provide cost effective access to higher quality imagery and data. Increasing UAS use also has inherent risks, associated with the equipment itself and with improperly qualified or trained operators, or operators working outside regulatory requirements.

Trihydro began developing a UAS program in 2014 to support our mining and reclamation projects, as well as other engineering and environmental projects. Trihydro spent a year researching equipment, applications, safety procedures, and applications before rolling out our program in summer 2015. Since commencing our program, we have worked with a variety of partners and clients performing aerial investigation, documentation, or mapping for process ponds, landfills, riparian areas, reservoirs, stockpiles, industrial sites, reclamation sites, and mine sites. Through our program development and UAS projects we have encountered many new and exciting applications and encountered numerous potential pitfalls.

This discussion will cover regulatory requirements, potential applications, footage, and products from a variety of projects, and example UAS standard operating procedures and best practices for successful UAS operation.

Additional Key Words: Unmanned, Drones, UAS, UAV, Regulations, UAS Applications, UAS Procedures, Aerial Mapping, Aerial Inspections

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[1] Paper presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA ***Reclaiming the West*** June 4-9, 2016. Published by ASMR, 1305 Weathervane Dr., Champaign, IL 61821.

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Got Aluminum? - Removing suspended metals with peat based sorption media

P. Eger[1], P. Jones, and D. Green[2]

Abstract:

Total aluminum requirements have been reduced to a monthly average of 0.45 mg/l for mine water discharges in West Virginia. As the discharge is required to have a pH greater than 6, essentially all the aluminum is present as fine particulates. Although both active and passive treatment can be successful in raising pH and removing essentially all the aluminum from solution, the low concentrations of suspended metals are causing permit violations. Peat based sorption media with its large surface area has been successful in removing suspended metals and laboratory tests were done with waters from several mine sites to determine the feasibility of removing aluminum prior to discharge. Particle size was estimated using sequential filtration. Particle sizes for the effluent from an active treatment plant were slightly larger than those treated passively. About 50 % of the particles were greater than 25 micron for the active treatment while 50% of the suspended material was between 5 and 8 microns for the passive treatment effluent. Although the initial water was below the discharge standard, the peat media successfully removed about 60-80 % of the suspended aluminum. Larger treatment beds are expected to provide better treatment and pilot testing has been recommended.

Additional Keywords: passive treatment systems, solids removal

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[1]Oral Paper presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA, June 4-9 2016.

[2]Paul Eger, Global Minerals Engineering, Hibbing, MN 55746. Peggy Jones and Doug Green, American Peat Technology, Aitkin MN.

Acid Mine Drainage treatment with Dispersed Alkaline Substrate and Limestone Beds

K.E. Dieterman, C.L. Kairies-Beatty, and P. Eger[2]

Abstract:

Although the Soudan Mine treats their entire discharge with a conventional ion exchange system, two smaller flows within the mine contribute 80 - 90% of the overall metals. If these waters could be treated individually, expensive surface treatment might be avoided. A limestone dispersed alkaline substrate (DAS) was successful in increasing pH from 2.5 to around 7 and removing over 99% of the iron, aluminum and copper and about 50% of the cobalt The bed operated successfully for about a year without plugging. The columns released manganese throughout the experiment and less than 10% of the manganese was removed in the limestone beds. Pretreating the limestone with potassium permanganate for about 2 weeks dramatically improved both manganese and cobalt removal to over 90%.

Additional Keywords: passive treatment system, dissolved metal removal, Soudan Mine

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[1]Poster paper presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA, June 4-9, 2016.

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Succession of Algae, Moss and Herbaceous Flora during 29 Years in Prairie Opencast Coal Mine, Inner Mongolia, China[1]

X. Fan[2], Z. K. Bai, P. Y. Sun

Abstract: The initial stage of primary succession on post-mining bare land is biological soil crusts (BSCs), which plays an essential role in soil development, erosion prevention, hydrological and nutrient cycles, and influences succession of vascular plants community. It includes 3 stages in succession order: cyanobacterial crust, lichen crusts, and moss crusts. Yimin opencast coal mine is located in Hulunbuir Prairie, one of the four biggest prairies of the world. In this paper, its west dump, the outer dump formed with soil substitutes from 1986 to 2008, is taken as an example. After 29-year natural recovery, a mixed vegetational community of BSCs (approximately 80% coverage) and herbaceous plants (<20% coverage) had formed on the dump, differing from surrounding intact sites, with scarce BSCs coverage and >70% herbaceous plants coverage. To study the flora community composition and succession of this ecosystem, 66 1mx1m herbaceous plots (33 of different reclamation age and 33 of original sites) were set to investigate community structure and biomass. Typical BSCs samples of different reclamation ages and original land were collected and each was divided equally into 2 parts. One part was dissected under anatomical lens to identify the moss species. The other part was inoculated on BG-11 medium and cultivated under the conditions of 70μE/(m^2·s), 25℃ and 12h/12h light-dark cycle. After 30 days, algae colonies were then identified under optical microscope. The result shows that cyanobacterial-moss mixed crust forms in 7a after reclamation. Filamentous cyanobacteria species rises first and then falls with reclamation age and the meaning species of reclaimed sites exceeds surrounding sites. 2 Moss species (waiting to be identified) appears in crust samples of <20a reclaimed sites and the third species appears and dominant the crust gradually from 20a. After 20a recovery, dominant herbaceous species of zonal vegetation appears, however, herbaceous biomass reaches only 1/3 of intact sites. Comparing with abandoned arable land, vegetation community succession on reclaimed sites is much slower. It suggests that top soil management is essential in this area, to initiate secondary succession after reclamation, which is faster than primary succession. Artificial BSCs is a possible method to accelerate succession on reclaimed sites with soil substitutes.

Additional Key Words: Biological Soil Crusts; Primary Succession; Topsoil Management

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[2] Xiang Fan, PhD student, Land Reclamation and Ecological Restoration, China University of Geosciences (Beijing), Beijing, 100083, Zhongke Bai, Professor, Land Reclamation and Ecological Restoration, China University of Geosciences (Beijing), Beijing, 100083, and Pengyang Sun, Land Reclamation and Ecological Restoration, China University of Geosciences (Beijing), Beijing, 100083.

What's So Great About Beavers?[1]

S. Firor [2]

The North American Beaver (*Castor canadensis*) was extirpated from the entire western United States in the 19th century. This animal is a keystone species in the ecological makeup of the west, and its loss has impacted everything from butterfly habitat to water supply. Beavers play a unique role in the ecosystem by actively modifying habitat. Their tree cutting and dam building activities promote plant diversity, establish wetlands, and decrease sediment loading. Restoration of habitat in conjunction with beaver reintroduction is being implemented in northern Idaho on sites impacted by mining, logging, water diversion, and other human activities. Beaver restoration can provide long-term stability and resilience of hydrologic systems in conjunction with other reclamation activities. We have implemented beaver restoration projects since 2007 on several miles of wet meadow stream systems in the Potlatch River watershed. These projects include techniques ranging from construction of imitation beaver dams to beaver reintroduction. The benefits realized on these projects include improved water management and retention, flood mitigation, enhanced ecological function, and increased species diversity. This presentation will include a discussion of the following: how the hydrologic environment, ecological landscape, and society are impacted by beavers; how beaver restoration is being implemented and preliminary results of these restoration efforts; how beaver restoration can be implemented in conjunction with mine reclamation; and how beavers and humans can coexist without threat to infrastructure.

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[1] Oral presentation at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4 - 9, 2016.

[2] Susan Firor, P.E., Principal Restoration Engineer, TerraGraphics Environmental Engineering, Moscow, ID 83843.

RIPPING AND NATIVE SEEDING TREATMENTS INFLUENCE ON VEGETATION COMPOSTION OF COMPACTED TAILINGS

J. A. Franklin and M. Aldrovandi

Abstract. On older reclaimed mine sites, both compacted soils and aggressive non-native ground covers can compete strongly with planted tree seedlings, hindering reforestation efforts. Deep ripping is. Successful tree establishment has been seen on sites where compaction is relieved by deep ripping herbicide is used to control ground cover, but herbicide treatments are expensive and may have a negative impact on planted trees. An experiment was established to test for tree growth and changes in vegetation composition on sites where compaction had been relieved by ripping, then treated with seeding or herbicide. Initial composition of vegetation was surveyed in August of 2014, and was dominated by non-natives *Lespedeza cuneate*, tall fescue (*Schedonorus arundinaceus*), and white clover (*Trifolium rep*ens), with a total herbaceous cover of 93%. Soils were cross-ripped to a depth of 1.2m on a 2.4m grid. Of 5 test sites, each was divided into 4 treatment areas, two of which were seeded with two different mixtures of herbaceous, primarily native species in Jan. of 2015. Bare-root, 1-0 tree seedlings of 15 hardwood species were planted on a 2.4 x 2.4m spacing. A third treatment had herbicide applied in a 0.5m radius around each planted tree. The composition of herbaceous vegetation was monitored in May and August. Vegetative cover was reduced to 66% across all treatments in May, and by August both seeded and control treatments had returned to initial levels (82-93%), while herbicide treatments still had significantly reduced cover (78%). Ripping did not reduce the frequency or dominance of lespedeza, but did reduce the presence of tall fescue from 52% of plots to 13%, and its dominance from to 34% to 4% of plots. Seeded species were observed, but did not dominate the plots in the first year. Continued monitoring of vegetation and growth of trees is planned.

Additional Key Words: hardwoods, warm-season grass, forestry, native species

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Innovative Approach Using GIS to Advance Reclamation and Bond Release

Rio T. Franzman[1] and Nathan J. Wojcik[2]

Abstract: Wyoming Department of Environmental Quality (WDEQ) Interim Vegetation Monitoring (IVM) requires mines to collect data to assess a mines performance in regards to reclaimed lands. Across industry, the data are reviewed by mine and WDEQ staff for content and an assessment of the data is made. However, in the current report format, it's difficult to look at data spatially or to identify trends. While this required process has value, we believe the utilization of an ArcGIS® database to capture and direct the focus of the data towards bond release is a more efficient tool.

Measuring reclamation success is an integral part of the bond release process. Integration of reclamation data and GIS functionality provides an efficient means to track bond release and verify reclamation unit status. Tracking the revegetation success and shrub reestablishment criteria are critical in the determination as to when an area is ready for bond release. It is also critical to determining the effectiveness of reclamation and to identify any additional work (seed mix, weed treatment, soil amendments, etc.) that may need to improve on reclamation success.

By developing a database with an easy to understand color coding system, mine operators can demonstrate visually the current status of the key bond release metrics and make valuable reclamation management decisions based off of it. In the current database configuration the database allows for varieties of datasets to be evaluated including: bond release metrics, seed mix, precipitation data, and other datasets allowing for a complete demonstration of reclamation status.

Additional key words: mining; mine closure; tracking; revegetation success; shrub establishment; reclamation management decisions

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Recovery Rate and Purity of Some Dissolved Metals in Mine Drainage from Abandoned Coal Mine[1]

Gil-Jae Yim[2], Song-Min Bok, Sangwoo Ji, Chamteut Oh, and Young-Wook Cheong

Abstract: Mine drainage discharged from abandoned mines is causing a lot of pollution. Conventional lime dosing process generates a lot of waste due to the generation of the sludge in the process. Therefore, this study aims to assess the feasibility of both treating the mine drainage while recovering individual metals and decreasing the amount of waste by decreasing the amount of sludge. In order to selectively recovery Fe and Al in the coal mine drainage as high-purity precipitation, we installed a selective sequential precipitation system with a buffer tank. The recovery rate and purity of the precipitates were evaluated from field measurement and chemical analysis. The water treatment circulation structure was designed to let the mine drainage, which flows into the neutralization and settling tank, completely react. Each processing tank was installed with a sensor to measure the pH and the temperature of the inflow water. In addition, a slanted board was installed in the settling tank to control the suspended solid that is emitted to the upper flow and to enhance the recovery rate and purity. Continuous operation was achieved by adding a removal system at the bottom of the settling tank to prevent the operation from stopping due to overflow from the accumulation of precipitates. We also evaluated the recovery rate and the purity of Fe and Al. The recovery rate of Fe and Al are 99.4–99.7% and 99.6–99.9%, respectively. The purity of Fe and Al was determined to be 98.7–99.8% and 99.1–99.8%, respectively.

Additional Key Words: Selective Sequential Precipitation, Dissolved Metal, Coal Mine

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1. Poster paper presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4 - 9, 2016. Published by ASMR; 1305 Weathervane Dr., Champaign, IL 61821.

2. Gil-Jae Yim, Principal Researcher, Geologic Environment Division, Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, Korea.

Validating a Method for Determining Specific Conductivity in Mining Wastewater[1]

J.L. Parks[2], G. Boardman, K. Gunther, C. Grey[*], S. Cox

Abstract: The USEPA issued guidance to reduce the impact of surface mining activities on receiving streams in the Appalachian region by limiting the specific conductivity (SC) of discharged waters to 300 – 500 μS/cm. Our review of existing literature indicated that mining impacted streams often have SC levels ranging from 500 – 2,000 μS/cm. Although numerous treatment technologies are available to remove SC, a method to estimate SC from a water's chemical make-up would be beneficial in that it would enable design engineers to anticipate how a treatment technique will impact the final SC. In this study the method proposed by McCleskey et al. in their 2012 *Geochimica et Cosmochimca Acta* paper entitled, 'A new method of calculating electrical conductivity with applications to natural waters,' was used to estimate SC in 24 solutions prepared by adding various chemicals to distilled water. The chemicals included NaCl, KCl, $CaCl_2$, KNO_3, $NaHCO_3$, Na_2SO_4, K_2SO_4, and $MgSO_4$ so that the four primary components of SC in Appalachian waters (sulfate, bicarbonate, calcium, and magnesium) could be evaluated. Concentrations ranging from 0.001 M to 0.1 M were used. The SC and pH of each solution were measured, and metals concentrations were determined by ICP-MS. MINEQL+ was used to estimate the concentration of each chemical complex for use in the McCleskey et al. method. For the monovalent ionic solutions (NaCl, KCl, KNO_3) comparisons between actual and predicted SC were excellent, with an average error of 3% for all concentrations tested. Overall, the method accurately predicted the SC of 15 of the 24 solutions within a few percent. All concentrations of bicarbonate (alkalinity) resulted in a measured SC about 15% lower than the method prediction. High concentrations of sulfate resulted in large deviations from the predicted SC.

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1. Oral presentation at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4 - 9, 2016. Published by ASMR; 1305 Weathervane Dr., Champaign, IL 61821.
2. Jeffrey L. Parks, Research Scientist, Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA 24061; Gregory Boardman, Professor, Virginia Tech, Blacksburg, VA 24061; Kristin Gunther, Virginia Tech, Blacksburg, VA 24061; Catherine Grey* (presenter), Virginia Tech, Blacksburg, VA 24061; Steven Cox, Visiting Assistant Professor, Virginia Tech, Blacksburg, VA 24061.

Proof of Concept Bio-Terrace Aluminum Removal at an Abandoned Metal Mine, Idaho [1]

James Gusek*[2], Lee Josselyn[2], Christopher McCormack[3], David Jenkins[4], and Joseph Larsen[5]

Abstract: Acidic mining influenced water (MIW) discharging from an abandoned drainage tunnel in south-central Idaho exhibits a pH of 3.5 with elevated dissolved iron (1,500 ppm), dissolved aluminum (800 ppm) and additional contaminants such as copper (143 ppm), zinc (83 ppm), cadmium (2 ppm), and manganese (44 ppm). Sulfate concentration is about 4.5 g L^{-1}. Typical MIW flow is on the order of 12 L min^{-1}. A "volunteer" terraced formation at the adit portal appears to be comprised of iron and aluminum precipitates; cyanobacteria and organic detritus appear to be facilitating aluminum precipitate deposition.

The observations at the tunnel portal lead to the construction and monitoring of four stainless steel troughs (6m long x 460mm wide x 50mm deep) that were configured to receive equal flows of MIW at rates of about 3 L min^{-1}. Each gently-sloped trough was fitted with different media: 1) leave litter covered with jute cloth, 2) inert filter media, 3) native soil covered with coconut coir, and 4) inert quartz sand placed between 25mm high plastic baffles. Each trough was inoculated with cyanobacteria algae harvested from the adit portal. Each trough received acidic MIW flow for 60 days in the summer of 2015. Within two weeks of startup, iron and aluminum precipitates were observed in the troughs in varying amounts, replicating the "volunteer" terraces that first prompted the proof of concept (POC) experiment.

Each trough removed iron and aluminum as evidenced by data collected during an "autopsy" event at the conclusion of the POC test. Preliminary removal rates ranging from 17 to 76 grams of iron/aluminum hydroxide precipitate d^{-1} m^2 were observed. The positive test results supported the design of a larger iron/aluminum terrace passive treatment system which is scheduled to be constructed at the site in 2016.

Additional Key Words: Iron, ARD, Passive Treatment

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Bench Scale Hexavalent Chromium Removal with a Biochemical Reactor[1]

James Gusek*[2], Lee Josselyn[2], Henry Sauer[3], Josia Razafindramanana[4]

Abstract: Circum-neutral mining influenced water (MIW) in runoff at an active nickel and cobalt mine in Madagascar exhibits elevated hexavalent chromium levels of about 2.0 mg L^{-1}. A low-grade ore stockpile and some site geologic characteristics contribute to the metal load that appears to vary with runoff rates and the volume of stored water in the drainage basin dam. This situation makes compliance unpredictable and difficult to remedy. The mine adopted a proactive approach to the issue and commissioned an on-site test to evaluate the effectiveness of the biochemical reactor (BCR) technology in reducing chromium levels at the site.

The BCR portion of the bench-scale test apparatus is comprised of seven 200-liter plastic drums each receiving a measured flow. All the BCR units are bottom-fed with water. Six receive MIW and the seventh functions as a control and receives "clean" water. The six "MIW" BCR drums are filled with three different media mixtures. Half of the drums have plants growing on the media surface; the corresponding "duplicates" for each mixture do not have plants. The non-plant BCR set effluents are fed to an additional series of open tanks that are filled with native soil and wetland plants for additional aerobic polishing. Mine personnel maintain the test system, measure field parameter data, and collect water samples for analysis.

The hydraulic retention time (HRT) in the BCR units is relatively short. The initial HRT was set to 48 hours and was progressively shorted to about five hours in the final two weeks of the 16-week test. Preliminary data show the BCR technology is appropriate and test effluents meet the environmental standards. These positive test results supported the design of a larger scale passive treatment system which is scheduled to be constructed at the site in 2016.

Additional Key Words: Passive Treatment, BCR, Madagascar, Nickel

Optional Data: Project Location Latitude: 18.85°S; Longitude 48.29°E

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The Use of Soil Sampling and Investigations to Improve Reclamation Costs

J. Hartsig, A. Dejoia, D. Buckalew*

Abstract

Arnold's Custom Seeding (ACS) reclaimed 47 miles of right-of-way (ROW) in Eastern Ohio during the summer and fall of 2015. The reclamation specifications for the ROW included a blanket lime application rate of 4.5 tons per acre. Steep terrain along portions of the ROW required helicopter application methods. Additionally, county soil surveys were investigated for soil pH recommendations. Out of the nine major soil series encountered along the ROW, five soil series indicated pH values that warranted a lime recommendation. Due to previous experience in the area, ACS recommended that soil sampling and analysis be conducted to determine the actual lime rates. Soil samples were collected from 40 separate locations along the ROW and sent to a soil testing laboratory for pH (1:1), and buffer pH (Melich III) analysis. Soil samples were reviewed by a Certified Professional Soil Scientist and lime requirements, when required, were determined to achieve a soil pH of at least 5.7. Soil pH as measured by laboratory analysis ranged from 5.1 to 8.1, with a median value of 5.8. Calculated lime requirements ranged from 0 to 4.5 tons per acre. Only 16 of the 40 samples required lime applications with only 25% of those samples requiring lime had lime rates of 4.5 tons per acre. The soil sampling allowed the team to only apply lime to required areas of the ROW where soil pH could negatively impact reclamation success. The use of soil sampling led to substantial cost savings without negatively impacting reclamation success. Site-specific soil testing and investigations, like those shown in this case study, can be incorporated on pipeline projects to help curb expensive reclamation efforts after construction and achieve appropriate reclamation criteria.

Additional key words: aerial seeding, acidic soils, Ultisol

Aaron Dejoia, CPSS; James Hartsig, APSS; Dustin Buckalew, *Presenter

LAB SCALE BATCH WEATHERED LIMESTONE TESTING TO DETERMINE SYSTEM SIZING[1]

A.P. Hollern[2], A.T. Hajec , J.E. Fortunato, W.H.J. Strosnider, C.A. Neely, D.J. Daley

Abstract: Design of limestone-based passive treatment systems is typically undertaken using information from limestone exposure testing. These tests generally use fresh limestone that had not been previously exposed to acid mine drainage (AMD). In order to better emulate operational conditions of an automatically-flushing limestone bed, three 17.5 gallon plastic tubs filled with 55% $CaCO_3$ limestone and raw AMD from the Puritan Mine discharge located in Portage, PA were closely monitored over a 24-hr period. The limestone had been used, and weathered, within a treatment system handling the same waters for 1 year. Alkalinity, pH, temperature, specific conductivity, and metal concentrations (Fe, Al, Mn) were measured. The AMD had an initial pH of 3.22, and dissolved metal concentrations of 8.06 mg/L, 10.57 mg/L, and 1.25 mg/L of Fe, Al, and Mn respectively. The goal was to determine a hydraulic residence time (HRT) needed to raise pH >6.5 and have all metal concentrations <1.0 mg/L. Rate constants for pH and metal precipitation were determined in order to find the appropriate HRT and apply that to the design of aerobic limestone batch reactor treatment systems. A simple model was created to predict how pH would increase depending on different limestone sizes. Using these findings, an automatically-flushing limestone bed system will be designed for the Puritan Mine discharge, allowing the recovery of key local streams.

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Innovations of land reclamation and ecological restoration in coal mining areas in China

Zhenqi HU[1]

Abstract: Coal is the most important energy in China, accounting for about 70% of energy consumption. More than 85% of total coal output comes from underground mining. Land subsidence due to underground coal mining is a serious problem in China. This paper introduced the impact of coal mining subsidence on environment and some Innovations of land reclamation and ecological restoration in China.

This study showed that reclamation is part of green mining, which is the key to repair the environmental damage. Renovation on concept and idea of reclamation is very important: The “reclamation” is not only the “land issue”, but also the “environmental issue”. Reclamation should not be the afterward activities (end-of-pipe solution), should be pre-mining or synchronous operation with mining. Concurrent mining and reclamation is a new technology and idea, which could restore much more land, which is the innovation of subsidence land reclamation. Subsidence land reclamation filled with river sediments instead of coal wastes and fly ask is another innovation on filling reclamation, which is environment-friendly reclamation method. Innovation on reclamation of coal waste piles with spontaneous combustion is to control re-burn of the coal waste pile.

Key words: Land reclamation, ecological restoration, coal mining, subsidence, coal wastes

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Mechanical Suppression of Grasses to Reduce Competition with Wyoming Big Sagebrush (*Artemisia Tridentata*) Seedlings in a Fire Disturbed Landscape[1]

Amy P. Jacobs[2]

Efforts to restore burned Wyoming big sagebrush (*Artemisia tridentata*) populations are frequently unsuccessful due to the inability of sagebrush seedlings to compete with established grasses which are not killed by fire. Current best management practices used to curb competition typically include seeding of native perennial grasses and use of herbicides. The objective of this study focuses on the efficacy of mechanical suppression of grasses competing with planted sagebrush seedlings using various mulch treatment types. The study site is located in a burned Wyoming big sagebrush landscape in Converse County, Wyoming. Approximately 16,000 container grown Wyoming big sagebrush seedlings were planted into 164 exclosures (95m^2). Each exclosure was planted exclusively using one of five mulch treatment with 95 seedlings per exclosure. Seedlings were planted in uniform rows with 2m separation between each. Monitoring of the site includes quantifying seedling survivorship and crown volume. Results indicate that treatment types have a significant effect on survivorship and an even more significant effect on crown volume (up to 400%). Research methodology and results will be expanded upon at time of presentation.

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Proof of Concept AMD Passive Bioremediation at an Abandoned Mine, Idaho [1]

David Jenkins[2*], Donald Stevens[3], Holly Trejo[4], James Gusek[5], and Joseph Larsen[6]

Abstract: Acidic mining influenced water (MIW) discharging from an abandoned drainage tunnel in south-central Idaho exhibits a pH of 3.5 with elevated dissolved iron (1,500 ppm), dissolved aluminum (800 ppm), and sulfate concentration of about 4.5 g L^{-1}. Typical AMD flow is on the order of 12 L min^{-1}. A presumed terraced formation at the adit portal appears to be comprised of iron and aluminum precipitates.

Observations at the tunnel portal lead to the development of static microcosm testing (SMT) simulating various environmental conditions in order to understand and promote the algae and bacteria growth and facilitate metals precipitation and eventual remediation through passive, natural means. The SMT testing involved simulating various treatment environments by fabricating four laboratory-scale test trays filled with acid mine drainage (AMD) from the portal and observed over a period of 20 days. The simulated environments involved and compared:

- The addition of glucose and local organics. The addition of glucose was to provide a readily available carbon source for the high-acid, metals precipitating algae (such as *Cyanidium caldarium*) to grow rapidly.
- Optimum temperature (approximately 30° C) trays versus chilled trays (just above freezing);
- Sunlight entry (in clear trays) and darkness in opaque trays;
- The addition of an inert, high-density bio-propagation mat to physically support algae growth and stability;

This paper will discuss the findings of the testing including implications for design of a full scale, passive AMD treatment system for the site. Also discussed will be the considerations and implications of this type of passive, inexpensive and green treatment technology to other sites with AMD treatment challenges.

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Novel Capping and Revegetation of an Abandoned Mercury Mine, California [1]

David Jenkins[2], Donald Stevens[3*], Holly Trejo[4], and Andrew Campbell[5]

Abstract: California has the largest exposures of serpentine in North America, and with it, the richest bodies of mercury ore. Nobody knows for sure how many abandoned mercury mines remain in California, but it ranges from at least 550 to as many as 2,000. As of 2009, the vast majority had never been studied for cleanup, and the federal government had tried to clean up fewer than a dozen of them. A few more mines have been remediated since then, including the Helen, Contact, Sonoma, and Rathburn Mines.

Mercury-laden sediments from these mines present a water quality risk to California streams, reservoirs, and the San Francisco Bay. The presumptive remedy for this type of contaminant transport involves consolidating mercury wastes and capping them with a water-shedding, erosion-resistant cover of clean soil. Revegetation of that soil plays an important role in the control of the cap's erosion and of the wastes beneath it.

Revegetation of serpentine soil, present at Rathburn, is challenging. It exerts a highly selective, demanding influence on plant life, which may grow sparsely. However, one of the best erosion control methods is allowing water to actually infiltrate the soil cap, which requires a paradigm shift in how environmental engineers envision repository caps to function.

This paper will discuss how a repository cap at the Rathburn mine was designed to isolate mercury wastes, promote infiltration through serpentinite soil, and economically support the growth of native plant species.

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Acid Soil Remediation and Revegetation of Metal Contaminated Pastures, Deer Lodge, MT[1]

S.R. Jennings[2], and T. Parker[3]

Abstract: Upland pastures near the Clark Fork River floodplain at Deer Lodge, MT became contaminated with copper, arsenic, zinc, lead, and cadmium through historic irrigation practices using river water with elevated metal levels. A mosaic of bare ground, sparse vegetation, invasive species, and acidic soil conditions resulted. Soil remediation was performed in 2015 on 36 ha (90 acres) using sugar beet lime (precipitated calcium carbonate) compost and a 5 cm (2 in.) thick borrow soil with low metal levels that was tilled into the upper 15 cm (6 in.) of the treated soil. The contaminated soil was treated to a total depth of 30 cm (12 in.) using conventional tillage equipment. Total and water soluble metal levels were measured before and after treatment showing the soil chemistry change from a phytotoxic condition to a soil solution dominated by alkaline cations and nutrients. Both water soluble and DTPA extractable metals were measured before and after treatment providing an example of their respective usability in monitoring 'plant available' metal levels. Seeded species included both native and introduced species adapted to the semi-arid conditions of the Deer Lodge Valley. Vegetation monitoring during the first growing season (2015) demonstrated the successful establishment of the seeded species.

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Metal Recovery using Biogenic Sulfide from Acid Mine Drainage

Sangwoo Ji[2], Gil-Jae Yim, Young-Wook Cheong, Chamteut Oh

Abstract: This study aims to recover metals from the acid mine drainage (AMD) using biogenic sulfide which was produced by the bioreactor contained the sulfate reducing bacteria (SRB). Bioreactor was used the native SRB bacteria mixed culture collected from the spent mushroom compost in passive treatment system located in Mungyeong, Korea. The Gapjeong coal mine drainage (pH 6.5, SO_4^{2-} 410±26 mg/L) was amended as sulfate source to the bioreactor. The temperature in the bioreactor maintained 35±0.2℃. The pH and Oxidation Reduction Potential (ORP) values were continuously sustained 6.9±0.3 and –900±50mV respectively. Metal sulfide precipitates were induced by mixing the Il-kwang mine AMD (pH 2.45±0.05, Al 34.15 mg/L, Fe 187.79 mg/L, Cu 18.42 mg/L, Zn 15.75 mg/L) with bioreactor effluent at pH 2.5 and 4.0. The precipitates of CuS and ZnS were observed. The ratio of metal sulfide precipitate in the pH 2.5 was higher than that at pH 4.5 about 9.9% of 22.4%. At the pH 4.5, the proportion of the metal hydroxide and calcium ferrite were higher than metal sulfide. At the pH 2.5, the reaction of Cu and Zn with biogenic sulfides and forming the metal sulfide precipitates is dominant. But at the pH 4.5, Fe and Ca precipitates are increased as iron hydroxide and calcium ferrite. The using biogenic sulfide for the metal recovery as metal sulfide from the AMD is very useful. But the impurities such as iron hydroxide and calcium ferrite are must be reduced. The more study is needed for getting more pure metal sulfide precipitates.

Additional Key Words: Metal sulfide, Metal hydroxide, Bioreactor, Sulfate Reducing Bacteria (SRB)

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Mining reclamation through service-learning: case studies from Wisconsin

Yari Johnson[1], Jasmine Wyant[2], Robert Feiden,[2] and Anna Gitlin[2]

Abstract: Service learning is an approach to teaching and learning in which students use academic knowledge and skills to address genuine community needs. Students from the Reclamation, Environment & Conservation program at the University of Wisconsin-Platteville engaged in service learning through two different mining reclamation projects. In 2014, sixteen students in a reclamation project management class worked with the Buffalo County Land Conservation and Resource Management Department to create a reclamation plan for the 12-hectare Breezy Point nonmetallic industrial sand (aka "frac sand") mine. In 2015, twenty-seven students in a reclamation revegetation class developed a revegetation planting plan for a 3-hectare nonmetallic mine with high pH soils (>8 pH) directly east of the Wisconsin Dells. This project culminated with students implementing the plan by planting 2,100 native trees suited to high pH conditions. Face-to-face meetings coupled with reflective assignments allowed students to gain insight into their own strengths and weaknesses as emerging reclamation professionals. Community partners provided feedback through email and face-to-face meetings with the students and instructor. Overall feedback from students and the community partners was positive. All participating students felt that the experiences enhanced their reclamation knowledge and skills. Students preferred the revegetation project to the Breezy Point project since it had a direct "hands-on" component and the students were able to see the revegetation plan in action. The community partners communicated that the students' expertise and contributions allowed them to accomplish tasks that they would otherwise not have been able to complete due to resource limitations. These two cases illustrate the viability of using mining reclamation for servicing learning in post-secondary educational settings.

Additional Key Words: nonmetallic mining, post-secondary education

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Rock Disposal Area Seep Water Treatment at the Jerritt Canyon Mine

Kennet Bertelsen, Debbie Johnston

Abstract: Jerritt Canyon Gold LLC (JCG) owns and operates the Jerritt Canyon Mine in northcentral Nevada. In late 2013 JGC entered into a Consent Decree with the US Environmental Protection Agency (USEPA) and the Nevada Department of Environmental Protection (NDEP) to design and construct treatment systems for mine-influenced water (MIW) at three rock dump areas (RDA) at the Jerritt Canyon Mine. The MIW seeps from the toes of the RDAs and has elevated levels of sulfate and total dissolved solids (TDS). JCG agreed to treat the MIW to surface water limits of 250 mg/L for sulfate and 500 mg/L for TDS.

The preferred alternative for the treatment system is a passive bioreactor (biochemical reactor). The sites are remote with steep terrain, limited access, and limited infrastructure, which influenced the cost effectiveness of other alternatives. A pilot-scale passive bioreactor was constructed for the Marlboro Canyon RDA in 2002. Using historic data for the treatment effectiveness of this sulfate reducing trench, Morrison-Maierle designed treatment trenches for the three sites.

The geosynthetic-lined trenches are broken up into individual treatment cells, each of which treats an equal volume of the MIW for each of the three sites. The design calls for upflow through the treatment media which consists of inoculated manure, straw, limestone, wood chips, and biochar is used in one cell at each site to test for possible added treatment benefits of this media additive. Treated effluent is collected at the top of the trench at each cell and is routed to a sulfate polishing unit. The treated water is discharged from the sulfate polishing units and gains further treatment through soil attenuation before being tested at the designated compliance point.

Key Words: Sulfate Reduction/Removal, Water Treatment, Passive Water Treatment

A Review of the Literature Pertaining to Passive and Hybrid Treatment Systems for Removal of TDS from Mining Impacted Waters[1]

S.S. Cox[2], G.D. Boardman, Z.E. Kemak*, J.L. Parks, C. Grey, and K. Gunther

Abstract: As the economic climate in the mining industry becomes more challenging, discharge limitations for mining impacted waters are becoming more stringent. Thus, the need for cost-effective and reliable total dissolved solids (TDS) removal processes is critical. Passive and hybrid treatment processes appear to have the greatest potential to satisfy this need. Although very valuable research in this area has been conducted and published, locating this work is challenging. For example, the keywords "TDS" and "passive" and "mining" used in a search of the journal database, *Engineering Village*, returns nine hits with no hits relevant to TDS removal. The same keywords used in a search of the journal database, *Web of Science*, returns one hit within the period of 1900 to 2015 with no hits relevant to TDS removal.

This paper presents a summary of the published and presented research pertaining to removal of TDS from mining impacted water by passive and hybrid treatment systems. Information was obtained from published manuscripts, regulatory reference guides, consulting reports on treatment options for mining impacted waters, conference presentations, and interviews with researchers in the field.

The review shows that passive and hybrid treatment systems have been effective for TDS removal at some sites, but ineffective at others. The review of the literature also suggests more work needs to be done to investigate and quantify TDS removal mechanisms so that process models can be developed and used to guide process designs.

Additional Key Words: discharge limitations, treatment options, removal mechanisms

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Update to Tribal-Led Remedial Action at the Tar Creek Superfund Site[1]

Tim Kent and Craig Kreman[2]

Abstract: The Quapaw Tribe Environmental Department, along with Quapaw Services Authority conducted the first ever tribal-led cleanup of a Superfund site in the nation at the Catholic 40 within the Tar Creek Superfund site. The Catholic 40 site is of cultural and historical significance to the Quapaw Tribe, as it contains evidence of important events in the history of the tribe. After removing source material from the Catholic 40 site, the Quapaw Tribe was left with a challenge, sampling identified that much of the transition zone soil was also contaminated and removing these soils (to a one-foot depth) according to the Record of Decision would be costly and impede the Quapaw Tribe from re-establishing vegetation for eventual grazing. The traditional cleanup approach risked leaving behind a barren landscape. Along with EPA, and the Oklahoma Department of Environmental Quality (ODEQ), the Quapaw Tribe took a step back to consider how to tackle this challenge, while meeting the site's cleanup objectives without destroying local environmental conditions. With the help of an optimization team from EPA's Office of Superfund Remediation and Technology Innovation, an innovative approach was suggested. The alternative approach included soil amendments that could potentially bind the contaminants of concern metals (lead, cadmium, and zinc) in place, making them immobile, removing the risk of exposure, and allowing transition zone soils to remain undisturbed. Following the addition of soil amendments and seeding, the Catholic 40 is under a technical performance measures phase that include both short- and long-term measures to evaluate the effectiveness of the amendments. This presentation will provide the audience with the experiences and challenges moving forward with remedial action at the Catholic 40 and provide an update of additional remedial action activities the Quapaw Tribe has taken on at the Tar Creek Superfund site.

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[1] Oral paper presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4-9, 2016. Published by ASMR; 1305 Weathervane Dr., Champaign, IL 61821.

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Revegetation of Jharia Coalfield Using Remote Sensing, Based on Thermal Infra-Red Data: A Case Study

Pradeep Kumar[1] and Agota Horel[2]

Abstract

Problem Statement: Strategic Revegetation of the fire-affected Jharia Coalfield by mapping and monitoring its spread and extent. For this purpose, we propose to use Remote Sensing and Thermal Infra-Red (TIR) Satellite data (LANDSAT 8), and develop a Mine Fire Information System (MFIS) for creating the digital mine fire database of the Jharia coalfield.

Introduction: Researchers have been striving to apply different techniques for the re-vegetation of the fire-affected Jharia Coalfield, which is located in the State of Jharkhand, about 250 km to the west of Kolkata, India. It is linked to Delhi and Kolkata, through the National Highway, NH2, which is a part of the Golden Quadrilateral Highway network of India. This coalfield is an exclusive storehouse of prime quality coking coal as well. The sickle shaped coalfield, having an area of about 450 sq. km, occurs in the form of a basin and is truncated with a major boundary fault on the southern flank. In this Coalfield, an estimated 1800 million tons of coal resources are blocked due to mine fires.

Methods and Materials: The methods and materials for this study are based on an analysis and mapping of Fire Front movement. We have also integrated remote sensing analysis with GIS/GPS for developing a geo-referenced digital database for this Coalfield. This includes the development of six monthly fire statistics of Jharia coalfield by integrating remote sensing analysis with GIS & GPS.

Experimental Design: For carrying out strategic re-vegetation of this fire-affected coalfield, we used TIR data, based on Aster data of October 2011 and LANDSAT 8 TIR data were used to analyze the status of fire during April 2013 and April 2014. Lastly, a digital Mine Fire Database (MFD) of this coalfield was developed. Based on the findings, a comprehensive re-vegetation strategy for the present coalfield was formulated. We have also integrated remote sensing analysis with GIS/GPS for developing a geo-referenced digital database for this Coalfield.

Conclusion: Based on the discussion of the results of the study, the efficacy of using TIR Satellite data and Remote Sensing for the implementation of re-vegetation of this vital region has been put in bold relief.

Keywords: Remote Sensing, TIR, Revegetation, Fire Statistics

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A Paired Comparison Study to Evaluate the Effect of Ionic Strength on Trace Metal Removal Products in a Vertical Flow Bioreactor Substrate[1]

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

Abstract: A variety of processes remove trace metals from mine drainage within vertical flow bioreactors. These processes may be impacted by less commonly examined qualities of mine drainage, such as ionic strength. A column study was performed in the laboratory, using two sets of bioreactors filled with spent mushroom compost and treating either "LOW" ionic strength (~10^{-3} M) or "HIGH" ionic strength (~10^{-1} M) simulated mine drainage (SMD). Both LOW and HIGH SMD contained approximately 0.50 mg/L each of trace metals Cd, Mn, Ni, Pb, and Zn. Ionic strength was adjusted by manipulating base cation (Ca and Na) and sulfate concentrations. Effluent samples were collected biweekly for one year and analyzed for pH, DO, ORP, conductivity, alkalinity, total and dissolved metals, sulfate, and sulfide. At the end of one year, substrates were collected from the top third, middle third, and bottom third of each column. Total Cd, Mn, Ni, Pb, and Zn concentrations were not significantly different between the two sets of columns. A six-step sequential extraction procedure and acid-volatile sulfide/simultaneously extracted metals analyses were used to more accurately describe the products of trace metal removal in the samples. The majority of Cd, Ni, Pb, and Zn were found in the refractory organic/sulfide fraction in both sets of columns, but there was not a significant difference in that fraction between treatments. In contrast, the majority of Mn in both treatments was found in the carbonate fraction (up to 52%), with a large amount also found in the exchangeable fraction (up to 45%). Significant differences ($p<0.05$) were seen in fractions of Cd, Mn, Ni, Pb, and Zn other than the sulfide fraction. Overall, the observed decrease in exchangeable fractions and increase in labile organic fractions with increasing ionic strength were most likely driven by effects of ionic strength on sorption and solubility.

Additional Key Words: Passive treatment, sequential extractions, acid-volatile sulfides, simultaneously extracted metals

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SWITCHGRASS BIOENERGY AS SILVOPASTURE ON RECLAIMED MINE SOIL[1]

David Lang[2], Jeremy Duckworth, and Vitalis Temu

Abstract: Switchgrass *(Panicum virgatum L.)* was established in August, 2008 on two topsoil substitute mixtures within strips of loblolly pines (*Pinus taeda*). P*anicum virgatum* is a native warm season perennial grass that has productive potential of up to 20 Mg ha^{-1} (~10 tons Ac^{-1}) and it persists for decades when harvested once per year. Loblolly is also native to the Southeast US. Both species provide for restoration of many ecologically diverse ecosystem services such as carbon sequestration. Switchgrass contains 16,000 kjoule kg^{-1} and is equivalent to lignite coal on a dry matter basis. Sulfur (0.03-0.05%) and ash (3-5%) levels are much lower than lignite, particularly when switchgrass is harvested late in the fall. Switchgrass co-fired with coal or converted to H via gasification is considered carbon neutral. Switchgrass provides excellent ground cover and soil stabilization once established and contributes to soil sequestration of new carbon. A successful stand of switchgrass with 5-6 plants m^{-2} was established and was evaluated for yield, nutritive value and bioenergy characteristics. Loblolly was also evaluated for growth and stand density. Soil was sampled to 0-15 and 15-30 cm depths along various transects to provide initial soil C organic matter sequestration and will be resampled periodically. Small samples of switchgrass as stems, leaves or whole plants were collected and ground to determine forage nutritive values and bioenergy characteristics by near infrared spectroscopy (NIRS). Minerals were also determined by inductively coupled plasma spectroscopy (ICP). Other parameters such as dry matter, ash and digestibility were also determined by physical methods or wet chemistry.

Additional Key Words: Soil Carbon Sequestration, Carbon Neutral, Soil Stabilization

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East Fork Ninemile Waste Consolidation Area Site Selection, Design and Initial Construction[1]

Cody J. Lechleitner, P.E.*[2], Dan Meyer

Abstract: The Successor Coeur d'Alene Custodial and Work Trust (CDA Trust) was established several years ago as part of the outcome of the $2 Billion Asarco bankruptcy. $460 million was provided to the CDA Trust for use in remediation of the Coeur d' Alene river basin (CdA Basin) which has been impacted by 100 plus years of silver, lead, and zinc mining. The first task in the remediation of the CdA Basin is locating a final resting spot for the mine waste that is close to the mine waste sites, a long-term stable location and flexible enough to allow for an unknown final waste volume. In this presentation, CDM Smith, a consultant for the CDA Trust, presents the creation of the East Fork Ninemile Creek Waste Consolidation Area from site selection through initial construction and waste consolidation. The EFNM WCA project provides a case study for cost-effectiveness by selecting a location for the waste consolidation area near the remedial actions sites and increasing the capacity of the site with rock buttresses that were constructed from an on-site quarry, while providing flexibility for the high potential for change in waste quantity. In addition, CDM Smith will present the initial construction and waste consolidation activities with lessons learned during construction.

Additional Key Words: mine waste, Superfund, repository, buttress

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Design Approaches and Lessons Learned for the Durant Canyon Reclamation Project – Silver Bow Creek / Butte Area NPL Site[1]

Pierre LeMieux[2]

Abstract. The Durant Canyon Reclamation Project is a 10.5 kilometer segment of the 42-kilometer long Streamside Tailings Operable Unit within the Silver Bow Creek / Butte Area Superfund Site west of Butte, Montana. Starting in the late 1880s, tailings and other mine wastes containing high concentrations of metals were discharged directly to Silver Bow Creek and redistributed through subsequent flood events, including a massive flood in 1908. These toxic discharges impacted the stream and floodplain with heavy metals and virtually eliminated aquatic life in the stream. Tailing deposits resulted in a floodplain that was largely devoid of vegetation and generally incapable of supporting wildlife. Durant Canyon remedial action construction included three separate phases starting in 2009 and concluding in 2015. Project work required excavating 644,000 cubic meters of tailings for shipment by rail to an off-site repository, reconstructing approximately 61 hectares of floodplain, constructing approximately 10.5 kilometers of new stream channel, and importing 378,000 cubic meters of backfill / cover soil. The work area was constrained not only by Durant Canyon, but also by Silver Bow Creek and three historic railroads grades (with numerous bridges) passing through the canyon. Additional project work included four large-scale piped stream diversions, bridge removal and relocation, large-scale fish barrier construction, wetland complexes and habitat improvements, and myriad stream channel and railroad embankment treatments (riprap, gabions, rock cover, erosion control fabrics, etc.) for infrastructure protection during flood events. This paper presents the design approaches used to dewater and access the work area, utilizing an effective design toolbox to minimize characterization requirements, account for dynamic field conditions, and provide for a flexible construction contract; and it also covers lessons learned during design and construction.

Additional Key Words: mine tailings, floodplain reconstruction, piped stream diversions, stream channel construction, fish and wildlife habitat improvement, wetland restoration, gabion mattresses, riprap.

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2 Pierre LeMieux, Project Manager/Reclamation Scientist, Pioneer Technical Services Inc., Helena, MT, 59601.

TREATMENT SYSTEM RESTORATION AND POWER GENERATION IN THE SLIPPERY ROCK CREEK WATERSHED[1]

R. M. Mahony[2*], D. A. Guy, C. F. Denholm, T. P. Danehy,
C. A. Neely, S. L. Busler, M. H. Dunn

Abstract: The Slippery Rock Watershed Coalition has been working for over twenty years to address the impacts of historic coal mining in the headwaters of Slippery Rock Creek. As part of a renaissance initiative, the coalition received a grant to fund three separate mine drainage-related projects in Butler County, Pennsylvania: 1) The 9,000-ton horizontal flow limestone bed at the Erico Bridge Passive Treatment System (PTS) was cleaned to re-establish flow and effective manganese removal; 2) The aerobic wetland at the McIntire PTS was lined with fine alkaline slag material (HARSO Mineral CSA) to address loss of flow attributed to construction in surface coal mine backfill; 3) The Jennings Environmental Education Center has repurposed a seldom-used Aquafix® machine as a pico-hydroelectric generator to demonstrate the viability of alternative energy at a former underground coal mine site. An overview of the projects including design information and construction techniques will be presented along with water monitoring data to demonstrate the increase in treatment performance after maintenance and repair activities.

Additional Key Words: Water Treatment, Acid Mine Drainage, Operation & Maintenance, AMD, O&M, hydropower, Aquafix

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2. Ryan M. Mahony, Env. Tech, Daniel A. Guy, Geology Tech., Timothy P. Danehy, QEP, Cody A. Neely, Env. Engineer (EIT), Clifford F. Denholm, Env. Scientist, Shaun L. Busler, GISP, Margaret H. Dunn, PG, Stream Restoration Incorporated & BioMost, Inc., Mars, PA.

A GIS Model to Guide Revegetation Efforts on Reclaimed Mine Lands

M. Mariano*, M. Sutherland, and R. Pal

Abstract: Butte, Montana is part of the largest EPA Superfund complex in the country due to an extensive history of metals mining, now comprising over 3.2 km-2 of reclaimed and restored mine lands. Until recently, revegetation projects were somewhat randomly selected with little regard to basic ecological background features essential to successful restoration. In order to maximize the level of success of these projects, an ESRI ArcGIS model was designed to calculate the best possible location and habitat for any of the plant species selected. The modeled locations are predicted to minimize the financial burden of the projects while maximizing revegetation survival rates in Butte.

The model was designed to utilize open access geographical and topographical information to determine the most ecologically suitable locations for known habitat types of species and/or groups of species. In addition, ill-suited revegetation areas containing undesirable reclamation species can be removed from consideration for planting. Reference sites that matched plant species to the ideal aspect, slope, and hydrologic conditions were incorporated to determine suitable planting areas on the Butte hill. Poorly suited locations and plant communities dominated by exotic species have previously limited the success of native plant revegetation projects in Butte. Using this model to determine ideal planting locations in Butte will increase the efficiency of the projects and improved planning for future plantings.

The true value of the model is that it is an iterative analytical program designed to be reused and/or modified to test differing variables and parameters specific to species. The model is shareable for licensed Arc software users and the “plug-and-play” nature makes it valuable with minimal training; similar to using a smartphone app. Modifications to the basic model can make it useful under any conditions worldwide.

Keywords: ecological restoration, mine reclamation, native plant revegetation, planning, suitable habitat.

Montana Moonscapes: Mitigating large-scale erosion on steep slope uplands in roadless areas[1] of the Anaconda Superfund site

Pedro Marques[2]*

Smelting activities in Anaconda, MT from the late 1800's to 1980 created a persistent aerial plume of contaminants that settled on the landscape, with devastating impacts on upland vegetation. Coupled with extensive logging to build mining infrastructure and fuel the first smelters, upland areas near the continental divide on certain soil types have been void of vegetation (including weeds) for nearly 100 years. Gully erosion of impressive scale has transformed the uplands into a network of sediment delivery superhighways. Landscape-scale assessment, prioritization and remedy/restoration demonstration projects have been undertaken over the past 5 years to reverse the sediment imbalance and restore native vegetation to the roadless portions of the Mt. Haggin Wildlife Management Area.

Soil amendment trials, innovative sediment catchment BMPs and natural sediment capture and storage techniques have been refined and scaled over the years, coupled with state-of-the-art unmanned aerial system (UAS) technology for long-term monitoring. Variations in geologic parent material, soil characteristics, topography, and surface roughness will be discussed and encouraging results from sediment retention and vegetation enhancement projects will be illustrated.

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2. Marques, Pedro, Restoration Ecologist, Watershed Consulting, LLC, Missoula, MT 59802

Composite Sampling - Pre In-situ Soil Reclamation with a BOMAG Recycler

M. Meadows*, S.T. Nelson, R. Anderson, A. Sanchez, E. Waterman, T. Howes, B. Slade, and S.T. Nelson

Two “agricultural” properties in the vicinity of a former smelter area in Tooele County, Utah were investigated to determine exceedance of a local residential standards for the two contaminants of concern (lead and arsenic). The paper will discuss 1. Calibration of the field XRF to “state of the art” geochemistry lab analysis (X-ray diffraction, leaching experiments, SEM imaging) 2. Comparison of what would be “naturally occurring” lead and arsenic based on the origin of the soil matrix and 3. Plan for which are the “limited” areas that would require soil removal or mitigation to meet residential standards. Study revealed cost savings by significantly reducing the areas of concern.

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1. M. Meadows, (student) U of U; S.T. Nelson (professor); R. Anderson & A. Sanchez, Anderson Engineering; E. Waterman, USEPA; T. Howes, Utah DEQ; B. Slade, Tooele County; S.T. Nelson, BYU.

Passive and Active Treatment of Arsenic and Antimony at a Remote Abandoned Mine Site in Idaho[1]

K. Minchow[2], T. Rutkowski, J. Pepe

Abstract: Remote abandoned mine sites in Idaho are abundant, and with no power and limited access, can provide unique challenges from a water treatment perspective. Golder was contracted by the Idaho Department of Lands to evaluate passive and active treatment alternatives for an adit drainage from one of these sites. Testing was intended to provide insight into effective treatment processes which can be applied to other abandoned mine sites in need of treatment.

Adit drainage flow is circumneutral pH and contains elevated arsenic and antimony concentrations. The treatment goal for arsenic may be as low as the US EPA drinking water maximum contaminant level of 10 µg/L. Flow is approximately 4 to 8 m^3/hr (cubic meters per hour). Bench scale testing evaluated several passive and active treatment processes including aerobic wetlands, iron co-precipitation, and various titanium and iron based adsorbent media.

Results from the bench testing were used to select technologies for pilot testing which, in turn, will provide design criteria for implementation of a full scale treatment. Both iron co-precipitation and media adsorption were effective in removing arsenic and antimony to the levels required for stream discharge. Aerobic wetlands, constructed in a lab setting, were found to be ineffective for removal of arsenic and antimony. In the end, granular ferric hydroxide media was the technology that met the needs of the site and was proposed for further testing in a passive configuration.

Additional Key Words: Remediation, Water, Adsorbent Media, Iron Co-Precipitation, Wetlands, Bench Testing, Passive Treatment, Arsenic, Antimony.

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2. Kristina Minchow is a staff engineer at Golder Associates Inc., 44 Union Blvd. Suite 300, Lakewood, CO 80228. Tom Rutkowski, P.E. is a senior project engineer at Golder Associates Inc. Jen Pepe is a senior engineer with Golder Associates Inc.

Evaluation of Small Tree and Shrub Plantings on Reclaimed Surface Mines in West Virginia

A. Monteleone[1*], J. Skousen, L. McDonald, J. Shuler, J. Pomp, M. French, and R. Williams[2]

Abstract: Thousands of acres of mined land are reclaimed annually in West Virginia (WV) and planted with hardwood tree species. Forestry and wildlife post-mining land uses require the planting of specific tree species designated by the individual mine permit and planting plan. The success of those tree plantings is dependent on creating a non-compacted and deep rooting medium to ensure optimum tree growth. Additionally the selection of tree and shrub species best suited for site conditions, and seeding with a complementary/non-competitive herbaceous ground cover increases the success of planting. While the Forestry Reclamation Approach (FRA) has proven to increase the probability of survival of commonly planted commercial tree species on mine sites, the successful establishment and growth of less typical fruit and nut producing small tree and native shrub species has not been extensively studied. Though these species are not planted as part forestry reclamation, they are commonly found in forest ecosystems of WV and are often an important component, contributing to both structural and floral species diversity. Additionally, these species are important for wildlife, providing a food source for a variety of vertebrate organisms, and recruiting insects and microorganisms, which are important for maintaining a sustainable and functioning forest ecosystem. For three years we examined survival, health, and growth of 20 species of mast and fruit producing shrubs and small trees to better understand their suitability for reclamation plantings.

Seedlings were planted in graded overburden material between 2008 and 2010 on four reclaimed surface coal mines in WV. The selected sites were reclaimed using conventional methods. The study was designed as a completely randomized block design. At each site, four blocks measuring 4,160 m^2, two east-facing and two west-facing, were established. Each block was comprised of 20 monoculture species plots, and within each plot 25 individuals of the selected species were planted on 2.4 m x 2.4 m spacing. Survival, growth, and health of these species were evaluated over time in order to determine the species which performed best on these sites. The best performing species overall were Washington hawthorn (*Cratageus phaenopyrum)*, black chokeberry (*Aronia melanocarpa)*, nannyberry (*Viburnum lentago)*, black cherry (*Prunus serotina)*, gray dogwood (*Cornus racemosa)*, and red mulberry (*Morus rubra)* in that order. These species survived and appeared healthy on most blocks. The poorest performing species were worst performers in descending order were choke cherry (*Prunus virginiana)*, persimmon (*Dyospyros virginiana*), flowering dogwood (*Cornus florida)*, and the worst performer being pawpaw (*Asimina triloba)*.

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Heavy Metal Characterization and Source Identification for Grove Gulch in Butte, MT[1]

R. M. Nagisetty[2]*, G. Craig, W. Drury

Abstract: Silver Bow Creek (in southwest Montana) is listed as impaired for arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), and mercury (Hg) in the Montana 2014 303(d) list. Grove Gulch, a major tributary to Blacktail Creek, flows approximately 6 miles before joining Blacktail Creek (headwaters of Silver Bow Creek) east of Lexington Avenue in Butte, MT. It drains primarily open range, a historic metal milling site (Timber Butte zinc mill) and a reclaimed mine waste repository (Copper Mountain Recreation Complex, CMRC). Historically, Grove Gulch has been modified to accommodate the mine waste repository (a small portion of the stream flows underground along the side of the CMRC) and a flood prevention project.

The primary objective of this study was to investigate whether the Grove Gulch is discharging significant loads of heavy metals into Blacktail Creek. Longitudinal Grove Gulch sample analysis indicated that zinc, Cu, Pb, and iron concentrations downstream of the CMRC were significantly higher than the upstream concentrations for both base flow and storm water runoff samples. The increased heavy metal concentrations downstream of CMRC in the base flow suggest that groundwater is flowing through mine waste before entering Grove Gulch, whereas, the similar concentration increase in runoff suggests the presence of mine waste on the surface near the reclaimed mine waste repository. The analysis also shows that that Grove Gulch is a significant source of heavy metals in Blacktail Creek. The results of this study are significant in that the study presents water quality concerns from a reclaimed mine waste "in-place" site. Results of this study will be used to design a passive subsurface bioreactor system to treat Gove Gulch heavy metals before they enter Blacktail Creek.

Additional Key Words: waste "in-place," water quality, mine waste repository.

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2 Raja M. Nagisetty, Assistant Professor; Garret Craig, Graduate Student; and William Drury, Professor, Environmental Engineering, Montana Tech of the University of Montana, Butte, MT 59701.

Comprehensive Watershed Restoration via Ecological Engineering: The Role of Passive Treatment[1]

R.W. Nairn*[2]

Abstract: Surface and ground waters in the Tar Creek (Oklahoma) watershed of the Tri-State Lead-Zinc Mining District were deemed to be degraded due to "irreversible man-made damages" over 30 years ago. This administrative decision resulted in minimal efforts to address risk from legacy mine waters. The entire Oklahoma portion of the stream from the Kansas border to its confluence with the Neosho River (~19 km) is listed on the state's Clean Water Act 303(d) List of Impaired Waters and is considered a Habitat-Limited Aquatic Community. In addition to impacts from metal-contaminated waters from artesian mine water discharges and waste pile leachate and runoff, physical degradation of stream channels impairs natural recovery. The first full-scale passive treatment system, constructed in 2008 to address elevated Fe, Zn, Pb, Cd, and As concentrations, has resulted in documented chemical and ecological recovery of a first-order tributary to Tar Creek. A second passive treatment system is scheduled for implementation in 2016. However, seasonally variable and significant (up to several thousand m^3/day) artesian flows remain untreated in the Tar Creek watershed. In the adjacent Beaver Creek watershed, multiple, interconnected yet smaller artesian discharges degrade that stream. Hydrologic and chemical data, generated by watershed-scale environmental monitoring efforts, indicate that these discharges are amenable to passive treatment (net alkaline with elevated iron and trace metal concentrations). In addition, tens of millions of tons of mining wastes remain on the land surface, contributing contaminated leachate and runoff to local streams. These nonpoint sources of metal-contaminated waters also appear to be amenable to passive treatment. Comprehensive watershed-scale restoration planning indicates that multiple, targeted passive treatment systems, in conjunction with land reclamation and related activities, would lead to considerable in-stream water quality improvement. Implementation of passive treatment technologies beyond the demonstration level requires revisiting and revising of previous administrative decisions.

Additional key words: wetlands, riparian areas, oxidation ponds, vertical flow bioreactors

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Developing a Conceptual Site Model in a Watershed with Multiple Mine Waste Dumps, Bunker Hill Superfund Site, East Fork Ninemile Basin[1]

Erik Naylor*[2], Alan Hughes LG*[3], Tom Mullen PG[4], and Christina Johnson LG[5]

Background/Objectives
Identification of ongoing sources of contaminant loading to the environment at contaminated sites is perhaps the most critical step to ensuring effective and lasting cleanup actions. At the Bunker Hill Superfund Site in Idaho potential sources of metals to an impacted watershed have been evaluated through a series of nature and extent investigations and ongoing water quality monitoring. The source(s) of metals loading to East Fork Ninemile (EFNM) Creek downstream and adjacent to mine waste piles had not been fully characterized. Site observations, investigations, water quality monitoring programs, and historical research identified a number of potential loading sources in addition to the waste piles that may be contributing to nonpoint EFNM Creek metals loading through groundwater discharges. An area-wide investigation was designed and implemented to establish how/where groundwater and surface water may be loading metals to the EFNM Creek from known sources, identify possible unknown sources, and provide baseline to evaluate the effectiveness of future remedial activities.

Approach/Activities
Building on data gathered in previous investigations, additional data gathering efforts were completed to generate a more complete conceptual site model. These efforts included high resolution thermal sensing along an approximately 1.5-mile (2.4-kilometer) reach of the EFNM Creek to observe surface water and groundwater interactions, a newly designed surface water monitoring plan, and groundwater monitoring at existing and newly installed monitoring wells. Data collection was followed by analysis of metals loading, thermal imaging data, water chemistry, and the relation of data to geological features and the potentiometric surface of groundwater.

Results/Lessons Learned
The recent investigations have identified a significant nonpoint source of metals loading into the EFNM Creek that was previously unknown/unanticipated and conversely, shown that a large mine waste rock pile is not a significant source of loading. This discovery opens the door to the possibility that 440,000 cubic yards of mine waste could be regraded in place, rather than the assumed remedy that would require at least 4 years of excavation. The potential change would save over 10 million dollars, while being protective of the environment and achieving project goals.

Additional Key Words: metals loading, sources, mine waste, groundwater, surface water

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Implementation of Two Passive Treatment Systems In Northern West Virginia[1]

C. A. Neely[2*], T. P. Danehy, R. M. Mahony, D. A. Guy, S. L. Busler, C. F. Denholm, M. H. Dunn, D. Petry[3], and N. Revetta[4]

Abstract: This case study highlights the design and construction of two passive treatment systems in Preston County, West Virginia. The first system, North Fork Greens Run Railroad Passive Treatment System (NFGRR PTS) was implemented for the Friends of the Cheat (watershed group). This treatment system addresses a relatively low-flow, acidic discharge that emanates from an abandoned underground coal mine site at which land reclamation had previously been completed. The design water quantity and quality data for the NFGRR PTS are: 7 / 29 gallons per minute (avg/design), pH 2.9 SU, acidity 400 (calculated acid value), total/*(dissolved)* metals concentrations of iron 104/*(53)* mg/L, aluminum 61*/(35)* mg/L, manganese 4*/(2)* mg/L, and sulfates of 2,000 mg/L. Constraints regarding the allotted construction area, as well as the quality of water to be treated contributed the challenges involved with the treatment of this water. A variety of passive treatment technologies (including: low-pH iron removal; siphon-driven, limestone-only, auto-flushing vertical flow pond; and Jennings-type vertical flow pond) were integrated into this design in order to effectively treat the water prior to discharging to North Fork Greens Run. The second project, Slabcamp Tributary Passive Treatment System was implemented for the Friends of Deckers Creek (watershed group). The Slabcamp Tributary PTS essentially addresses a heavily-impacted stream as well as two discrete discharges (OLC 250 & OLC 300) from an abandoned underground coal mine. The design parameters for OLC 250 are: 154 gallons per minute, pH 3.1 SU, acidity 127 mg/L, dissolved metals concentrations of iron 1 mg/L, aluminum 14 mg/L, manganese 1 mg/L, and sulfates 228 mg/L. While OLC 300 has design water quantity and quality data of: 60 gallons per minute, pH 2.8, acidity 247 mg/L, dissolved metal concentrations of iron 9 mg/L, aluminum 23 mg/L, manganese 1 mg/L, and sulfates 330 mg/L. Currently, both discharges and the stream confluence in a 5.4-acre AMD-impacted wetland prior to entering Deckers Creek. Complete construction of the system was restricted due to the available project budget. Additional treatment components for OLC300 were recommended and approved; however, the recommended components were not built in this construction phase as additional funding needs to be secured.

Additional Key Words: Friends of the Cheat, Friends of Deckers Creek, Low pH iron removal, siphon, Jennings-type vertical flow pond

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Salix Spp. as a Biomass Crop: Investigating its Potential on Mined Lands and the use of Biochar as a Soil Amendment.

H.A. Nobert, D.W. McGill, S.T. Grushecky, J.G. Skousen, and J.L. Schuler

Abstract: Rising energy demands and costs have increased the need to develop alternate sources and markets. Biomass plantations are proposed as part of the renewable energy solution. In West Virginia, over 50,000 acres of previously mined and reclaimed land are suitable for cultivation with bioenergy crops, including woody plants. The feasibility of growing shrub willow (*Salix* spp.) for restoration purposes was assessed on reclaimed surface mines and fallow agricultural land in West Virginia. Replicated field trials were established and monitored over one growing season at four sites throughout the state. Within the field trials, biochar was tested as a soil amendment to mitigate soil quality issues associated with mine soils and fallow agricultural land. To characterize *Salix* spp. potential as a feedstock, thermogravimetric analysis, analysis of elemental concentrations, and heating value were measured. Wood properties for one year-old material were compared with the specifications required for woody biomass combustion or ethanol plants. Relative to these specifications, ash content was slightly higher (2.7% vs. 1.0%) as was nitrogen (0.98% vs. 0.35%), whereas volatile matter was lower (79.8% vs. 82.0%). Based on these standards, *Salix* spp. grown on reclaimed surface miens or fallow agricultural sites appear to be a suitable biomass feedstock for combustion and biofuel production. Biochar improved growth 80.7% and yield 72.4% compared to non-amended plots. Improved growth and yield in biochar amended plots in the first year of growth gave willow saplings a competitive advantage over weeds. Additionally, biochar has shown long-term positive impacts in field studies, and improved growth and yield during the first year may prove to give higher yields in the long-term.

Additional Key Words: surface mine, willow, reclamation

The Physiological Characteristics to Estimate Species Potential as Mine Reclamation Ground Covers[1]

E. Nurtjahya[2], and J.A. Franklin,

Abstract: In finding what physiological characteristics can be used to predict ground cover success on mine reclamation sites, fourteen herb and grass species, whose seeds are widely available commercially within the southeastern United States, were tested. Establishment and early growth was tested on three different soils i.e. vermiculite and quartz sand mixture, quarry overburden, and coal mine overburden in a greenhouse. We tested germination rates in the pH range of 5–10, and the early growth, chlorophylls a and b, and carotenoids pigment content, and transpiration rates of 14 herbaceous species to determine whether these traits can be used to predict ground cover success on mine reclamation sites. The preliminary results indicate that plant height and cover, transpiration rate, and foliar pigments may be used to select plant adaptability to mined soil. Red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) showed the greatest potential as ground cover for mined soils in the eastern United States. Species with a moderate growth rate, which may be able to tolerate and persist in the low-nutrient environment of reclaimed mines, are more likely to be adopted for widespread use. The field experiment is being conducted to monitor the growth performance of the clovers in the field, and which soil factor affect most.

Additional Key Words: physiological characters; cover crops; reclamation; mine revegetation; red clover and white clover

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Mineral Sands Mine Soils in Southeastern Virginia: Comparison of Physical and Chemical Properties after Eight Years[1]

Z.W. Orndorff[2] and W.L Daniels

Abstract. Significant areas of prime farmland in the upper Coastal Plain of Virginia have been disturbed by heavy mineral sands mining. Mine soils created by wet deposition of tailings and slimes into mined out pits exhibit physical and chemical properties that limit agricultural use due to abrupt textural changes, heavy compaction, and inherent infertility of the processed subsoils. In 2004, the Carraway-Winn Reclamation Research Farm (CWRRF) was developed by Iluka Resources Inc. at the Old Hickory mine in Dinwiddie County to evaluate reconstruction strategies for returning mined lands to agricultural production. The objective of this study was to document and characterize changes in the chemical, morphological and physical properties of these variably reclaimed (via addition of topsoil or biosolids vs. control) mine soils after two and eight years of intensive rowcrop management. Sixteen soil profiles were described and sampled to 2 m in 2006 and 2014 at directly adjacent locations. Soil profile descriptions included horizon depths and designations, color, structure, consistence, presence and depth of roots, and any other noteworthy morphological features. Bulk soil samples from each major morphological soil horizon were analyzed for particle size distribution, bulk density (at fixed depths), pH, extractable nutrients, and organic C and N. Several beneficial changes were observed between the two sampling dates. Organic C increased slightly from an average of 0.61 to 0.80%. Bulk density for Ap horizons decreased from 1.6 to 1.2 g cm^{-3}, from 1.8 to 1.5 g cm^{-3} directly below the Ap, and from 1.7 to 1.4 g cm^{-3} at 50 cm. Pedogenic subsoil alteration was indicated by development of weak subangular blocky structure and the presence of thin, discontinuous clay films in eight profiles. Densic layers were observed in two profiles for both sampling dates. Relative to pre-mining soils, overall rooting depth and density was limited by the massive nature of most subsoils and particularly by stratified high sand tailings layers.

Additional Key Words: Biosolids, compaction, slimes, tailings, titanium mining, topsoil

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Determination of Hydraulic Retention Time for Passive Treatment System Oxidative Unit Using Rhodamine[1]

L. Oxenford[2]* and R. Nairn

Abstract: The oxidative cells of passive treatment systems are designed to optimize iron removal efficiency based on area adjusted mass removal rates and hydraulic retention time (HRT). Experimentally derived values for both parameters are used to evaluate system performance with respect to design as the system ages. Tracer studies are used to determine the flow characteristics of hydraulic systems, yet their application to passive treatment cells is problematic due to measurement interferences associated with the mine drainage matrix. The high conductivity background signature from total dissolved solids and optical interferences from suspended iron oxyhydroxides limit feasibility of common tracer methodologies. This project determines the hydraulic residence time within three oxidative units of a passive treatment system after seven years of operation by monitoring the transport of a fluorescent dye, Rhodamine (530 nm excitation, 555 nm emission) and evaluates sampling methodologies to minimize interferences in field measurements. Rhodamine-WT (3.8 L of 200g/L stock) was introduced to an oxidation pond at three influent seeps simultaneously (volume proportionate to individual seep flows, Q_{total} = 7.42 L/sec), and concentrations were measured with YSI-rhodamine sensors (#6130) continuously (15-minute logging interval) and discretely (one sample every hour via programmable autosampler) over 14 days. Rhodamine concentration (µg/L) was measured for both total and filtered (0.45µm-Nylon) discretely-collected samples. HRT, % rhodamine tracer recovery, and iron removal efficiency were determined for each cell in the oxidative unit. Calculated HRTs were less than theoretical values based on design of the preliminary oxidation pond; however, they were longer than expected for the secondary surface flow wetlands due to the effects of significant precipitation during the study. Discrete and continuous monitoring methodologies yielded both pros and cons with respect to their field execution and resultant data quality, and thus should be selected based on resource availability and location site-specific needs.

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DESIGN AND CONSTRUCTION CHALLENGES FOR THE SOUTHEAST COMMERCE PASSIVE TREATMENT SYSTEM[1]

B.J. Page[2], N.L. Shepherd, and R.W. Nairn

Abstract: Abandoned mine drainage (AMD) issuing from historic mining operations in the Tri-State Lead-Zinc Mining District has substantial detrimental impacts on local streams. AMD discharges typically have ecotoxic levels of Fe, Zn, Pb, Cd, and As. Passive treatment systems that rely on naturally occurring biogeochemical processes for retention of metal contaminants are an important tool in watershed restoration. The Mayer Ranch Passive Treatment System near Commerce, Oklahoma, part of the Tar Creek Superfund Site, has significantly improved the chemical and biological quality of the receiving stream, a first-order unnamed tributary (UT) to Tar Creek. However, an untreated AMD discharge continues to degrade UT. The Southeast Commerce Passive Treatment System (SECPTS) project will design, construct, and evaluate a second system to address degraded water quality in the UT watershed. SECPTS will further decrease contaminant loading through a combination of biogeochemical, microbiological, and physical mechanisms in multiple process units. The site history and current site conditions present unique challenges for the design and construction of the process units. These challenges include reclaimed mine collapse features, a previously installed underground drainage system (addressing uncontrolled flows from the filled collapses), constrained available land area, limited elevation change for gravity driven operation, and effectively day-lighting the AMD given current conditions. To help address these challenges, monitoring of water quality, water quantity, and water surface elevations of the underground drainage system and mine pool have been ongoing. In addition to regular monitoring, a series of drainage system plug tests have been conducted to help understand the hydraulic contributions, connections, and limitations of the drainage system. This presentation will focus on the findings of the plug tests and other identified challenges for design and construction of the SECPTS.

Additional key words: passive treatment, elevation, Tar Creek, AMD

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The Effectivness of Native Seed Dispersal Islands in Reclaimed Mine Lands Domintated by Eurasian Grasses [1]

Robert W. Pal[2], Kriss Douglass, Mark Mariano, Krystal Weilage

Abstract: One hundred years after the intensive operations of mining and smelting, Butte still has serious environmental problems. Reclamation efforts, guided by the EPA's Superfund program, includes cleanup of contaminated sites. The approach has been to cap these areas with clean soil and re-vegetate using commercial seed mixes which are mostly comprised of Eurasian grasses.

Native plant diversity is required by the Annotated Rules of Montana in restoration but is nonexistent on the reclaimed sites. The Native Plant Program at Montana Tech has tried several approaches to increase native plant diversity. One method utilized seed dispersal islands. These are small native diversity hotspots which are established within the reclamation sites to spread their seeds into the grass-dominated plant community.

To evaluate the success of this technique, we set up 40 x 4 transects at each site. Transects ran from the center of the dispersal islands to each of the cardinal directions. Each transect was 25 m long and contained the same number of 1x1 m quadrates. An average of 15 native plant species were installed into the islands. We regressed the species number against the distance from the center of the transect.

We found plant species richness decreased significantly (R^2=-0.773; $P<0.001$) when moving away from the center from about 11 to 5.6 in just 6 meters. At 25 m the average species number was 4.2 and was mainly composed of Eurasian grasses (e.g. *Agropyron cristatum* 56%). Only a few native species spread out further than 5 m of the center (e.g. *Arabis holboellii, Linum lewisii*).

Our results suggest that establishing seed dispersal islands was a successful novel approach to providing native seed sources as most of the installed plants established. However, the dense cover of Eurasian grasses inhibited their spread. Therefore, further interventions (e.g. creating dispersal sinks) are needed to assist the spread of natives and to hinder the dominating effects of the reclamation grasses.

Keywords: Butte, Montana, exotic grasses, native plants, restoration

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The Relationship between Student Service Learning and Technical Assistance in Mine Water Reclamation[1]

K.J. Palmer[2], J.S. Vinglish[3], M.A. Reckner[4], W.H.J. Strosnider[5]

Abstract: The Saint Francis University (SFU) Center for Watershed Research and Service was established in 2012 with the desire to meet technical, labor, and volunteer needs of local watershed restoration organizations. The Center has recently developed a stem of this relationship to help our local organizations in their efforts to monitor and improve local waterways by providing the design, construction, and installation of weirs. Weirs, being a simple structure, allow for the students to gain valuable design, construction, field experience, and theoretical underpinnings while providing a service to organizations free of charge. The time investment required for a weir installation is technically demanding and manpower intensive for organizations already trying to make the most of their budget and time with volunteer and retiree staff. The strong backs of undergraduate students are welcomed to provide this service. The value of flow data in water quality monitoring and reclamation far exceeds the cost of a weir with the Center's stock of tools, materials, and time. Installing weirs is a simple way for us to help and eliminate any cost to our nonprofit partners. Over the last 3 years, the Center and associated SFU students have installed and provided maintenance to 20+ weirs. This service learning and technical student/professor assistance concept has begun to expand into a relationship where guided students have monitored a system awaiting renovation, started preliminary designs, and have participated in snapshot sampling efforts. This presentation will go into the details of how the program is being run and funded as well as how you could use this model to help your organization, firm, or students, including and beyond weir installations.

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1. Oral paper presented at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4-9, 2016.

2. Kelsea J. Palmer, Env. Engineering Laboratory Manager, St. Francis University, Loretto, PA.
3. Joshua S. Vinglish, Env. Undergraduate Engineering Student, St. Francis University.
4. Melissa A. Reckner, Kiski-Conemaugh Stream Team Director, Conemaugh Valley Conservancy, Inc., Johnstown, PA.
5. Dr. William H.J. Strosnider, Env. Engineering Associate Professor, St. Francis University, Director of the Center for Watershed Research and Service, Loretto, PA.

CONTAMINANT AND TREATMENT DYNAMICS IN THE GREATER RIO JUCKUCHA WATERSHED

Hannah Patton, Chris Evans, Freddy Llanos, Penny O'Connor, Pedro Muíño, Rachel Wagner, and William Strosnider

Abstract: The mining of Ag, Pb, Zn, and Sn in Potosí, Bolivia has been intensive since Spanish conquest in the 1500's. As a result of the extensive mining history of this region, the Rio Juckucha Watershed, located outside the city of Potosí, has been continuously contaminated by acid mine drainage and processing plant effluent for an indeterminate amount of time. Rural inhabitants in this area rely on the local surface waters for drinking water, animal watering, and irrigation, however in most locations the water present is unsuitable for any of these activities. Two Open Limestone Channels (OLCs) and an Anoxic Limestone Drain (ALD) have been installed in the watershed in order to help restore water quality. In addition, active treatment (lime dosing and sedimentation) has been implemented at a major mine within the watershed. Streams in the Rio Juckucha watershed were sampled during the dry season (May 2015), at various points near contamination sources and treatment systems, as well as communities located downstream. The pH in upstream sampling sites, prior to treatment efforts, was generally found to be quite low at around 3. Sites downstream of treatment systems saw an overall increase in pH with water from sampling sites at the downstream communities, each reaching a pH of above 6. The active treatment system at the mine successfully raised the pH of the outgoing water from the mine to 11 initially and this water maintained a neutral pH further downstream. The data indicates that the OLCs, ALD, and active treatment system are generally successful at improving water quality. However, important reaches of stream and some reservoirs in the watershed remain highly impacted. Overall, due to the efforts of universities, private enterprises, communities, government, and nonprofit partners, water quality is improving in a watershed once thought to be irreparably contaminated.

Additional Key Words: alkalinity, iron, passive treatment, pyrite, specific conductivity, tailings and mineral processing, total metals concentration

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TOTAL DISSOLVED SOLIDS IN AN OHIO MINED AREA[1]

Jonathan Peterson* [2]

Abstract: Total Dissolved Solids (TDS) within a large creek and its tributary sometimes exceeded the local regulatory limit of 1,500 milligrams per liter. The TDS mainly stemmed from a coal mine and it's settling ponds, from which dissolved loads were carried to the creek and tributary via outfalls. The existing compliance strategy was to control the timing of problematic outfalls, reducing flows when exceedance was imminent; however, because of the variability of weather and mining activities, identifying the problematic outfalls would require more-frequent measurements than could be performed manually.

Data logging stations, deployed on the creek and tributary between each mining outfall, recorded conductivity (for TDS) and pressure (for flow) at 10-minute intervals. Field testing resulted in an innovative design for the data logger housing. A telemetry station was installed to provide real-time warnings should TDS-thresholds be exceeded downstream of the coal mine. Data analysis includes calculations of mass loading and of the annual TDS delivered by each outfall.

Results indicate that there are four outfalls whose mass loads are particularly problematic, and that TDS is occasionally resultant from an unknown source located upstream of the coal mine. The session will include some cost saving lessons and briefly explore options for data comparison.

Additional Key Words: Total Dissolved Solids, Data Logging, Telemetry, ARD

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Environmental Control of Shrub Density Development at the Seneca II Mine, 1987-2014, Routt Co. CO [1]

*V.R. Pfannenstiel [2] and D.L. Buckner [3]

The Seneca II Mine in Northwest Colorado was a surface coal mine operated by Seneca Coal Co. from 1968 to 1999. Original native vegetation of the site was dominated by big sagebrush (*Artemisia tridentata*) and mountain snowberry (*Symphoricarpos oreophilus*) with approximately two-thirds co-dominated by Gambel's oak (*Quercus gambelii*), serviceberry (*Amelanchier alnifolia*), and chokecherry (*Prunus virginiana* var. *melanocarpa*). In addition to standards for plant cover, herbaceous production, and species diversity, presence of 1000 woody plants per acre was required. Efforts to seed and plant woody species were conducted from the earliest years of reclamation and increased over time. However, woody plant presence totaled mostly below 200 stems per acre early on. Moderate grazing (35-40% utilization) was instituted to reduce herbaceous vegetation competition and this improved density numbers generally to levels of 300 stems per acre through the 1990's. From 2000 to 2004, drought conditions developed depressing cover levels to approximately half those experienced during the previous wetter years. By 2002, average shrub density had increased to over 1800 stems per acre. With the return of moist conditions, average levels declined to 800 stems per ace, but 22% of the area averaged 2700 stems per acre by 2011. The process of plant succession during the development of vegetation on reclaimed mined land is strongly affected by the interaction of plant competition and climate/ weather conditions.

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Patches: Optimizing the ecological benefits of different reclamation soils across the landscape in the Alberta mineable oil sands region

Brad Pinno[1] and Ira Sherr[2]

Abstract: The goal of land reclamation after oil sands mining in the boreal forest of northern Alberta, Canada is to re-establish functioning forest ecosystems, including the development of a natural plant community and other functional ecosystem components. A study based at the CNRL-Horizon oil sands project is comparing ecosystem development on different operational reclamation soil treatments, i.e. upland based forest floor-mineral mix (FFMM) and lowland based peat-mineral mix (PMM), in comparison to natural forest benchmarks. There are clear differences in the benefits of each reclamation treatment with FFMM having increased biodiversity as a result of the biological legacy of the past forest floor while PMM has increased tree establishment and productivity due to the higher water holding capacity of the soil. "Patches" is a new operational reclamation approach incorporating the differing ecological benefits of both reclamation soil types on the same landform. Building from experience in forest harvesting practices and natural landscape patterns, patches of differing sizes and shapes of FFMM were placed within a matrix of the more abundant PMM. These patches of FFMM are intended to serve as lifeboats and colonization centres for native biota. Initial studies are focusing on determining the optimal size and spacing of the FFMM patches. Plant species-area curves were developed and show that patch sizes of approximately 1,500 m^2 are recommended to allow initial establishment of one third of the total number of native vascular plant species in the area with smaller patch sizes favouring introduced species and larger patch sizes needed for woody species. Initial spatial patterns indicate no relationship between plant species richness and distance to soil type boundary with the rate and distance of spread of native plants from the FFMM patches being an important monitoring consideration in future years. This work on Patches will help in the development of more efficient and effective reclamation areas which take advantage of the ecological differences in available reclamation soils.

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Interim reclamation: the benefits of temporary reforestation for meeting final reclamation goals

Brad Pinno[1], Amanda Schoonmaker[2] and Robert Albricht[3]

Interim reclamation is conducted during the active life of an industrial facility to ensure land disturbance is minimized, environmental footprint is reduced, and final reclamation goals can be achieved. It has been suggested as a best management practice associated with industrial activities on public lands in Alberta, Canada. Current interim reclamation practices vary widely at present in Alberta but generally include re-contouring and stabilization of slope banks and vegetating with grass cover crops. However, ongoing weed management is a necessity of this approach and may be required for the entire life of lease operations. Within the boreal forest region of northern Alberta, we propose that intentional, temporary reforestation, which has not been widely utilized, may provide the most benefit to long-term (up to 40 years) but non-permanent reclamation soil stockpiles which will be used in final forest land reclamation. These benefits include maintaining a root and seed propagule bank and coarse woody material readily available for final reclamation, long-term soil erosion control, reduced invasion of undesirable or weedy vegetation through increased forest cover and shading, maintaining a biologically viable soil, and increased habitat availability for wildlife. Reforestation of interim reclamation sites should therefore enhance final reclamation and reforestation outcomes. A newly established, large-scale field study located at the ConocoPhillips Surmont SAGD bitumen recovery facility will evaluate the best reforestation procedures to achieve early forest cover and reduce the need for ongoing and repeated weed management throughout the productive life of the site.

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Natural Processes for the Restoration of Drastically Disturbed Sites

David F. Polster

Abstract: Natural processes have been revegetating naturally disturbed sites (landslides, volcanic explosions, earthquakes, etc.) since the advent of terrestrial vegetation about 400 million years ago. Understanding the way these natural processes operate to restore disturbances provides a framework for the design of restoration programs for anthropogenic disturbances (mines, industrial disturbances, etc.). The first step in the design of a natural process based restoration program is to identify what it is that is preventing the natural recovery from occurring (filters). Common abiotic filters are steep slopes, adverse texture, nutrient status, adverse chemical properties, soil temperature extremes, compaction, adverse micro-site conditions and excessive erosion (Polster 2015). Biotic filters include herbivory, competition, propagule availability, phytotoxic exudates, facilitation and adverse species interactions (Polster 2015). Once the filters that are preventing recovery are identified and addressed, the natural processes will operate to restore the site. Care must be taken not to solve one problem by creating another. Traditional grass and legume seeding has been used to control erosion on many reclamation sites. However, the seeded cover has been found to restrict the growth of woody species so if a forest is what the restoration program is directed at then seeding with grasses and legumes is a poor idea. Making sites rough and loose (Polster 2015) can address a number of filters (compaction, excess erosion, lack of micro-sites, soil temperature extremes) and costs about a third of the cost of traditional hydroseeding. In many cases, there are ample seed sources nearby and making a mine site rough and loose can initiate the recovery process. Pioneering species often have effective seed dispersal mechanisms so creating the right habitat can result in the establishment of the pioneering species that are adapted to the local conditions. Natural processes such as making sites rough and loose (like trees in a forest turning up the soil) can initiate recovery on drastically disturbed sites.

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David F. Polster, R.P.Bio, M.Sc., Restoration Ecologist

REVEGETATION TRENDS AND LESSONS AT TWO MONTANA COAL MINES BASED ON 20 YEARS OF MONITORING[1]

R. A. Prodgers[2]

Abstract: Bighorn Environmental Sciences monitored revegetation at Spring Creek Coal Mine (SCM) and Decker Coal Mine (DCM) in semiarid southcentral Montana for 20 years using consistent transect locations and methods. Measurements include canopy coverage, air-dried peak standing crop (PSC), and shrub density. About 30 SCM fields were old enough to evaluate temporal trends. Findings include:

- Ten years after seeding, postmine perennial productivity and canopy coverage were trending upward and exceeded both performance standards and premine vegetation.
- Shrub density declined in about 4/5s of fields. Meeting the shrub density standard of 5,740/ha for wildlife habitat, the primary postmine land use, is a major revegetation challenge.
- Rosana western wheatgrass tripled in relative cover by the conclusion of monitoring. It combines environmental suitability and vigorous rhizomatous spread. Introduced sheep fescue spread even more abundantly, quadrupling relative cover from the early years to one decade or more later, also spreading to adjacent fields.
- Cheatgrass, which replaces annual forb weeds in unsatisfactory seedings, showed no net temporal trend.
- The explosion of the first-year kochia impairs seeding success through interference competition. Prevention requires mine-wide effort. Next, litter impedes interseeding, requiring chemical weed control and litter removal. The first seeding opportunity is the best.
- Shrub seedings are far more successful on suitable spoil than topsoil. However, some spoil meeting the chemical-physical suitability criteria does not support satisfactory revegetation. Scoria can be a fine shrub and diversity substrate or disappointing.
- Heavy-seeded Chenopod shrubs can be established through drill seeding even among vigorous, competitive grasses.
- Light-seeded sagebrush establishes best when seeded apart from the heavy-seeded plants.
- The most prevalent contribution of direct-haul coversoil to revegetation is weeds, not native perennials.

Additional Key Words: performance standards, seeding shrubs, revegetation substrates, plant litter, seeding techniques, interseeding, pre-emergent herbicides.

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OPEN LIMESTONE CHANNELS FOR ACID MINE DRAINAGE TREATMENT: EFFECTS OF AGITATION ON PH INCREASE

S. Rensel[1], J. Gaughan, S. Wolfe, L. Aviles, A. Rovder, C. Spellman, K. Tomkowski, W. Strosnider, J. Bandstra

Abstract: Open limestone channels are common acid mine drainage treatment unit processes. However, performance dynamics are relatively poorly understood. In order to begin to develop better models of open limestone channel dynamics, acid mine drainage from a local source was exposed to limestone under varying rates of agitation. The acid mine drainage acquired for experimentation was obtained from the abandoned Swank 13 mine site near Frugality, PA (pH 3.42). Limestone rocks approximately 5mm-25mm in diameter and 90-95% $CaCO_3$ were employed in the study within 1-L cubitainers. Using 500mL of acid mine drainage and 300g of limestone per test sample, four different tests were performed with three such samples in each test. The independent variable was the rotations per minute (rpm) enacted by a shaker table, being 0, 50, 100, and 150rpm. It was found that as rpm increased, the rate of change in pH of the contaminated water increased. For the mine water to reach pH of 7, it took approximately 175 min at 0 rpm, 100 min at 50 rpm, 60 min at 100 rpm, and 40 min at 150 rpm. Results will be used as part of a broader study to better model limestone dissolution in open limestone channels.

Additional Key Words: passive treatment, water quality, limestone dissolution

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Long-Term Study Identifies Avenues for Improving Revegetation Efforts[1]

Matthew J. Rinella[2] and Erin K. Espeland

Abstract: Restoring native plants to mined grasslands is challenging because seeded natives often fail to establish. Following these establishment failures, areas become invaded by exotic annual weeds, such as cheatgrass and mustards, or exotic perennial species, such as crested wheatgrass and smooth brome. Where seeded natives do establish, species diversity often remains low, with key plant groups (i.e. warm-season grasses, forbs, shrubs) underrepresented or absent. Over the previous several decades, reclamation managers have tried a wide range of seed mixes, seeding equipment, soil handling methods, and other practices. We studied long-term outcomes of these widely varying practices to identify avenues for improving reclamation efforts. Vegetation data from 327 reclamation areas on nine Wyoming and Montana mines were matched with historic records describing reclamation practices used. This allowed us to estimate effects of management (e.g. seed rates) and environment (e.g. precipitation) on annual and perennial weeds, seeded grasses, forbs, and shrubs. We found annual weeds were much less abundant when seed mixes included one or more specific grasses (i.e. western wheatgrass, thickspike wheatgrass, slender wheatgrass, and green needlegrass). While it is important to sow one or more of these grasses, sowing them at high rates is counterproductive: Sowing high grass seed rates prevented shrub establishment without boosting long-term grass establishment. Grass competition was such a strong factor limiting shrubs that more shrubs established in dry years because low water prevented grasses from rapidly outcompeting shrubs. Preventing the undesirable exotic crested wheatgrass from establishing is critical, because once established, this species tends to gradually increase through time and outcompete seeded species. Compared to directly hauling topsoil, stockpiling topsoil appears to limit crested wheatgrass establishment by deeply burying seeds. We think our approach of studying past reclamation efforts to identify more consistently effective reclamation practices could prove useful in reclaiming a variety of systems.

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Rethinking Arsenic Reclamation of a "Hellafund" Site, Montana[1]

S.Robinson[2], T.Hartshorn[3], and T. McDermott[3]

Abstract: Historical copper mining and smelting has left a legacy of hundreds of square miles of contaminated soils across the Deer Lodge Valley (DLV), Montana, meriting designation of four Superfund sites stretching more than 100 river miles from Butte to Milltown. Despite hundreds of millions of dollars of reclamation progress, soil samples collected along the Clark Fork River floodplain in 2014 contained 1100 mg As/kg, ~3000 mg Cu/kg, 900 mg Pb/kg, and ~1000 mg Zn/kg (Sánchez-Espinoza 2015). These highly contaminated soils represent a potential human health risk, principally from an exposure perspective as unvegetated soils can be mobilized under the dry and windy conditions characteristic of this region. We characterized additional soils in 2015 and 2016 for metal and metalloid content, as well as the microbiological capacity to oxidize the more toxic and mobile form of As arsenite (AsIII) to arsenate (AsV) via a simple $Ag(NO_3)_2$ test. Prior work (Sánchez-Espinoza 2015) suggested the combination of arsenite-oxidizing *Agrobacterium tumefaciens* bacterium with basin wildrye (*Leymus cinereus*) yielded impressive biomass growth responses in contaminated DLV soils relative to uninoculated basin wildrye. Therefore, we paired different bacterial isolates able to oxidize 1 mM As(III) with higher-value grass species to document whether revegetation outcomes might be improved through the explicit manipulation of DLV microbial communities adapted to As-contaminated soils, and if so, the phytostabilization return on reclamation investment. Our results suggest cost-effective reclamation of extensive contaminated areas could include field-scale inoculation with bacteria capable of ameliorating As toxicity, analogous to the widespread use of *Rhizobium* inoculum with legumes.

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ASMR GEOLOCATION OF RECLAMATION RESEARCH SITES 1998-2007: A PRELIMINARY ANALYSIS

A. Rovder[1], S. Wolfe, S. Long, P. Smyntek, R. Wagner, W. Strosnider

Abstract: The American Society of Mining and Reclamation (ASMR) has proceedings dating back to the early 1980s. These proceedings include reclamation research studies undertaken across North America and the globe. However, the information within these proceedings risks being lost or overlooked because the papers lack geographic reference. In order to compile the locations of all the papers from 1998 to 2007, geographic information was gleaned from the text of the papers, and authors were contacted where sites were not referenced. Google Earth placemarks were created. Latitude and longitude as well as location names, descriptions, technical topic categories, and html links to the ASMR abstracts or other information were included within each placemark. The new geo-referenced proceedings can also be analyzed for trends in reclamation research through the years or simply used to efficiently locate regional research studies. A variety of maps were created to visualize the spread of ASMR research over time and the geographic distribution of technical topic areas. Results will be integrated as part of a broader study of spatial and temporal trends in reclamation research.

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Green Remediation of Acid Mine Drainage Impacted Water: A Field-scale Filter Development using an Industrial Byproduct[1]

A. RoyChowdhury[2], D. Sarkar, Y. Deng, and R. Datta

Abstract: One of the most concerning environmental problems associated with mining activities is the production of a highly acidic and metal-rich solution called Acid Mine Drainage (AMD). In absence of proper management practices, AMD severely impacts surrounding ecosystems. This study developed a green remediation technology using the metal-binding and acid-neutralizing capacity of an industrial by-product, namely drinking-water treatment residuals (WTRs) to remediate AMD-impacted water. The main objective of this study was to design a filter media using locally generated aluminum (Al) and calcium (Ca)-based WTRs to treat AMD-impacted water collected from the Tab-Simco coal mine in Carbondale, IL. Initially, WTR-filter bed-columns were prepared using 30 cm x 2.54 cm clear PVC pipes. As WTRs are relatively impermeable, a series of hydraulic tests were performed with sand as substrate, and based on these test results, a 1:6 WTR to sand ratio was used to optimize permeability of the filter media. Al- and Ca-WTRs were mixed at 1:1 ratio. A 53mL filter bed volume and 15 mL/min flow rate were used during the study, and representative samples were collected from various bed volumes up to 24 hr. After obtaining satisfactory results from lab scale studies, a field scale 55 gallon drum filter was designed and tested. Results showed that the WTR filter media removed 99.9%, 99%, 99.9%, 100%, 100% 99% and 44.8% of the initial Fe (137mg/L), Al (80mg/L), Zn (11mg/L), Pb (10mg/L), As (5mg/L), Mn (33mg/L), and SO_4^{2-} (2481mg/L) concentrations, respectively from AMD water. The result showed that pH of AMD-water was increased from 2.27 to 7.8. Our study demonstrated that this "green" (recycling of a waste product), inexpensive (raw materials obtained free-of-charge), and ecologically sustainable (no adverse effect on ecosystem) technology can effectively treat AMD-impacted water systems.

Additional Key Words: Water Treatment Residuals (WTRs), Tab-Simco mine, Passive AMD Treatment.

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INTEGRATED APPROACHES OF WATER AND SOLID WASTE MANAGEMENT IN MINING RECLAMATION OF COIMOLACHE MINING COMPANY-PERU [1]

R. Huancaya[2], A. Sagástegui, D. Sánchez*, J. Gabriel, E. Meza, A. Fernández, C. Quinto

Abstract: Coimolache Mining Company (CM) is a Peruvian mining company dedicated to the extraction of gold and silver. The regulatory approach of the Peruvian law, states an environmental management in which the integration of water, solid waste and mining reclamation is not encouraged. Thus, after obtaining fresh water for use in the mine, this water must be treated and then discharged into the environment. The solid waste disposed in authorized areas. The mining reclamation executed on a schedule in which the majority of it is implemented at the end of the operation. In Coimolache since 2012, we have implemented a model with industrial ecology approach. In this model, the three components are managed in an integrated way. The organic solid waste is treated using effective microorganisms technology. Under this technology, solid waste is converted into organic products that are used as inputs to our mine reclamation process. Coimolache implemented the advancement of the mine reclamation using as main input the products obtained from the organic solid waste. The advancement of the mining reclamation, in turn, has allowed us to reduce the areas exposed to rainwater and thus treat less amount of acid water. Finally, the water that is treated instead of being discharged into the environment is reused in all our processes including in the mining reclamation. This approach has enabled us to reduce $1,674,463.95 USD that represent 55.7% of saving in operating expenses in water treatment over a period of 3 years. In the case of solid waste, we saved an amount of $180,120.00 USD that represents 57% of savings on solid waste management. Finally, with the advancement of mining reclamation, we have stopped the generating 1,570,133 m^3 of acid mine water. This work shows a management model that can be replicated in other mining companies as a saving.

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2. Ricardo. Huancaya, General Manager, Coimolache Mining Company, Cajamarca, Perú. Alfredo. Angulo, Deicy. Sánchez (presenter), Jimmy. Gabriel, Elizabeth. Meza, Angel. Fernández, Cesar. Quinto, Environmental Area, Coimolache Mining Company, Cajamarca, Perú.

INTERACTIVE EFFECTS BETWEEN LIME, ORGANIC MATTER, AND BACTERIA IN THE ESTABLISHMENT OF *LEYMUS CINEREUS* IN MINE TAILINGS

Sánchez, D[1*]; McDermott, T[1]; Zabinsky, C[1]; Neuman, D[1]; Hartshorn, T[1]

Abstract: The landscape legacy of historical metal-mining activity can persist for decades. The most frequent strategies used for the remediation of contaminated soils include the use of synthetic membranes to isolate contaminants (>$0.5 million/acre), direct revegetation (less expensive but difficult to sustain), or lime amendments ($5,000/acre). Looking for more cost-effective bioremediation approaches, we performed a set of greenhouse studies to determine what combinations of soil amendments would lead to the best vegetative response, and potentially associated reductions in soil arsenic (As) levels, in "slickens" collected from the Lampert Ranch along the upper Clark Fork near Warm Springs, MT. In our first greenhouse experiment, we planted *Leymus cinereus* (basin wildrye), compared (after 12 weeks) plant growth, and foliar metal concentrations across treatments. Amendments included single or factorial additions of 5% lime, organic matter (+OM), and an arsenic-oxidizing (+oxbact) strain of *Agrobacterium tumefaciens (Agtu)*. Surprisingly, the OM+oxbact treatment revealed among the best plant growth and arsenic uptake response. We then performed a second greenhouse experiment with two levels of OM (1.5% and 5%) and an additional treatment: a mutant (reducing strain) of *Agtu.* Basin wildrye grown in soils amended with 5% OM generally did better than those grown in soils amended with 1.5% OM. At the same time, foliar As uptake (biomass multiplied by As concentration) was unexpectedly high (0.020 mg pot^{-1}) for plants grown in soils amended with 5% OM + oxbact, 3 times greater than foliar arsenic uptake in plants grown in soils amended with 5% OM+ lime and 4 times greater than foliar uptake by plants grown in soils amended with 5% OM and the reducing strain of *Agtu*. These results suggest the combination of OM and *Agtu* oxbact strain could provide a potentially cost- effective approach to remediating As-contaminated soils. Finally, our study results imply that soil restoration approaches could be improved through a greater consideration of microbial communities supported by these re-establishing vegetation communities, which could lead to more sustainable ecosystem successional trajectories.

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UAS (drones) De-mystified, and How They Can Help Your Mining Reclamation Project[1]

Josh Schane*[2] and Tom Mullen, PG*[3]

Abstract: The use of unmanned aerial systems (UASs), more commonly referred to as drones, is increasingly becoming a low-cost, easily deployable alternative to collecting spatial data. In addition to obtaining aerial images and video, UASs can be equipped with remote sensing packages such as LIDAR, near-infrared/multispectral sensors, and thermal imagers. Further, the data acquired from these applications can be easily imported into GIS and Civil 3D/CAD for use in spatial analysis and mapmaking.

Recently, Maul Foster and & Alongi, Inc. (MFA) utilized an UAS in the reconnaissance of an inactive quarry along the St. Joe River in Shoshone County, Idaho. A small UAS with autonomous flight capabilities was deployed using a digital camera to map the approximately 10-acre (4.1-hectare) site. The mission entailed approximately 15 minutes of flight time to survey the quarry. Using GPS ground-control points, a digital surface model (DSM) with an accuracy of +/- 1 meter was generated using overlapping photos in photogrammetry software. The model was imported into Civil 3D in which volume estimates were calculated under various mining scenarios.

The use of UAS technologies are versatile and can not only assist in the evaluation of mining schemes, it can also be used in developing reclamation plans as well as documenting reclamation activities. The temporal resolution (refers to the precision of a measurement with respect to time) required to monitor large scale mining projects is often very high, in the sense that your mine site could change every day. UAS can be deployed to monitor changes in terrain after mining activities, calculate stockpile volumes, calculate drainage/water management, and model planned blasts and excavations.

We understand that employee safety is of utmost importance at any mine site big or small. By being able to remotely gather data from above, UAS technology can reduce the amount of time staff spends on site. These data acquisition schemes can be completed in a matter of hours which includes flight planning, executing the mission, and post-processing the data. Data that usually would take days or weeks to produce using traditional methods. And because manpower is reduced and high-accuracy data products are created quickly, there is a direct reduction of costs.

Additional Key Words: reconnaissance, GPS, LIDAR, sensors, photogrammetry

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Hydraulic and Biological Maintenance Challenges and Solutions in an Aging Passive Treatment System[1]

N.L. Shepherd, R.W. Nairn[2]

Abstract: The ten-cell Mayer Ranch passive treatment system, in the Tri-State Mining District, Oklahoma, was constructed in late 2008 to treat 1000 LPM of net alkaline, iron-rich, abandoned lead-zinc mine water. Since construction, the system has successfully and consistently improved water quality, decreasing Fe, Zn, Pb, Cd, and As concentrations and leading to both biogeochemical and ecological recovery in the receiving stream. However, numerous challenges, both biological and hydraulic, have required regular maintenance commitments. With the improvement of water quality came the re-colonization of *Castor canadensis* (North American Beaver) and *Ondatra zibethicus* (Muskrat). Muskrat infestations into berms required barrier (e.g., hog wire fence) placement and regular vegetation management to maintain piped flows. Beavers, although not present in the system proper, have returned to the effluent structure, and other downstream long-term monitoring sites. Repeated physical destruction of beaver dams simply led to rapid re-establishment, so water level management devices were designed and implemented. A unique design, consisting of multiple perforated corrugated pipes, PVC connections, and submerged inflow and outflow orifices, was used. The device was placed through the beaver dam and was covered by debris. The device is intended to allow treated waters to silently bypass existing dams, preventing pooling of waters which negatively impact system performance and sampling efforts. In addition, hydraulic conductivity problems in vertical flow bioreactors provided further operational complications. It is likely that a combination of exogenous organic substrate degradation and volunteer vegetation establishment have contributed to these issues, which have yet to be successfully addressed. Additional piped hydraulic throughput issues between an initial oxidation pond and surface flow wetlands were examined and resolved using sewer drain video inspection devices, plumbing snakes, and targeted pumping using a constricted orifice device. Operation and maintenance challenges are common to passive treatment systems, and lesson learned at the Mayer Ranch site may help to influence designs elsewhere.

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SURVIVAL AND GROWTH OF CHESTNUT BACKCROSS SEEDS AND SEEDLINGS AFTER 8 YEARS ON SURFACE MINES[1]

J. Skousen*, T. Cook, K. Dallaire, S. Scagline, A. Monteleone, L. Wilson-Kokes, J. Joyce, T. Keene, C. DeLong, and E. Pena-Yewtukhiw[2]

Abstract: Many foresters consider the loss of the American chestnut from eastern USA forests as one of the greatest forest ecological disasters in the 20th Century. The American Chestnut Foundation has been attempting to restore chestnut to the forest by the use of a breeding program to backcross blight-resistant Chinese chestnut to American chestnut and selecting those strains with blight-resistance. Third-generation backcross seeds and seedlings have been produced and were made available for out-planting in 2008. Surface mined lands are a potential land base for re-introducing these chestnut seedlings back into eastern deciduous forests. Seeds and seedlings of these backcrosses from The American Chestnut Foundation were planted on two surface coal mines in West Virginia. The first study, initiated in 2008, used seeds of two parental species of chestnut and three breeding generations (100% American, 100% Chinese, and B_1F_3, B_2F_3, and B_3F_2 backcrosses) which were planted into loosely-graded mine soils. First year establishment was between 66 to 81%. After the 4th year, survival had declined for all chestnut stock types except for Chinese (80%): American 40%, B_1F_3 55%, B_2F_3 40%, and B_3F_2 44%. Average height after the 4th season was not significantly different among stock types, averaging 50 cm in height. The second study, initiated in 2009, involved planting seeds and seedlings of these same chestnut stock types into brown sandstone (pH 4.5) or gray sandstone (pH 6.6)). Only a few of the 250 seeds germinated, so further analysis was not possible. Planted chestnut seedling survival, after the third year, was around 80% on both substrates. After eight years, further declines in survival were noted for all stock types at both sites. Chinese had the highest survival at 63%, while the others ranged from 25 to 50%. Average heights were much greater after eight years compared to the third and fourth years. Clearly, surface mines provide opportunities for introducing blight-resistant chestnut backcross trees into the Appalachian forest.

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[2] J. Skousen (Professor), T. Cook (Navigator Technical Services), K. Dallaire, S. Scagline, A. Monteleone, L. Wilson-Kokes, J. Joyce, T. Keene, C. DeLong (Graduate Students), and E. Pena-Yewtukhiw (Associate Professor), Division of Plant and Soil Science, West Virginia University, Morgantown, WV 26505.

Open Limestone Channel Performance for Aluminum-Rich Acid Mine Drainage

Charles Spellman Jr[1], Kevin Tomkowski, Sergio Carvajal-Sanchez, Caleb Weyant, James Krug, Logan Stern, David Wolfe, Dallas Mosier, Arthur Rose, Edward P. Zovinka, Joel Bandstra, William Strosnider

Abstract: The Swank open limestone channel (OLC) was installed in 2011 for the treatment of Al-rich acid mine drainage (AMD) from the Swank 13 mine in Dean Township, PA. The 275m limestone channel treats AMD which impacts Clearfield Creek, a major tributary to the West Branch of the Susquehanna River. The channel aims to abate AMD which has an average acidity of 61.4 mg/L as $CaCO_3$ equivalent, pH 3.46, Al 7.3 mg/L, Fe 0.49 mg/L, and Mn 0.71 mg/L. On average, the system is able to reduce the concentration of Al to 6.5 mg/L and raise pH to 4.14. The pH increase ranges from as little as 0.11 to as high as 1.14 units, depending upon the flow rate. During lower flows, pH of the system plateaus around 4.4, as protons released from the formation of $Al(OH)_3$ counteract proton uptake from $CaCO_3$ dissolution. A mathematical relationship between the residence time of the channel and the acidity removal rate was developed using rhodamine tracer tests, flow rates, and metals concentrations. Residence times ranged from 13 to 140 minutes and Al removal ranged from nil to 0.4 mg/L. Over the years, treatment effectiveness has diminished somewhat, likely due to armoring with Fe-oxides. The simple model developed may be used to predict treatment performance when designing future OLC's for the treatment of similar Al-rich, low-Fe, AMD.

Additional Key words:

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1. Charles Spellman, Kevin Tomkowski, Sergio Carvajal-Sanchez, and Caleb Weyant, Undergraduate Environmental Engineering Students, Saint Francis University, Loretto, PA. James Krug, Logan Stern, Dallas Mosier and David Wolfe, Undergraduate Chemistry Students, Saint Francis University, Loretto, PA. Edward Zovinka, Professor, Saint Francis University Chemistry Department. Loretto, PA. William Strosnider & Joel Bandstra, Associate Professors, Saint Francis University Environmental Engineering Department. Loretto, PA.

Fluorescent Dye Tracing in Abandoned Mines for Adit Discharge Source Control[1]

C. Storrar*[2], N. Anton, C. Coover, A. Frandsen, and M. Peters

Abstract: A tracer study using fluorescent dyes was conducted at two abandoned, historic, mine sites in the Basin Mining Area Superfund Site. Adits at both the Crystal Mine (Operable Unit [OU] 5) and the Basin Mine (OU 6) discharge acid mine drainage (AMD) into nearby receiving streams. The AMD contains high levels of heavy metals and arsenic and has been identified as the greatest threat to water quality in the Basin watershed. This study sought to identify sources of surface water that may be infiltrating into the mine workings and creating AMD from the adits and springs at both mines. Three fluorescent dyes (sulforhondamine, eosine, and fluorescein) were deployed within, or near, prominent surface water features at each mine site prior to major snowmelt at the sites. The adits, springs, and streams as each site were monitored for the presence of the dyes using activated carbon (AC) samplers that accumulated the dyes over their sampling period. The AC samplers were analyzed by a laboratory, using a spectrofluorometer, for the presence of the dyes. At the Bullion Mine, one of dyes injected in streams and wetlands near the top of the mine area was detected at several acidic springs near the adit portal. Though the Bullion Mine study was complicated by work to dewater and stabilize the adit concurrent to the tracer study. At the Crystal Mine, two different dyes were detected within the adit discharge. In addition, at both sites, dyes were detected within the surface water streams nearby, which was expected. This study qualitatively determined a connection between surface water surface water and discharge of apparent mine influenced water/AMD from the adit portal (Crystal) and springs (Bullion) at these sites. This information may be used for further investigation or source control designs at the mine sites.

Additional Key Words: Acid mine drainage, activated carbon sampler, surface water

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2. Chapin Storrar, Project Manager/Water Resource Engineer; Nick Anton, Environmental Engineer; Curt Coover, Hydrogeologist; Angela Frandsen, Environmental Engineer, Mark Peters, Geologist; CDM Smith, Helena, MT 59601.

Passive biological treatment approaches to reduce conductivity in waters affected by mine drainage: Key challenges & research needs[1]

Peter M. Smyntek[2], Rachel C. Wagner[2], Sergio Carvajal-Sanchez[2], T.M. Wynn-Thompson[3], Leigh-Anne H. Krometis[3],William H.J. Strosnider[2*]

Abstract: The Environmental Protection Agency proposal to implement a specific conductivity threshold of 300 μS/cm presents a substantial challenge for surface waters affected by mine drainage. Although passive biological treatment (PBT) approaches have been employed to improve water quality for over 30 years in regions affected by mine drainage, the focus of these PBT systems has been the removal of acidity and metals, and the extent to which PBT approaches can simultaneously reduce conductivity has not been examined in detail. Given the considerable expense and management associated with traditional approaches to reducing conductivity in wastewaters (e.g. reverse osmosis), it is worth reviewing whether passive systems can be used in lieu of or in conjunction with traditional systems. This presentation will provide a comprehensive review of published studies of PBT of mine wastewaters that report conductivity values.

Review of these studies suggests the performance of PBT in reducing conductivity is highly variable. Observed increases in conductivity could likely be attributed to dissolution of calcareous carbonate substrates or the leaching of ions from materials used to construct PBT systems. Decreases in conductivity appeared related to the efficacy of sulfate reduction, which showed substantial temporal variation. Two of the main treatment approaches, wetlands and anaerobic bioreactors, demonstrated similar efficacies, with reductions in conductivity of approximately 40% in some cases, which is near the maximum theoretically predicted value. Most work has focused on relatively high conductivity waters (>1000 μS/cm) where much higher reductions are required, so future studies should examine the potential of PBT systems to reduce conductivity from intermediate values (<750 μS/cm) to the target thresholds. Characterization of environmental factors that limit the efficiency of sulfate reducing microorganisms within PBT systems would assist greatly in developing future design recommendations.

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Cost Effective Plans for Successful Mine Closure – Recent Case Studies

Marc S. Theisen[1]

Abstract: Successful rehabilitation, reclamation or closure of massive soil and vegetation disturbances from mining requires a comprehensive and holistic approach. Those overseeing rehabilitation efforts must assimilate and stage several considerations into a working relationship that integrates five fundamentals for successful mine closure. Employing the discipline to work through the discovery sequence of the first three fundamentals – to analyse soils and substrates, pick the right plant materials for the site and select the most cost effective erosion and sediment control techniques, will undoubtedly head a project in the right direction.

These fundamentals must be followed by the development of clear and comprehensive construction plans and specifications to effectively communicate the project requirements to contractors and installers. Once construction commences, onsite oversight of acceptable installations must be conducted by qualified inspectors. Then, the active rehabilitation sites must be regularly inspected and maintained after each significant precipitation or other potentially damaging event. Inspections should be conducted by qualified professionals whose expectations are consistent with the installer as well as the owner and regulatory entity(s). Failure to systematically execute on any of these fundamentals can undermine the best laid plans of any mine closure project.

Mined land sites offer unique and unpredictable challenges for successful closure efforts. Published handbooks or manuals can provide general approaches to mined land reclamation, but rarely can they address the specific needs or conditions of unique mining sites. Successful restoration most typically comes from carefully controlled onsite trials and iterative installations to assess efficacy of various treatment combinations. Such treatments must then be refined and customized to develop cost effective closure plans. Exhaustive research on suitable soil amendments, plant materials and erosion control techniques should be planned and budgeted for – as integral steps in the mine closure progression.

Five selected case studies from North America, Latin America, Asia and Oceania – demonstrating diverse climates with contrasting environmental and site conditions will be offered to illustrate the discovery (required information gathering) and implementation (execution) of the five mine closure fundamentals for successful mine closure.

Key words: erosion control, cover systems, vegetation establishment, mine closure, reclamation

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Removal Action at the Monte Cristo Mining Area[1]

R.M. Tobias[2]

Abstract: The Monte Cristo Mining Area (MCMA) is an abandoned gold mining district situated in a remote area of the northern Cascade Mountains in eastern Snohomish County, Washington. The former millsite, mines, haulage ways, tram terminals, assay shack, and ore collector are located within a complex patchwork of Forest Service-administered lands, patented claims, Inventoried Roadless Area (IRA), and the Henry M. Jackson (HMJ) Wilderness. Operations from 1889 to 1920 resulted in elevated concentrations of legacy contaminants, primarily arsenic and lead, which have been documented in surface water and sediment in a 15.29-kilometer stretch of the South Fork Sauk River and tributaries.

Due to the remote setting, a low-volume access route was developed to access the mines and features for a Removal Action. The approximate 4.02-kilometer access route was constructed through an IRA from 2012-2014. The alignment required installation of three log-stringer bridges over tributaries, each capable of accommodating up to 36,287 kilograms. Earthwork was initiated in June 2015 to address physical and chemical hazards associated with nine mine features at the MCMA. Waste materials were consolidated in the repository from July through October. Removal of about 1,529 cubic meters (m^3) of waste rock from the Pride of the Woods Mine (located within the HMJ Wilderness) necessitated the use of a heavy-lift helicopter to move excavators and haul material with 1.68 m^3 self-dumping bins. Following placement, the repository was lined and covered with a one-meter soil cap to promote establishment of early seral vegetation.

Heavy recreational use, coupled with concerns over archaeological and wilderness resources, and endangered species complicated Removal Action objectives. To address these concerns, continuous archaeological monitoring was conducted during all earth disturbing activities. Furthermore, minimization measures were implemented to limit incidental take of marbled murrelet (*Brachyramphus marmoratus*), bull trout (*Salvelinus confluentus*), and designated critical habitat.

Additional Key Words: None

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Looking at Reclamation in terms of Ecological Restoration

Michael J Vice

With the different components that make up reclamation, it is easy to lose site of what we really need to be doing when reclaiming land. Our main goal is always to establish vegetation and control erosion, but what else are we missing? We need to look at land reclamation as if we were constructing a pyramid. First, we need a solid foundation for which all the other layers will be dependent upon and each consecutive layer thereby becomes dependent upon the underlying layer before it. Ultimately, the layers of the pyramid will become interdependent on each other, not only going up the pyramid, but also back down. For a solid foundation we need to focus on the health and microbiology of the soils, as well as the geomorphic landform. With the landscape and soils in place, our next focus needs to be water systems and erosion control. Next is plant systems and diversity. Will the slope aspect impact our vegetation and can we utilize those changes to provide more diversity, depending on the region's moisture regimes. The diversity of the plant species has a big impact on the next layer of the pyramid, which involves pollinators and other insects. What are we doing to attract bees, butterflies, and other insects that not only impact the next layer, but can impact the layer of the plant systems? With these layers in place, the next layer of attracting birds and small mammals falls more easily into place. Are we helping by providing habitat and cover? And finally, are there considerations for larger mammals? If we can look at reclamation in terms of an ecological restoration pyramid, then we can have successful reclamation.

Geochemistry and Biota of Bolivian Hypersaline Lakes

L.G. Mignogna, S.T. Long, B.A. Pillot, P. Muiño, W.H.J. Strosnider, and R.C. Wagner

Abstract: Bolivia is home to some of the most extreme geology, geography, and climate in the world; consequently, water bodies, especially those in the highlands, exhibit unique and extreme characteristics. Partly due to extreme conditions and general inaccessibility, very few studies have been conducted on the unique water quality and ecosystems in highland Bolivia. Geochemistry and biota were sampled and analyzed in three hypersaline, high-altitude lakes: Laguna Hedionda (4,129m), Laguna Verde (4,333m), and Laguna Colorada (4,305m). All lakes are located in Southern Bolivia, near the Salar de Uyuni, the world's largest salt flat. The chemistry of the water included ranges of specific conductance from 60,801µs to 215,426µs; pH from 7.45 to 8.11, dissolved oxygen from 3.73mg/L to 32.14mg/L, and temperature from -0.6^{0}C to 10.3^{0}C. Alkalinity ranged from 440mg/L $CaCO_3$ eq to 1,163mg/L $CaCO_3$ eq. Anions, total metals, and total dissolved metals were also analyzed. Of particular note is the abundance of the anion chloride, which revealed as much as 166,502mg/L in Laguna Verde; while the total metals sample of sodium exceeding 34,000mg/L and potassium exceeding 6,000mg/L in Laguna Colorada. The richness of macroinvertebrate species was relatively low, as expected in an extreme setting. Inspection of the samples from each lake confirmed four different macroinvertebrate orders: Anostraca, Brachycera, Ostracoda, and Amphipoda. Organisms in the order of Anostraca were most abundant. Microorganisms were sampled for community analysis; a low diversity is expected due to extreme conditions. These rare habitats are truly remarkable, and offer a glimpse into an extraordinary world that leaves so much to be discovered.

Additional Key Words: watersheds, endorheic basin, mineralogy, anions

THE SPENCEVILLE COPPER MINE RECLAMATION[1]

William J. Walker, Ph.D[2]

Abstract: The Spenceville Copper Mine is an abandoned copper mine located in the Sierra Nevada foothills of California. The mine was operated intermittently from the 1880's until 1918. The site was covered with mine tailings and overburden materials. In addition, the central portion of the site was occupied by an acidic, flooded open pit, which contained approximately 6 million gallons of water with a pH averaging 2.5. The U.S Army owned the site from 1941 to 1962, at which time it was transferred to the California Department of Fish and Game (DFG) with the creation of the Spenceville Wildlife Refuge.

We developed a mine closure plan in cooperation with California Department of Fish and Game (DFG) that addressed the following: (1) closure objectives; (2) geochemical and geotechnical characterization of the water and mine waste; (3) alternative remedial approaches for treating the mine water, disposing of the mine waste, and filling the pit; (4) evaluation of options in terms of technical and economic feasibility, regulatory compliance and environmental impacts; (5) preliminary designs and detailed costs estimates for two closure options; and (6) selection of a preferred closure plan based on how well each option met the closure objectives.

A water treatment plant was constructed and used to treat the pit water. The treated water was then applied as irrigation water to land in the vicinity of the site. The mine waste was excavated, treated with lime, and placed in the dewatered pit. A layer of borrow soil was placed as cover over the entire site, and a mine impacted stream was restored to its original channel. In addition to these tasks, closure activities had to address the potential for unexploded ordnances, reclamation of shafts and tunnels in the dewatered pit, and documentation of cultural resources.

The talk will discuss these various activities and how they ultimately led to a successful mine closure.

Additional Key Words: Listing of those not in the title.

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1. Oral presentation at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4 - 9, 2016. Published by ASMR; 1305 Weathervane Dr., Champaign, IL 61821.

2. William J. Walker (presenter), Senior GeoChemist, Sovereign Consulting Inc. 5333 SW Admiral Way, Seattle WA 98116.

Deep Till Method In-situ Soil Reclamation with a BOMAG Recycler[1]

Erna Waterman[2], R. Anderson and A. Sanchez, and T. Howes

Abstract: For many years deep tilling has been an alternative as a clean-up methodology for soil impacted with lead and arsenic. Typically, the success of deep tilling has been limited due to inefficient mixing deeper than just the top few inches. This study evaluated the deep till method using a BOMAG recycler, a machine that more aggressively mixes soil. Specifically a Recycler, commonly used for recycling pavement surfaces, was evaluated to determine its effectiveness in mixing soil with the purpose of reducing the concentration of lead and arsenic concentrations in the shallow horizons of soil. The intent of the study was to reduce metal concentrations to below Action Levels by thoroughly distributing the metals throughout a deeper 18 inch horizon. The study area borders a former copper and lead smelter. Operations from the site resulted in elevated concentrations of arsenic and lead within the shallow soils of the study area. Pre-sampling indicated a majority of shallow soils exceeded Action Levels for both arsenic and lead, with concentrations rapidly decreasing with depth. A 5-acre test plot, with a wide variation of metal concentrations was treated.

The study concluded that where economic or other restraints dictate, this procedure can be an effective option for achieving Action Levels.

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2. US-EPA; Anderson Eng. Inc., and Utah DEQ.

Interstate-Callahan Upper and Lower Rock Dumps

Remedial Action Construction Project

Tony Wesche

Within the Upper Basin of the Bunker Hill Mining and Metallurgical Complex Superfund Site, the Interstate-Callahan mine was one of the largest producers of ore in the Ninemile Creek watershed. Over its life, the mine produced approximately 1.4 million tons of ore containing approximately 2 million ounces of silver, 100 million pounds of lead, and 300 million pounds of zinc. The primary contaminant of concern for the Interstate Callahan Upper and Lower Rock Dumps Site (IC Rock Dumps) was lead. Lead concentrations in the mine wastes at the IC Rock Dumps were up to 29,100 mg/kg. The IC Rock Dumps filled two tributary drainage valleys and the East Fork Ninemile (EFNM) Creek stream channel.

The IC Rock Dumps RA consisted of excavating 216,000 bank cubic yards of mine waste materials over approximately 18 acres. The primary objective of the project was to complete excavation and removal of mine waste materials for placement in the Waste Consolidation Area (WCA) and restore native ground surface to match surrounding native conditions. Once excavation of mine waste materials was complete, reconstruction of the two tributary drainage channels and EFNM Creek was completed. Approximately 1,600 lineal feet of tributary channel and 1,700 lineal feet of EFNM Creek was reconstructed within the boundaries of the IC Rock Dumps. Amended cover soils were placed post-excavation to all disturbed areas and seeded.

The Successor Coeur d' Alene Custodial and Work Trust (Coeur d' Alene Trust) was established as part of the Asarco settlement in the Coeur d' Alene river basin which has been impacted by 100 plus years of silver, lead, and zinc mining. This presentation presents the remediation completed at the IC Rock Dumps by the Coeur d' Alene Trust.

Post-Deep Till Method for In-Situ Soil Reclamation with a BOMAG Recycler[1]

M. Williams*, G. Gardner, S. T. Nelson and E. Waterman

Abstract: Post in-situ BOMAG Recycler sampling at variable depth (0-9" and 9-18") revealed attenuated lead and arsenic downward advection. Areas where surface soil was left mostly undisturbed showed distinctly higher levels of contaminants only in near-surface soils. Areas which were subject to regional changes such as storm drainage, roads or other disturbance revealed a more uneven distribution of contamination. This framework for analysis may reduce the mitigation costs by revealing optimization using the BOMAG Recycler based on site specific information.

Analysis of post in-situ soil sampling concluded that residential lead and arsenic levels can be met using this reclamation method. The results of this effort make a robust template for future remediation activity, including volumes of soil to be handled and the likelihood of reaching remediation goals.

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1. Oral presentation at the 2016 National Meeting of the American Society of Mining and Reclamation, Spokane, WA: Reclaiming the West, June 4 - 9, 2016. Published by ASMR; 1305 Weathervane Dr., Champaign, IL 61821.

2. M. Williams* (student presenter), G. Gardner (student) Stephen T. Nelson, Professor of Geo-Chemistry, Department of Geological Sciences, Brigham Young University, Provo, UT 84602; Erna Waterman, Project Manager /Environmental Engineer US EPA Region 8, Denver, CO 80202.

Underground Mine Subsidence Evaluation, Closure, and Risk Management[1]

T.G. Wilson[2]

Abstract: CDM Smith has completed evaluations and closures of multiple underground mine subsidence features across the U.S. under design-built contracts. Numerous hazards and challenges are associated with underground mine subsidence features as it can be very difficult to understand the characteristics of a subsidence feature making it equally as difficult to design and implement solutions that can be constructed safely and will provide long-term risk reduction.

Typically data from historic mine maps is used to design and develop work plans for mine subsidence feature closure. However, it can be very difficult to relate underground features spatially with the ground surface topography using only paper maps. For multiple sites, CDM Smith has digitized historic mine maps and developed a Vulcan 3-D model to accurately evaluate the locations and characteristics of mine workings. The Vulcan 3-D model can be adjusted to tie in with the surface survey by identifying mine features including portals and vent raises that can be identified on historic mine maps and at the ground surface. The modeling results are then used to evaluate various closure methods ranging from polyurethane (PUF) plugs, earthen-backfill, and monolithic-concrete slabs to provide safe and cost-effective reclamation. Test hole drilling and Ground Penetrating Radar (GPR) surveys are also used to confirm the location of underground mine features and can also be used to verify that unexpected near surface voids are not present below work areas.

Modeling efforts have also been used to identify areas that could potentially subside in the future by identifying near surface voids where stope excavation extended to near the ground surface. This allows yearly maintenance inspections and safety measures to be focused on areas that are prone to future surface ground movement.

Additional Key Words: Design build, subsurface site characteristics, long term solutions

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Streamlining the Reclamation Monitoring and Reporting Process: A Digital Reclamation Monitoring Tool

Nathan J. Wojcik[1], Peter J. Gordon[2], Rio T. Franzman[3], and David R. Reinhart[4]

Abstract: Reclamation monitoring, data collection, and reporting are consuming, inefficient and costly, and susceptible to observer error. Traditional data methods typically stall monitoring efforts and reporting processes, often causing field monitors to fall behind monitoring schedules and agencies to become overwhelmed with unorganized data, photos, and monitoring reports. As a result, surface disturbances that are reclaimed and meet success standards may not be reviewed and/or overlooked, and the operator becomes held in bond for far longer than was ever intended. SWCA Environmental Consulting has developed an entirely digital solution that modernizes the data collection process, develops a customizable database, and automates reclamation reporting.

The database-driven web application developed for reclamation monitoring is specifically designed and customized to standardize the data collection process and meet the reclamation requirements for the operator and the appropriate agencies. The reclamation monitoring system operates under a digital platform using tablets with high quality internal digital cameras and survey-accurate GPS units, and customizable forms. A general-purpose database management system provides the software tools necessary to organize that data in a flexible manner, including tools to edit and query data, and to produce customizable reports. Automated reports are generated from standardized and customizable operator-specific templates. Data are geo-referenced and displayed on a web mapping tool using ArcGIS Server. ArcGIS Server connects the database to a GIS platform to display the data in a web-accessible dynamic map along with all supporting reference information. This process is completed in near-real-time and provides a searchable platform for visual exploration and reporting.

Additional key words: time-efficient; cost-efficient; GIS; database-driven web application; mine closure; bond release

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The Holistic Approach to the Design, Monitoring, and Future Performance Assessment of a Surface Barrier[1]

Z.F. Zhang[2*], M.D. Freshley, D.M. Wellman, M.D. White, and M.J. Truex

Abstract: In the reclamation and restoration of mine lands, a surface barrier (or cover) can play many roles. Surface barriers may be used to contain waste in place, reduce or eliminate water infiltration through the waste zone, restrict O_2 ingress into or hazardous gases egress from the waste zone, neutralize acid formation in mine tailings, and provide an environment friendly media for vegetation development. One of the challenges of applying a surface barrier is that effective designs vary dramatically depending on a number of factors such as the waste type (e.g., non-hazardous, hazardous, radioactive, or toxic), climate (e.g., precipitation, temperature), topology, and spatial scale (e.g., depth and lateral distribution). Thus, the design approach, associated performance predictions, and monitoring methods to verify effectiveness are important for successful application of a surface barrier.

Elements of holistic approaches to surface barrier applications have been developed by Pacific Northwest National Laboratory (PNNL) through studies and demonstrations of surface barrier construction and performance since 1985. In the past three decades, interim or permanent surface barriers with a range of design lives were demonstrated in lysimeters or on waste sites. Their effectiveness has been tested under natural conditions or introduced stresses (i.e., enhanced precipitation, controlled fire). The performance of the barriers has been monitored with sophisticated monitoring systems for a period over two decades. The surface barrier module was developed and included in the Subsurface Transport Over Multiple Phases (STOMP) numerical simulator to predict future long-term (e.g., decades to centuries or longer) performance of surface barriers. The STOMP with the surface barrier module can be used in evaluating the functionality of alternative barriers during the design phase. Additionally, recent guidance has been developed for use of integrated systems-based approaches to monitoring of complex waste sites. When monitoring data becomes available, the model can be calibrated and used to predict barrier future performance. The resulting holistic approaches to design, performance prediction, and monitoring of surface barriers are also applicable to mine lands.

The key to successful restoration of mine lands is that a surface barrier must be designed, evaluated, and monitored in a holistic way by considering the major components such as the site (e.g., characteristics, main issues of concern, risks to the environment), the remedy (e.g., barrier design, functionality, and long-term performance), and the environment (e.g., ground water, surface water, and vegetation) as an integrated system. Case study examples show how elements of the surface barrier design, performance prediction, and monitoring approaches developed for waste sites can be effective for mining site applications.

Additional Key Words: Surface Cover; Mine Land; Reclamation; Containment

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Restoration in Challenging Northern Climates

Alex Zimmerman

Restoration and revegetation has been a challenge for degraded soils in difficult environments. Often, after construction or mining operations, the soils lack organic content and biological activity necessary for long term nutrient cycling and vegetation establishment. Unwittingly many standard practices can actually work against the goals of long term restoration by focusing on short term measures. Sustainable site restoration relies on providing the necessary conditions and materials for a healthy soil to build and creates an environment that can truly sustain the restoration efforts. Pioneered in the restoration of large scale construction projects and tested for function as well as microbial activity biotic soil amendments have become a trusted option for challenging restoration efforts. This presentation will examine the traditional specifications used to develop restoration plans and identify where shortcomings exist and improvements can be made. Attendees will review the soils analysis years after biotic soil amendments have been used to quantify the different outcomes and gauge the performance of the restoration. Case studies in northern climates, high altitude, and arid environments will be presented and the lessons learned will be discussed. The best use of and specification of biotic soil amendments will be discussed so that attendees will gain an understanding of the options available when implementing a restoration plan that incorporates both conventional best practices and biotic soil amendments. Tested application rates and establishment results will be provided from projects in Alaska, Canada, Colorado, Washington, Oregon, and Idaho.

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Reclamation Practice Influences on the Post-Mining Plant Community at a Virginia Mine Site after Six Years[1]

C.E. Zipper[2], S.K. Klopf, D.M. Evans, R.J. Krenz, J.A. Burger

Abstract: Surface mines often disturb forest plant communities in eastern USA. Reclamation practices on Appalachian surface mines include soil construction, soil grading and herbaceous seeding. Past research has demonstrated influence by these reclamation practices on establishment and growth of native trees planted during reclamation. In early 2008, we initiated an investigation of influences by these reclamation practices on post-mining plant communities. Two soil grading (smooth grading and loose grading) and three ground cover vegetation seeding (conventional, tree-compatible, and annual ryegrass only) treatments were established in all combinations on two reclamation areas, both on steep slopes, and planted with native trees. Two treatment combinations (loose grading – tree-compatible seeding; and smooth grading – conventional seeding) were also applied on a third reclamation area by the mining operator in 2006 and 2007, and that area was planted with native trees. The three reclamation areas were on differing soil types. Tree survival, tree growth, and plant community composition were measured on all areas in 2014. Understory plant communities were comprised primarily of non-seeded and exotic taxa. Larger trees of native species were found on annual-ryegrass and tree-compatible seeded areas, and greater native understory plant cover was found on the annual-ryegrass seeded experimental areas than on conventionally seeded areas. Size, richness, and density of native trees and groundcover by native understory taxa were greater on soils of weathered sandstone origin, mildly acidic like native forest soils, than on soils constructed from unweathered alkaline siltstones. On soils constructed from unweathered alkaline siltstones, primary plant-community components were the invasive exotics autumn olive (*Elaeagnus umbellata*) and sericea lespedeza (*Lespedeza cuneata*). Planted trees established and grew well on areas where tree-compatible and annual ryegrass seedings were applied to soils constructed from weathered sandstones. Planted trees established and grew poorly and exotic taxa dominate plant communities on areas where soil materials constructed from alkaline siltstones are unfavorable to native trees. These findings demonstrate the importance of soil-material selection and seeding practices for successful reforestation of Appalachian surface coal mines and are consistent with findings by prior research.

Additional Key Words: Reforestation, Afforestation, Appalachia, Coal Mining

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