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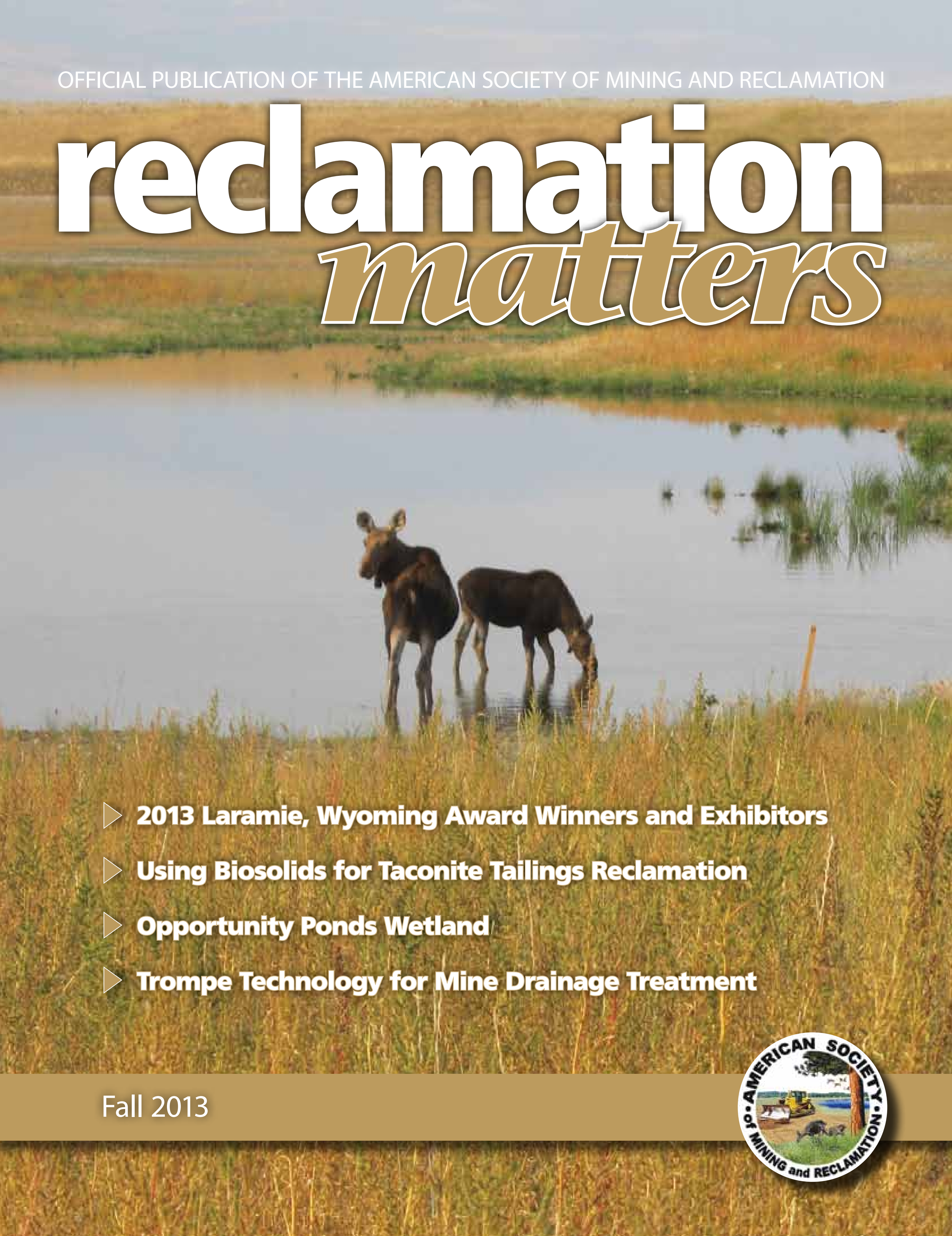
reclamation *matters*



- **2013 Laramie, Wyoming Award Winners and Exhibitors**
- **Using Biosolids for Taconite Tailings Reclamation**
- **Opportunity Ponds Wetland**
- **Trompe Technology for Mine Drainage Treatment**

Fall 2013

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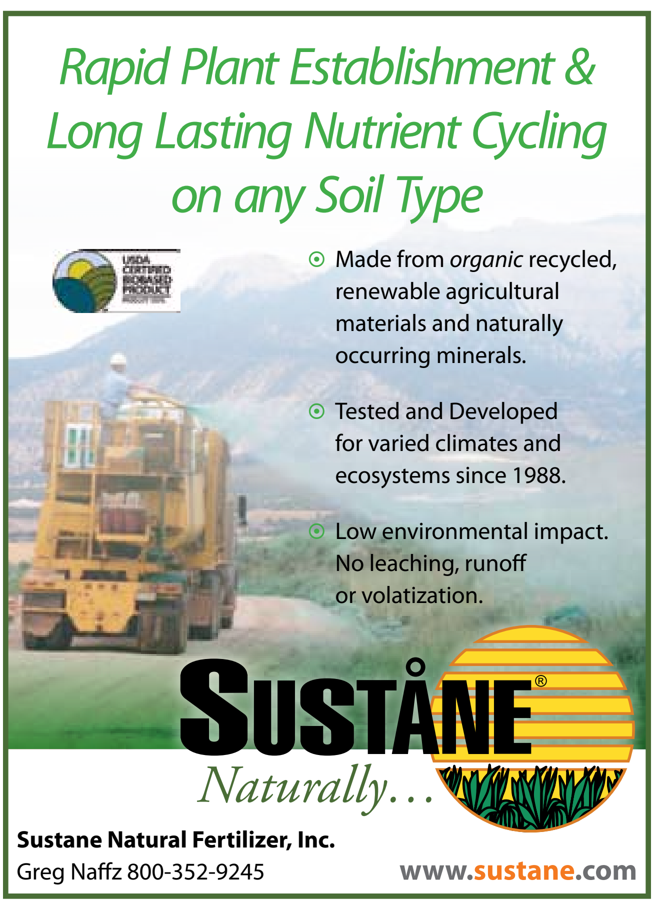

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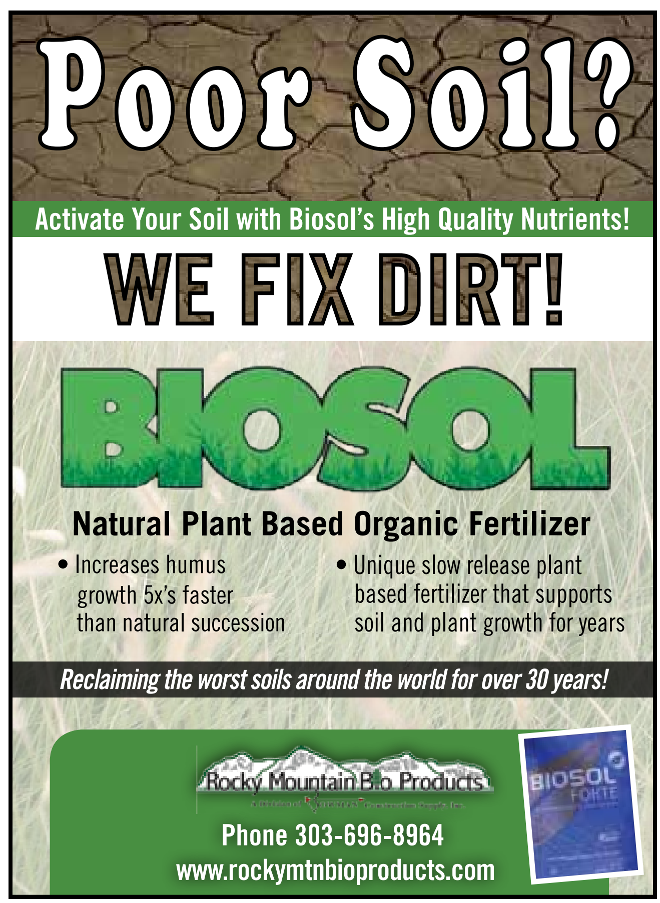

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contents

Change For The Better

By Bob Nairn, ASMR President

"There are many ways of going forward, but only one way of standing still." - Franklin D. Roosevelt

Change can be scary. Changes - both big and small, professional and personal, gradual or immediate - are part of life, and despite changes that may initially challenge or even intimidate us, we go on, often growing and becoming more enlightened residents of this pale blue dot we call home. Becoming President of ASMR is a change for me, although I can't say it is one that overly intimidates me (I never should have agreed to run if that was the case!). However, I will say that it is a challenge, and I sincerely thank the ASMR membership for allowing me to take on that challenge.

The society has changed a lot in the two and a half decades since I first became a member. In the next year, working closely with the National Executive Committee (NEC) and the membership, I plan to help us continue to change in a positive manner, to make progress, to go forward and not stand still. Perhaps the biggest challenge we will face this next year is the transition in the Executive Secretary position from Dick Barnhisel to Bob Darmody. Bob has some big shoes to fill, and I look forward to working with him as ASMR's base of operations shifts from Kentucky to Illinois.

Over this next year, through several new initiatives, we'll attempt to build on ASMR's spirit of community, which I see as a real strength of our society. Sometime soon, you will receive an electronic survey from ASMR, asking you about the national meeting, about recruiting and retaining members, and other issues. We need your input! Please respond to that survey as it will help us make ASMR a stronger organization. We'll also continue and expand our efforts to promote the role of members of Student and Early Career standing. The NEC is working on by-laws changes and we hope the next election ballots you'll see will have races for new Student and Early Career representatives. We also recognize that ASMR needs to become a more electronically oriented, more 21st century society. With help from our younger, technically savvy members, look for changes to ASMR's electronic presence - the web, LinkedIn, Facebook, etc. I also ask for your help in expanding ASMR's membership beyond our traditional base in coal mining and reclamation. Much of what we do is applicable to any land or water disturbance - precious and base metals mining, limestone, sand and gravel, clay and shale, road construction, oil and gas exploration and production. We have a lot to offer. We need to expand the scope of the society's annual meeting, our publications and our membership to other industries.

Change can be scary, but the right kind of change is constructive and exciting. I also steadfastly believe that any change for a society like ours needs to be inclusive of our members' desires, so please feel free to send me your thoughts. I want to hear from you. Thanks in large part to our outgoing Executive Secretary, ASMR is on firm financial footing, and the newly formed Financial Advisory Committee will work to develop a diverse and productive investment portfolio, allowing us to make progress.

In closing, I will serve as chair and host of the 31st National Meeting of ASMR in Oklahoma City, Oklahoma, June 14-19, 2014. At the Laramie meeting, we started the ASMR '14 OKC Win Free Stuff Contest. It's simple:

1. Get a free ASMR '14 OKC koozie
2. Use your koozie to keep your favorite beverage ice cold
3. Take a digital photo of you and your koozie at the most unusual or exotic mining and reclamation place possible
4. Send that photo to me at nairn@ou.edu before June 1, 2014
5. Win free stuff at ASMR '14 OKC!

Please contact me if you were not in Laramie and need a koozie! A little change, a little fun, and hopefully one that helps us make progress. ■

Is Your Work Your Calling?

By Jeff Skousen

I am one of those lucky ones in the world who enjoys going to work. Some days are not as glorious as others, but generally I am excited to be outside doing reclamation work, helping people who are doing reclamation work or reading and writing in my office on reclamation work and environmental issues. I recently came across an article which described ways in which most people view their work.[1, 2]

Most people see their work as either a Job, a Career, or a Calling.

"People who have Jobs are only interested in the material benefits from work and do not seek or receive any other type of reward from it. The work is not an end in itself, but is a means that allows individuals to acquire the resources needed to enjoy their time away from the Job. The interests and ambitions of people with Jobs are not expressed through their work. They want to make a buck and punch their time cards so their real lives can begin.

"People with Careers have a deeper personal investment in their work and mark their achievements not only through monetary gain, but through advancement within the occupational structure. This advancement often brings higher social standing, increased power within the scope of one's occupation, and higher self-esteem.[3] They want to climb the ladder of success, ranking their satisfaction mostly by the height of their climb.

"People with Callings find their work inseparable from their life. A person with a Calling works not for financial gain or career advancement, but instead for the fulfillment the work brings to the individual. The word "calling" was originally used in a religious context, but most people who view their work as a Calling see it as socially valuable, an end in itself, and contributing to something beyond themselves.[4] They are committed to their work because it enables them to connect to a greater purpose, express a deeper meaning, or advance a higher value.

"The Job-Career-Calling distinction is not always clear, nor dependent on occupation. Within any occupation, individuals may have all three kinds of attitudes toward their work. For example, a higher percentage of teachers and Peace Corps employees may think of their occupations as Callings, but salespersons, medical or automobile technicians, factory workers, and secretaries could view their work as a Calling. Such people could love their work and think that it contributes to making the world a better place."[1]

Your investment of time and energy to your work, both on and off of the job, may help you determine the category of worker you are. So, how do you categorize yourself? Is your work your calling? ■

[1]Wrzesniewski, A., et al., 1997. Jobs, careers, and callings: People's relations to their work. Journal of Research in Personality 31: 21-33.

[2]Sutton, P. 2013. What is your calling? P. Techn. Journal, March 2013.

[3]Seligman, M. 2002. Authentic Happiness. Free Press, New York.

[4]Bellah, R.N., et al., 1985. Habits of the Heart. Harper & Row, New York.

Early Career Message

By Chris Fields-Johnston

WOW! What a great turnout for the 4th Annual Early Career Professionals Social Event this year in Laramie, WY. This year's social event was held on the University of Wyoming campus at the newly constructed 79,000 square foot Visual Arts Building that recently received national recognition for its energy efficient engineering and design features. Attendees were encouraged to explore the entire facility and were treated to some wonderful pieces of art created by UW faculty and students.

Attended by well over 100 people, this year's event truly revealed the type of membership we have in ASMR. An even spattering of more established professionals from industry and academia, early career professionals, and new members attending for the first time painted the canvas of this year's event … ok, maybe that is going too far, sorry. Established professionals were asked to mentor an early career professional for the first part of the evening to help facilitate conversation and have an opportunity to share some of their experiences and knowledge. In addition, the mentors were asked to make introductions to other established professionals who may have the same interests. One of the goals of the Early Career Professionals group is to provide insight into how being part of ASMR can help early career members develop their careers. Thanks to the time and effort invested by the established professionals, I think the early career professionals in attendance understand how ASMR can help develop their careers.

Throughout the evening, attendees enjoyed live music by Jascha Herdt and Peter Queal and a variety of beers and wines, two of which were award winning brews from the Black Tooth Brewing Company in Sheridan, WY. In the background you could hear stories being told and experiences being shared as people formed new relationships. As the evening came to an end, a lucky few got to take home some simple reminders of Wyoming.

I want to mention a couple more things before I go. Please don't forget about the "Recruit One Member (ROM)" campaign. It is our responsibility as members of ASMR to contribute in any way possible. As Early Career Professionals, I think recruiting is one of the simplest ways for us to contribute. Think of other professionals you know that may be in a situation similar to yours and let them know how much you receive as an ASMR member.

I would also like to thank those that financially supported the Early Career Professionals Social Event last year in Laramie: Inter-Mountain Labs, BKS Environmental Associates, Wyoming Reclamation and Restoration Center, Virginia Tech, Western States Reclamation, and KC Harvey Environmental!

Thanks to all that attended this past year, and I look forward to seeing you again next year in Oklahoma City! Again, your support and enthusiasm are why these events have become such a success. ■

ASMR's Online Journal

By Dr. Richard (Dick) Barnhisel, Executive Secretary 1999 to 2013

I would like to thank all of the ASMR members for your support and encouragement these past years since I became your Executive Secretary and began to serve in this position on January 1, 1999. I think ASMR has gone a long way during this time. Our membership has been somewhat like a yo-yo, going up and down over this period of nearly 14 years. We had 369 members when I became Executive Secretary, with a high of active members at 432 and the low at 329. Current membership is 404.

I began reclamation research in 1972 and, in 1974, I joined the Reclamation Council, one of the early predecessor organizations of ASMR, which had been established by Bill Plass, Ben Greene and Dick Vande Linde. Later in 1984, the name was changed to the American Society for Surface Mining and Reclamation and then to ASMR in 2003.

I would like to think that my largest accomplishment has been putting the society on a firm financial foundation. The total net worth of the society was a little more than $50,000 in 1999 and we are near $500,000 today.

We have progressed from sending out everything as hard copies to electronic, although some members still wish to get hard copies. We have a web page, which I launched in 2003, which always needs to be improved. The web page gets on an average of 1,100 hits per month.

Our annual meetings have always taken much effort from the organizers and from me. Each meeting takes a large expenditure of time due to producing the proceedings: receiving papers, sending them out for peer review, editing them, and burning as many as 500 CDs to distribute at the annual meetings.

Last October, with the help of Dennis Neuman and others, we launched an online Journal. All future accepted papers will appear in this online Journal including papers written for this year's meeting, rather than in Proceedings, which have been phased out. The Proceedings had their place, starting with our first annual meeting in Owensboro, Kentucky in 1984. There were only 22 papers given that year, compared to 130 abstracts submitted this year, one of our largest meetings since the meetings in Pittsburgh in 1994. We have work yet to be done on this Journal, which has the acronym of JASMR for the Journal of the American Society of Mining and Reclamation.

Our Journal just obtained an ISSN number at the end of April from the Library of Congress. We have a couple things in the works that will bring JASMR up to the highest standards of all Journals. These are primarily indexing services that will attract more to our web page. If you have not been there, its address is simple www.asmr.us or Google the American Society of Mining and Reclamation. The first issue of Volume 2 was put online the last of July 2013, and papers are being prepared for the second issue, which I hope to put online in November. Plans are to continue with at least two issues per year.

Mining in the eastern US has declined and hence the number of members has declined. Having been a professor at the University of Kentucky for 45 years, I realize that often research goes where the people can obtain grants to support these activities. As a result, the papers we get now have shifted from research papers to more case and demonstration papers. I feel that our journal will provide an outlet for these kinds of papers, which were, and still are, often rejected by other journals.

In closing, this has not been something I have accomplished on my own. My wife Lela has done a lot of the work associated with the society, and I consider this job as being a team effort. She has helped with the financial records and submitted reports to the IRS annually as required for non-profit organizations such as ASMR. She also was the person at the ASMR booth each year, greeting the persons attending our meetings and answering questions while I was attending sessions and other meetings such as the NEC.

I hope all of you will lend support to Dr. Robert Darmody who will take over the Executive Secretary position when I step down October 31, 2013. This is a large job, but I hope to be able to assist him by managing the ASMR web page as well as serving as the Editor-In-Chief of our Journal. By having more time, my goal is to elevate this online journal to be first class, which will relieve Bob from much of the work associated with producing the proceedings each year.

I look forward to working with many of you, but in a slightly different role. Lela and I extend our gratitude to each of you as we change jobs in the society and look forward to maintaining our friendships with you. ■

Greetings from the incoming Executive Director

By Robert Darmody

At the end of this October, Richard Barnhisel will step down as the Executive Secretary (ES) of ASMR. Dick served as the society's second Executive Secretary. In 1999, he replaced William T. Plass, who had been the ES since the founding of the society in 1973. Dick will be a tough act to follow; he was truly the heart and soul of ASMR. Together with his wife Lela, he saw the society grow and change from its earliest days of paper and fax machines into the age of computers, pdfs and e-mails. His contributions are numerous, and I am truly impressed with what Dick and Lela do behind the scene to keep the society functioning smoothly. As a former president of ASMR, I can speak with certainty about their contributions.

For those of you who don't know me, I am currently an emeritus professor of soil science at the University of Illinois, Department of Natural Resources and Environmental Sciences. I retired last year after 31 years of doing research and teaching at Illinois. I taught Introductory Soil Science, Pedology, and Soil Judging among other classes. I was head of the University of Illinois Mine Reclamation Research Program and was the agronomy/soils research specialist for the Illinois Mine Subsidence Research Program. I got my PhD degree from the University of Maryland and first walked on a strip mine (as they were known in those days) in 1976 in West Virginia with my soils professor Del Fanning. I am a lifetime member of ASMR and, in addition to my term as president, I was chair of the Soils and Overburden Technical Division of ASMR for many years.

My vision for ASMR includes maintaining its mission as the source of quality information about coal and mineral mining and reclamation activities. I believe that ASMR should be seen as a neutral body, not necessarily promoting or opposing mining, but always working towards minimizing its impact and maximizing reclamation success.

The job description for the Executive Secretary includes providing administrative support to ASMR, coordinating annual meeting support and outreach activities, maintaining membership and meeting databases, maintaining finances and budgets, coordinating election processes according to the society by-laws, and conducting routine society business. All ES actions must comply with the current objectives, directives, financial obligations and policies set forth by the society's National Executive Committee, comprised of the president and committee delegates, and in the society's by-laws.

This is a tall order for anyone, but Dick proved a good role model. Thankfully, he has indicated he wants to stay on in an editor capacity for ASMR, which will lighten the heavy ES load. As I previously mentioned, Dick (and Lela) Barnhisel will be a tough act to follow, so please wish me luck. One last thought, if you would like to help with the running of ASMR, to make what it should be, we are always looking for volunteers and candidates for elected offices, so please do what you can to make ASMR successful. ■

Wild Women of Reclamation Are Off and Running

By Brenda Schladweiler

It is hard to imagine where you could have crammed one more activity into a jam-packed week at the Second Annual WRRC Land Reclamation Symposium/30th Annual Meeting of ASMR, but we did. Last minute organization and publicity (thanks to the plenary session on Monday morning) allowed word to get out and enthusiasm to build during the day for a shadowy organization called "Wild Women of Reclamation."

On Monday night after the poster session, the organizational meeting of the Wild Women of Reclamation met to discuss: 1) who we are; 2) what we want to be; and 3) how to move forward. A great mix of ages, home state and careers showed up to discuss those points. Named in conjunction with a similar organization in the Society of Range Management (SRM), there was plenty of room for wild women in several organizations and disciplines. Several women volunteered to help organize future events such as ASMR in Oklahoma City in 2014 and activity between the Laramie and OKC meetings, if possible. Most women desired mentorship and professional support, in which there was plenty to go around that night.

Monday night's meeting kicked off friendships that lasted into the next night's activity for the Early Career folks, as well as familiarity of faces in the hallowed halls of knowledge during the succeeding days' activities. Wild Women of Reclamation is on the agenda for OKC (Bob Nairn, as committee chair for planning ASMR in 2014, has promised to make room). Stay tuned for more. ■

Paul Griswold with Melvin Davies

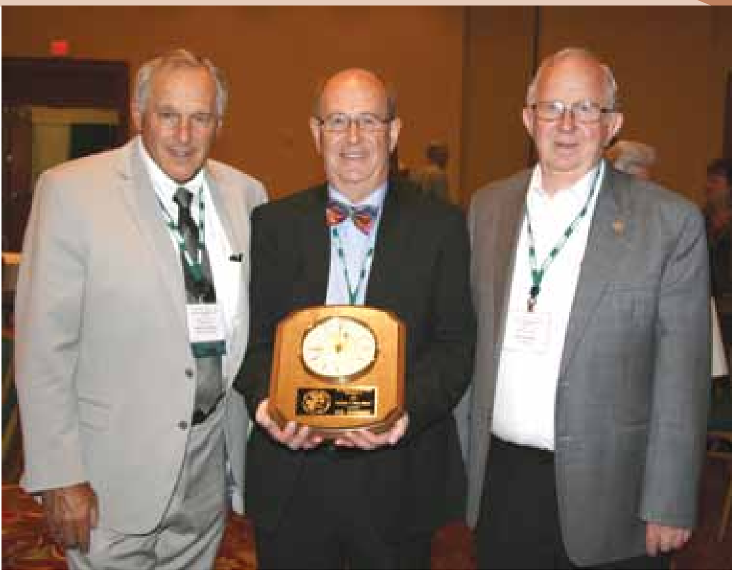
2013 ASMR Reclamationist of the year Award

Paul Griswold

Our recipient of the 2013 Reclamationist of the Year Award has been involved in land reclamation for over 20 years. He has been a member of ASMR for numerous years and has presented papers at two of the national conferences. As Senior Environmental Assistant with the coal mining industry, Paul has been responsible for developing and implementing an in-house reclamation program. His responsibilities include field application of revegetation best management practices, acquisition and maintenance of equipment, administration and coordination of the reclamation grazing program, environmental mitigation activities including fugitive dust control, and assisting with environmental monitoring programs. His successful handling of these duties has resulted in the mine receiving the 2012 OSM National Reclamation Award as part of the company team. Paul's understanding of reclamation technology and ecosystem restoration has been recognized within the company and he was invited to travel to Australia in 2012 to address reclamation issues and challenges at one of their operations.

While working in the contractor land reclamation industry earlier in his career, our recipient led reclamation programs for his employer at no less than 20 mining and oil and gas companies in 12 western states. His work led to awards in excellence in reclamation from OSM for two of the mines where he worked. His nominator Vern Phannesnstiel stated "All who are associated with him soon know 'The Gris' is a gentle giant of a man always willing to lend a hand and share knowledge and a smile." He further stated that our recipient is "one who reflects the spirit and intent of the ASMR Reclamationist of the Year Award."

It is with great pleasure that we present Paul Griswold, Senior Environmental Assistant with Peabody Energy, North Antelope Rochelle Mine, Gillette, WY, as our 2013 recipient of the American Society of Mining and Reclamation Reclamationist of the Year Award. Congratulations, Paul. ■



ASMR 2013 William T. Plass Award

Neil Humphries

Our recipient of the 2013 William T. Plass Award has been involved in reclamation research for 40 years. Neil has served ASMR in the organization of the international liaison organization, IALR, served on the NEC, and has attended 10 of the last 18 national conferences. He also served as a senior editor of the Journal Reclamation Review. He has worked across a wide range of mineral extraction and construction products and mine wastes for a number of companies. He has designed and delivered many reclamation schemes for agriculture, forestry, nature conservation and ecosystems, landscape and sport amenities. Many of these practices have been recognized as outstanding and have received public and industry recognition. One such practice was the summarization and writing of a Good Practice Guide on the handling and management of topsoils during the mining and reclamation period. This guide was published in 2000 and after 13 years remains the standard reference for handling of agricultural soils in the UK. In the UK, semi-natural vegetation and habitats that are of national importance are designated by the government as Sites of Special Scientific Interest and given legal protection. Therefore, the creation or re-creation of sites that meet the SSSI criteria are of national importance for protection. Our recipient has accomplished such re-creation by restoration not just once but three times in England and Wales. One of his letters of support stated, "Professor Humphries' approach to dealing with land disturbance and other similar endeavors has been based on a rigorous scientific approach based on sound data and evidence using his considerable experience and expertise. It is a model that has engendered confidence and support from the environmental sector enabling successful outcomes to be achieved." Our recipient of the William T. Plass Award received his BSc in Botany from the University of Exeter, his MA in Applied Biology from the University of Cambridge, and his PhD from the University of Liverpool.

It is with great pleasure and satisfaction that I announce Professor R. Neil Humphries as the 2013 recipient of the William T. Plass Award of the American Society of Mining and Reclamation. Congratulations, Neil.

Professor Humphries was nominated by Dr. Robert Darmody, University of Illinois (retired). ■

Scholarship Recipients

Undergraduate Scholarship - Rebecca Peer, St. Francis University

MS Scholarship - Kenton Sena, University of Kentucky

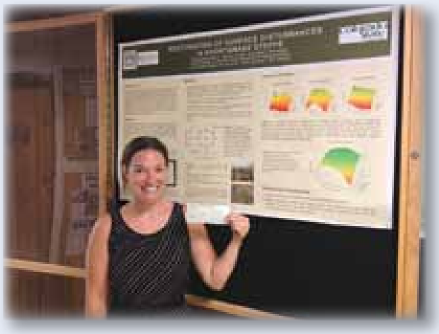
PhD Scholarship - Katie Rothlisberger-Lewis, Texas A&M

Presentation Winners

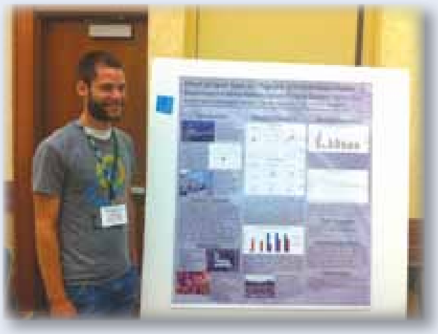
1st Place Presentation - Leah Oxenford, University of Oklahoma

2nd Place Presentation - Jessica Odenheimer, West Virginia University

Poster Winners



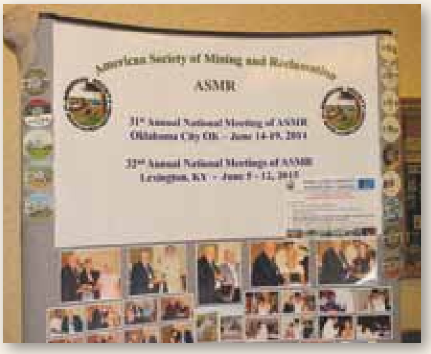
1st Place Poster - Stephanie Barr, Colorado State



2nd Place Poster - Kenton Sena, University of Kentucky

3rd Place Poster - Hannah Angel, University of Kentucky

Exhibitors - Laramie, Wyoming



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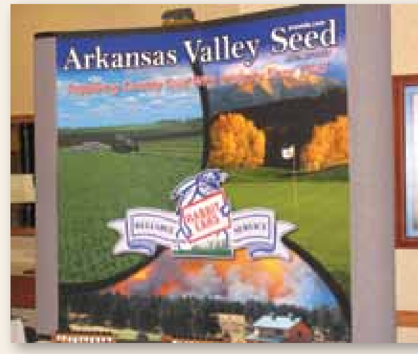


Arkansas Valley Seed

BioMost, Inc.

BKS Environmental Assoc., Inc.

Electronic Data Solutions

Energy Labs

Pacific Inter-Mountain Dist. -
Erik and Bill Krippaehne

Granite Seed and Erosion Control

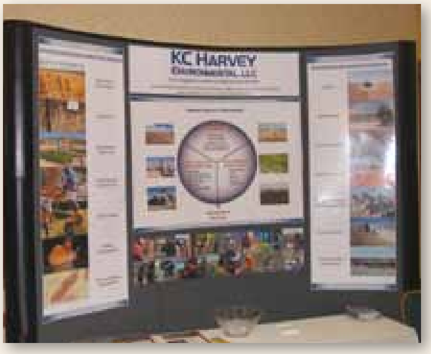
Herrera Reclamation

Inter-Mountain Labs

Western States Reclamation -
Joe Schneider and Dave Chenoweth

Exhibitors - Laramie, Wyoming

JRW Bioremediation



KC Harvey Environmental LLC

Profile Products - Laura Girard and Doug Graham

Bio Lynceus LLC - Mark Sembach

ACZ Labs - Mike McDonough

Office of Surface Mining

Perma Matrix

Presto Geosystems

Habitat Management - Robin Bay and Wayne Erickson

Rocky Mountain Bio-Products

Rocky Mountain Reclamation

Rantech Corp. - Stephanie Zier

Exhibitors - Laramie, Wyoming

Stevenson Intermountain Seed

InterTech and Coffee Engineering - Susan Babbitt and Tim Stamp

Sustane Fertilizer and Nilex Eivil Environmental

Trihydro

Triton Environmental

Truax Company, Inc.

University of Kentucky

Wind River Seeds

From BS to BMP – Using Biosolids for Taconite Tailings Reclamation

P. Eger, C. Lincoln, T. MacMillan, K. Hamel, K. Dykhuis, C. Maxwell, J. Takala

Introduction

Seventy percent of the United States' iron production comes from Minnesota. Six operating mines produce 40 million tons of taconite pellets annually by crushing, grinding and magnetically recovering the iron. Since the average grade of the iron ore is about 25% magnetic iron, about three-quarters of the material must be disposed of as waste (tailings). Currently there are about 33,500 acres of land covered with taconite tailing waste. These tailings range in particle size from 1 inch gravel to fine silt and clay (Figure 1). The coarse fraction (medium sand to gravel) is often used to build the dikes for the tailings storage areas. Coarse tailings are alkaline and low in organic matter, nitrogen, phosphorus, cation-exchange capacity, electrical conductivity, and moisture holding capacity (Noyd et al., 1992). The gray/black color of the tailing results in large temperature extremes, especially on slopes that face south or west. The large open expanses typical of these basins create conditions which often result in severe wind erosion.

Figure 1. Coarse taconite tailings

Minnesota mineland reclamation rules require that all tailings areas be revegetated and achieve a vegetative cover of 90% after three growing seasons, except for slopes that face south or west, where a limit of five growing seasons applies. Standard reclamation practice is to apply 500 lb/acre of diammonium phosphate, 50 lb/acre of a cool season grass mix, and 2 ton/acre of hay mulch. Although this approach was very successful on the medium to fine-grained tailings on the interior of the basins, it was not effective on the roughly 9500 acres of coarse tailings material. Even after five years, vegetative cover on this material rarely exceeded 60%. A better reclamation approach was needed for this material.

Biosolids application began at United Taconite (UTAC, formerly EVTAC) in the early 2000's and was successful in improving vegetation. The standard mineland reclamation approach was successful in producing acceptable vegetation, but the reclaimed tailings still had low fertility and organic content. The Western Lake Superior Sanitary District (WLSSD) needed biosolids application sites for fall and winter applications when nearby agricultural fields could not receive material. Since the interior of tailings basins are flat (0.5-1.0% slope) and confined, biosolids could be applied in the winter with no concern that surface runoff would escape the site. Biosolids applications have become an integral part of the closure and management of the basin.

In 2007, a local dairy farm was expanding production and needed additional land to produce alfalfa to feed the larger herd. The University of Minnesota Extension in St. Louis County suggested that given the alkaline nature of the tailings, alfalfa should do well on tailings treated with biosolids and they worked to bring the taconite industry and sanitary district together. In 2008, an agreement was made between UTAC and Takala Farms to use part of the interior of the basin for the production of alfalfa. This was the first time an agreement for production from a closure tailings basin had ever been made.

Background

Initial studies using various organic amendments including peat, municipal

Figure 2. Three year cover, standard mineland reclamation

Figure 3. Three year cover, municipal solid waste compost

solid waste compost, yard waste and paper mill residue were conducted using small plots (8 ft x 13 ft) and demonstrated the application of organic amendments significantly improved vegetative cover (Eger et al., 1999; McCarthy et al., 1995; Norland et al., 1995, 1993). Although percent cover generally increased with increasing amounts of organic material, 20 tons/acre was selected as a cost effective rate. That rate produced vegetation which met the three year cover standard (90%) after two growing seasons (Melchert et al., 1994) (Figures 2 and 3).

In 1997, testing moved to full scale demonstration plots and the first application of amendments, including biosolids, was made to a 25-ac (10-ha) section of a northeastern facing portion of a coarse tailings dam (Eger et al., 2000). Vegetative cover on all the amended plots was at least 50% higher than the cover produced by the standard mineland reclamation practice.

Although organic amendments were successful, there was no nearby source that could provide the volume needed for reclamation. Biosolids were available from Duluth, which was about 60 miles (100 km) away, but regulations limited application to the rate of nutrients required by vegetation (the agronomic rate). Although this rate improved vegetation, it gave only 75% cover, which did not meet the required cover of 90%. So, higher rates of biosolids addition were needed. This raised the possibility of releasing nutrients from the excess biosolids and impacting water quality. In 2002, EVTAC (now UTAC), Western Lake Superior Sanitary District (WLSSD) and the MN DNR began a research program to determine an application rate that would produce acceptable vegetation, meet reclamation standards and not adversely impact water quality.

Methods

A plot study was combined with a full-scale demonstration project (Figure 4). A 12-ac (4.8 ha) portion of EVTAC's tailings dam was used for the full-scale demonstration area and 14 small bins were used to evaluate the effect of the organic amendments on water quality and vegetation. Each bin was individually lined with a 40 mil LDPE liner so surface runoff, infiltration, and vegetation growth could be monitored separately for each treatment (Figure 4).

Six treatments were applied to the small bins in duplicate and each treatment was applied to a 2-acre (0.8 ha) portion of the tailings dam (Table 1). Two bins were left as untreated bare tailing controls. In addition to biosolids, paper mill residue (PMR) from Stora Enso in Duluth was added as a high carbon substrate to help tie up any excess nitrogen released from the high rates of biosolids.

Figure 4. Small bin study

The bins and side slopes were planted in June 2002. A standard reclamation seed mix (Table 2) was used and all planted areas were mulched at the rate of 2 tons/acre.

Table 1. Treatments applied in coarse tailings study, 2002

Treatment	Biosolids	Paper Mill Residue	Comments
	Tons/ac		
Control	0	0	Plots were not fertilized or seeded.
Standard Mineland Reclamation	0	0	Plots fertilized with 500 lbs/acre of diammonium phosphate (18-46-0)
Biosolids[a]	3.1	0	
100 N	6.2	0	
200 N	12.4	0	
400 N			
Biosolids + Paper Mill Residue[b]			
200 N	6.2	28	
400 N	12.4	56	

[a] Biosolids addition rates were designed to provide the lbs of available nitrogen listed.
[b] Paper mill residue addition rates were adjusted to provide a Carbon to Nitrogen ratio of 25:1

Results

Metal levels in the biosolids were generally about an order of magnitude below the requirements for exceptional quality sludge. Metal levels in the paper mill residue were lower than the biosolids and also easily met land application limits (Eger and Antonson, 2005). Given the low level of metals, the major concern was nitrate release.

Water Quality / Surface water

The volume of surface water generated from the plots was insignificant even during a 4.1 inch (10.4 cm) rain event. Due to the small volume of flow, only nitrate was measured. Nitrate concentrations were very low, with all values below 0.1 mg/l.

Infiltration

Nitrate concentrations were measurable in all plots and concentrations increased with increasing concentrations of biosolids (Figure 5). Average concentrations ranged from 1.8 mg/L in the control plots to 48.5 mg/L in the 400N Biosolids (Table 3). The nitrate concentrations in the plots with the paper mill residue were significantly less than the plots with biosolids alone. Over the entire study, nitrate averaged 15 mg/L for the 200N application and 40 mg/L for the 400N. The addition of paper mill residue reduced the overall average concentrations in both treatments to 9.3 and 15.0 mg/L, respectively.

Nitrate mass release

The total mass of nitrate-N that left the bins was calculated by multiplying the concentration of the sample by the collected volume. For periods of flow without a sample, an average concentration calculated from the preceding and following samples was used. The percent of flow that was sampled ranged from 65-73% in 2002 and from 53-57% in 2003.

The nitrate-N release from the control plots was subtracted from the total release for each treatment to give the net nitrate release. The net release ranged from 6 grams to 47 grams and was lowest in the plots with paper mill residue and highest in the 400 N plots (Table 4). Mass release increased with increasing application of biosolids. The percent of applied nitrogen that was released ranged from 7.3% for the

Table 2. Reclamation seed mix, composition

Common Name	Percent	Lbs/acre
Lincoln Smooth Brome Grass	19.4	10.7
Creeping Red Fescue	15.8	8.7
Perennial Ryegrass	14.6	8.1
Climax Timothy	11.9	6.6
Vernal Alfalfa	11.9	6.6
Norcen Birdsfoot Trefoil	11.9	6.6
Yellow Sweet Clover	11.9	6.6
Inert Ingredients	2.0	1.1
	Total:	55

Table 3. Water quality summary, average concentrations 2002-2003.

	Control	Standard Mineland Reclamation	Biosolids 100 N	Biosolids 200 N	Biosolids 400 N	Biosolids 200 N + Paper mill residue	Biosolids 400 N + Paper mill residue	Surface Water Standards	Ground Water Standards
pH	8.46	8.41	8.40	8.43	8.39	8.41	8.30	6.5 to 9.0	6.5 - 8.5 (S)
Specific Conductance	711	752	828	843	1100	900	1130		
Calcium	14	17	17	16	22	18	25		
Magnesium	88	99	107	104	128	110	128		
Chloride	0.5	0.6	3.5	5.1	13.5	8.3	14.8	230	250 (S)
Sulfate	90	97	150	144	209	161	219		250 (S)
Arsenic	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.053	
Copper	0.002	0.002	0.003	0.002	0.002	0.005	0.006	0.015-0.023	
Zinc	0.008	0.011	0.009	0.009	0.010	0.009	0.012	0.191-0.343	
Cobalt	0.001	0.001	0.001	0.001	0.001	0.004	0.009	0.005	
TKN	0.1	0.2	0.2	0.2	0.4	0.6	0.8		
Nitrate-N	1.8	10.5	12.3	14.9	48.5	9.3	15.0		10
Total Phosphorus	0.007	0.012	0.009	0.007	0.008	0.009	0.010		

All concentrations in mg/l or standard units. ½ the detection limit used for metal concentrations less than detection limit. Surface water quality criteria (chronic standard) for 2B waters (aquatic life and recreation, non-drinking water). Standards for the trace metals are a function of water hardness. A range of 200 mg/L to 400 mg/L was used to compute chronic toxicity values for Cu, and Zn. Waters of the State (www.revisor.leg.state.mn.us/arule/7050/0222.htm) . Drinking water standards (http://www.epa.gov/OGWDW/wot/appa.html).

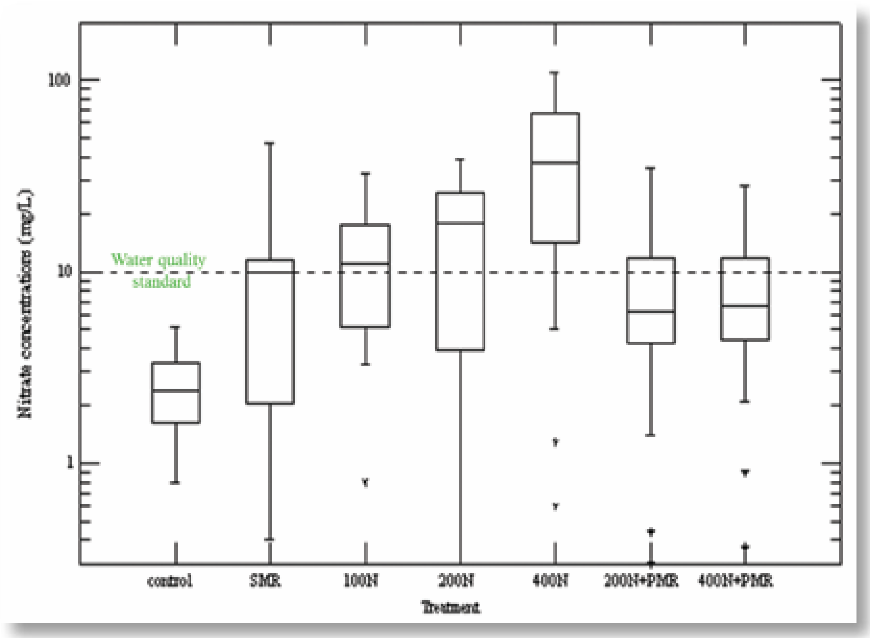


Figure 5. Nitrate concentrations, 2002-3

400 N +PMR plots to 41.8% for the 400 N treatment. Mass release for the 100 N plots was essentially the same as the standard reclamation treatment and was only about 40% greater in the 200 N plots. The release in the plots with paper mill residue was 20 to 40% lower than the standard mineland reclamation treatment (Table 4).

Vegetation

Biosolids were applied to the large scale demonstration plots in June 2002. The demonstration plots were hydroseeded in late June/early July. The seed mix was the same that was used for the bins. The plots were not mulched immediately as would have been the normal practice. Mulching began about 10 days after seeding.

Vegetation established very slowly on the slopes. During 2002, the first growing season, no vegetation was observed on the lower slopes until the end of July and the upper slopes remained bare for the entire growing season. Due to the sparse vegetation, no quantitative measurements of percent cover were made in 2002. By fall 2002, vegetation had started to grow on the lower portion of the slope but the upper slope was still generally bare through-

Table 4. Total Nitrate-N release for each treatment (mass in grams)

Amendment	Available Nitrogen [1] added	Total net release treatment - control	Percent of applied N
Control	0		
Standard Mineland Reclamation	25.3	9.8	38.7
Biosolids (100 N)	28.1	10.3	36.7
Biosolids (200 N)	56.2	14.0	24.9
Biosolids (400 N)	112.4	47.0	41.8
Biosolids (200 N) + paper mill residue	56.2	6.0	10.7
Biosolids (400 N) + paper mill residue	112.4	8.2	7.3

[1]Data from WLSSD was used to calculate the available nitrogen added to each plot that received biosolids. The available nitrogen content in the PMR was assumed to be negligible.

Figure 6. Tailings basin, spring 2003

Figure 7. Tailings basin, spring 2012

out 2003. At the end of the third year, only the 400 N + PMR plot met the three year reclamation standard of 90%. Vegetation increased in 2005 and percent cover on the lower slopes in all but the 100 N plot exceeded 90% cover (Table 5)

Biosolids have now been applied to most of the interior of the entire basin and have produced complete revegetation (Figures 6 and 7). (Note: The bare area has not been treated yet since the long term plan is to create a wetland around the pond). Organic matter has increased in soil samples collected from areas that have received continual biosolids application (Figure 8).

Alfalfa production has been quite successful on the tailings. In years with normal precipitation, three cuttings can be made and yields are on the order of 4-5 tons/acre (Table 6). These exceed production on unmanaged fields and are comparable to well managed and fertilized farms in the area (Takala, personal communication, 2012).

Discussion

Percent cover with biosolids has been substantially greater than areas treated with the standard reclamation approach with seed, mulch and inorganic fertilizer. In the past, biosolids application has been limited by agronomic rates to around 100 lbs N/acre. Although this improved vegetation, another application of biosolids was needed to meet mineland reclamation standards of 90% cover.

Based on plot and demonstration data, a biosolids application of 200 N was selected as the optimum rate. Although the nitrate concentrations are somewhat greater than the water quality standard, it was only slightly greater than the average concentration from the 100 N and the standard mineland reclamation treatment during the first year. Although percent cover did not meet the 90% standard after three years, cover was almost complete on the lower portion of the slope in the

Table 5. Percent cover on Demonstration Slope 2003 - 2005.

	Upper Slope			Lower Slope		
Treatment	2003	2004	2005	2003	2004	2005
Standard Mineland Reclamation (SMR)	0-10*	5-25*	NM	25	5-25*	NM
Biosolids (100 N)	15-20*	13	72	41	62	86
Biosolids (200 N)	10-15*	44	74	54	72	*98*
Biosolids (200 N) + Paper mill residue	20-25*	46	78	41	67	*92*
Biosolids (400 N)	NM	48	76	41	82	*94*
Biosolids (400 N) + Paper mill residue	NM	47	86	62	**94**	*90*

*Whole plot estimate due to lack of cover. Percent cover is the average of 12 randomly sampled plots on each slope.
NM In 2005 the site received biosolids and was reseeded. **Bold**; percent cover meets 3 year reclamation standard (90% cover). *Italics*; exceeds 90% cover value after 4th season
Biosolids application on the interior of the basin

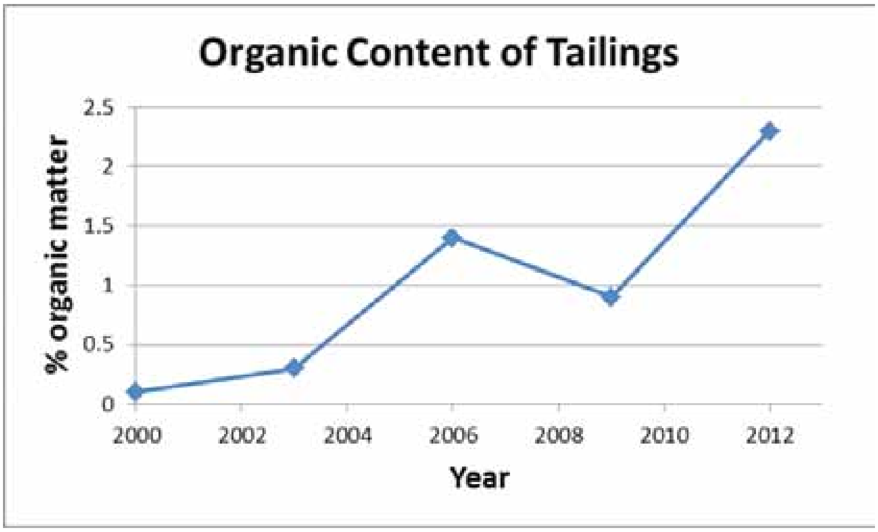


Figure 8. Organic content increase of fine tailings receiving annual application of biosolids

Table 6. Alfalfa yields, 2008-2012

Year	Yield in tons/acre (dry matter)	Number of Cuttings
2008	1.7	1
2009	4.0	3
2010	4.1	3
2011	5.0	3
2012	3.1	2
Typical yield, managed fields	2.5-3.0	2
Typical yield, unmanaged fields	1.0-1.5	1

fourth year after seeding. The extremely poor vegetative growth in the first season was very unusual but could be related to the delay between seeding and mulching.

Although percent cover was higher with 400 N, the average nitrate concentrations were about 3 times higher than the 200 N treatment and 3-5 times above the standard. In addition, the average sulfate concentration in the first year was slightly above the water quality standard. Although the addition of paper mill residue with 400 N successfully controlled nitrate release and generally improved vegetation, the large amount of material needed would increase the cost substantially. At the highest application rate, 400 N+PMR, two applications of biosolids were required and the slope had to be disced three times to incorporate the large amount of paper mill residue. The 200 N biosolids only required a single application and discing. The use of paper mill residue also released small amounts of mercury and cobalt (Eger and Antonson, 2005)

In 2005, the Minnesota Pollution Control Agency (MPCA) approved the use of 200 N as a Best Management Practice (BMP) for the revegetation of coarse taconite tailings. Since that time biosolids have been applied at two additional sites (Keetac and US Steel) and vegetation has met reclamation standards. UTAC leasing the tailings basin for agricultural production was a turning point in the reuse of Minnesota minelands. After previous failures, the alfalfa production is the first commercially viable success.

Conclusions

Cooperative research demonstrated that biosolids could be applied at higher than agronomic rates to taconite tailings to meet reclamation standards without adversely impacting water quality. The data was reviewed by the regulatory agency and a new best management practice was approved. This BMP has now been successfully applied at other mines.

Fine tailings reclamation has progressed from simple land stabilization to production of agricultural crops. Biosolids, a necessary waste product of our culture, can now be used not only to reclaim disturbed lands but also to accelerate the soil development process and help produce food for society. ■

Figure 9. Three year cover, standard mineland reclamation

Figure 10. Three year cover, Biosolids 200 N

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OPPORTUNITY PONDS WETLAND – A 500-ACRE WETLAND MITIGATION PROJECT


Excavation and shaping

Introduction

What does it take to create a wetland out of a borrow pit in the Rocky Mountains of Montana? Planting over two million wetland plants in three years provided many lessons on establishing native wetland vegetation in an area with a short growing season, poor soils, and lots of local wildlife eager to gobble up the plantings as soon as they were in the ground. With so many factors challenging our efforts, we quickly learned how critical it is to control the factors we could control. Planting at the right time and only using well adapted high quality planting stock, excellent planting techniques, and proper hydrologic placement meant the difference between life and death for the suite of over 35 native species selected for this site.

The project site is south of Highway 48 between Warm Springs and Anaconda in southwest Montana. The excavation of two areas resulted in creation of the proper surface water and shallow groundwater conditions for supporting wetland vegetation. The goal of this project is to utilize wet areas resulting from excavation to create a mitigation wetland. The excavated site was shaped to mimic nearby wetland reference sites, and planting was designed to create plant communities similar in species composition and community arrangement to native wetlands in the area.

The climate of the site is semi-arid, with long, cold winters and periods of strong winds. The average precipitation is about 14 inches per year, about half of which typically occurs in May and June. The growing season is short with the last frost typically occurring early in June and the first frost late in August. Common emergent wetland vegetation in the vicinity includes sedges and rushes. Shrub communities consist primarily of willows, water birch, and extensive patches of aspen. Wetlands in the vicinity of Opportunity Ponds provide valuable habitat for white tail deer, moose, and water birds.

Construction

Groundwater is the primary water source for the Opportunity Pond Wetland. Our dependence on groundwater at an excavated site in an arid environment demands careful planning, very accurate excavation and planting, and – especially important – the ability and willingness to refine plans based on the actual conditions found during construction.

For the Opportunity Ponds project, the design team used historic groundwater data to develop a minimum groundwater elevation map for the wetland design. The excavation plans ensured that groundwater was intercepted by using the contours as the design water surface elevation. The plans were then adjusted in the field in each of the wetland cells (defined by dikes) such that the intercepted groundwater established a hydrologic gradient from un-saturated soil, to saturated soil, to surface water. This gradient provides a variety of water regimes that facilitate the establishment of a diverse wetland plant community.

Machine-control technologies using digital site design information combined with automatic control of dozer blades through the use of GPS-based positioning technology provided fine-scale accuracy during final shaping. This resulted in final contours that provided proper hydrology

Construction Complete Ready for planting

for plant communities and eliminated time-consuming surveying and staking.

Capitalizing on the natural slope of the land and the groundwater gradient, contour dikes (e.g., cross-slope dikes) were constructed at key positions within the wetlands area to break the area into wetland cells. Islands and depressions were added to increase habitat diversity.

Fine-grained cover soil material was applied to provide a favorable growth medium. De-watering activities were stopped after construction and soil placement were completed, then the hydrology of the site was allowed to reach equilibrium. This gave us a better picture of what the final hydrology would be and aided in modifications of the planting plan to match that hydrology.

Revegetation

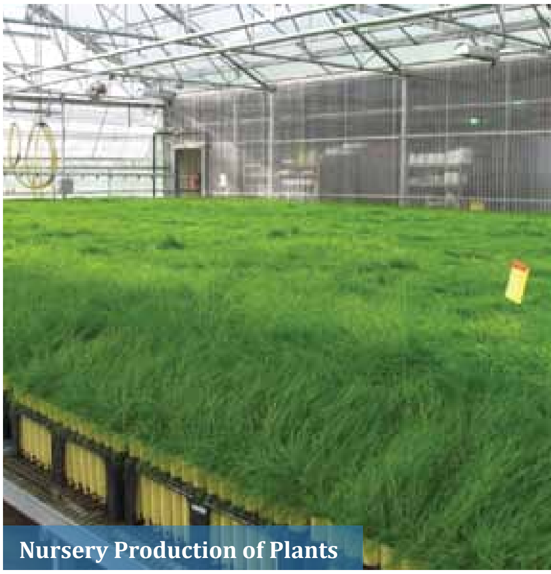
A diverse wetland mix was seeded as each cell was completed, prior to shrub planting. Immediately following seeding, monitoring plots were set up to provide information about individual species seeding success and to guide adaptive management activities. By using this information, seed mixes were modified to reduce cost and increase success. For example as a result of our monitoring Baltic rush was removed from the wetland seed mix because we found that it would likely colonize the site naturally.

The species of container-grown plants selected for planting were those species observed within the vegetative communities near the site, and were differentiated based upon the hydrologic regime or indicator status (i.e., water depth, inundation tolerance) and documented plant association. Plants were situated in niches along the hydrologic gradient so that each particular species was located at the appropriate elevation in relation to the ground-surface water level.

Poor quality plant material is one of the most common causes for failure of wetland plantings. Therefore, we developed strict specifications for container plants to ensure optimum plant survival. Specifications required that plants be grown from seed or cuttings (both collected from the Upper Clark Fork River Basin). Submission of data sheets listing the collection locations, amount of raw seed collected, and collection date were required to document seed sources. The use of plants and seed native to the area ensured that the plant material would be adapted to site conditions, which was a major reason why we achieved high survival rates.

Plants were required to be well shaped, vigorous, and healthy, with a well-branched root system, and also free from disease, harmful insect and insect eggs, sun-scald injury disfigurement, and abrasion. Herbaceous plants and willows were grown in 10 cubic inch containers, and shrub containers had a volume of 60 cubic inches. We specified the 60-inch containers for shrubs in the upland planting zones because the greater root depth ensures contact with consistent soil moisture. The willows did not require deep containers because we specified that they be planted in the lower portion of the shrub zone where they would have consistent contact with soil moisture.

All plants were required to have fibrous roots established, enabling them to be easily removed from containers while maintaining their shape and intact root mass. Specifications called for all plants to be hardened off (grown in climatic conditions similar to the planting site) prior to delivery, and willows to be stored in coolers in a dormant condition until planted. We conducted nursery inspections at four key points in the plant production cycle to verify compliance with the specifications: 1) completion of crop sowing; 2) comple-



Nursery Production of Plants


Morning yoga for planting crews

tion of germination; 3) completion of potting up to larger size (for shrubs); and 4) one-month prior to delivery.

All woody plants were inoculated (in the nursery) with mycorrhizal fungi, and the grower was responsible for verification of successful mycorrhizal colonization. Mycorrhizal plants, with their enhanced ability to take advantage of available moisture and nutrients, are especially important on this site with its low fertility soil and droughty conditions. Plants were delivered in a covered truck and shipped in cardboard boxes labeled with both botanical and common names and the quantity of plants in each box.

All plant deliveries were coordinated with planting oversight staff and staged to meet the needs of the planting crews and minimize the need to hold plants on site. We assessed plant quality on delivery, and rejected unacceptable plants (those not meeting the specifications listed above), which were then replaced by the nursery. The combination of detailed plant specifications, nursery inspections during plant production, and careful inspection of arriving plants assured the excellent plant quality that contributed significantly to successful plant establishment.

Project Oversight

Each wetland cell was divided into discrete planting units so plant numbers could be determined based upon area. As the planting proceeded, we tracked quantities planted in each planting unit to ensure that the each species would be well-distributed across all wetland cells. Boundaries of planting zones were marked on the ground and we then reviewed and modified them to reflect actual hydrology. The “on the ground” modifications resulted in proper placement of plant material based upon site conditions, and ultimately resulted in high survival rates.

We conducted a sampling procedure for plant installation, randomly sampling 20 plants twice a day to verify that plants were installed at proper hydrologic zones, spacing, and depth, and with good soil contact and proper vertical alignment. We immediately discussed any planting quality issues with the planting contractor and led a discussion with the entire planting crew at the next morning meeting.

We developed a plant placement chart to illustrate proper planting zones for all species in relation to the water elevation. We prepared detailed planting prescriptions to guide the planting contractor including the size of patches to plant, optimum hydrologic conditions, tolerance to inundation and salts and other factors to ensure proper placement of each species.

We held two 1-day plant installation training sessions each planting season. These sessions covered proper use of planting tools, safety, care of plants, placement of plants and proper planting techniques. The training sessions also presented the background for the project and the potential benefits to the site, wildlife and future generations of Montanans. This ensured that all planters were aware of proper planting techniques and the need to adhere to them. Many of the planters and crew leaders were students or recent graduates with backgrounds in environmental studies or biology. In response to requests from many of the crew, we held question and answer sessions to provide a venue for increasing crew member understanding of the importance of the project. The value of these sessions was clearly demonstrated through the enthusiasm of the crew, quality of the workmanship and the success of the revegetation efforts.


Willow Planting

The revegetation contractor implemented some innovative employee support actions to ensure the success of the

Rotary Planter

project. The potential for injuries on the project was significant and the crew size was as high as 80 planters. Therefore, the importance of safety was highly stressed. Group stretching and yoga was led by a trained staff member following each daily tool box safety meeting. This resulted in no lost time accidents on the project. Crew-members were also supplied with back-pack hydration systems and lunches were delivered to crews in the field each day. The extra cost of these actions was more than recovered by savings from increased productivity, safety and worker morale.

Plant Installation

With over two million plants to put into the ground and a short growing season in which to work, plant installation had to be fast and efficient while still maintaining quality. Planting methods were chosen based on container size (deep rooted versus smaller containers) and accessibility (saturated zones versus upland areas). The planting crew used the following machine and hand planting methods.

- Rotary Planter: This is an excavator-mounted planter that has a revolving magazine with a capacity of 50 plants and 3 rings. It is controlled by the operator so three different species can be loaded and the operator can choose the best species to plant in any specific spot. The planter is designed for use with deep rooted container plants. It can be used around the perimeter of the site where access does not require driving through saturated soil. Advantages of this technology are speed of planting and ability to dig holes with adequate depth for the deep rooted shrubs in rocky soils.
- Mini-excavator with auger: This is for sites not accessible with the rotary planter so deep rooted shrubs were installed in holes excavated with the auger.
- Two-man auger: Some sites were not accessible with the rotary planter or mini-excavator. For these sites, two-man augers were used to dig holes for deep rooted shrubs.
- Tree planting hoes: Hand planting using "hoedads" was the most efficient method for willows and emergent plants that were grown in small containers. Hand planters could access the saturated and inundated areas, and the "hoedad" is well-designed for use with the 10 cubic inch containers.
- Dibble bars: Dibble bars (round metal tools used to make a hole for planting containerized plants) were only used for installing herbaceous plants in areas with fully saturated and inundated soils. They are not recommended for areas with fine soils because the sides of the planting hole can become compacted resulting in air pockets.

Planting started in early May of each year with woody plants. It is beneficial to plant woody species before the spring flush of root growth. That way the plants are in the ground ready to take off as soon as the temperate warms. The planting crew hand planted willows in natural appearing bands in the lowest and most moist areas of the shrub zone. Deep rooted shrubs were planted in the appropriate hydrology for each species using the "Rotary Planter" or hand planting in holes excavated by power augers. We worked closely with the crew to assist them in proper placement of plants and any needed on-the-ground modifications to the planting plan.

Herbaceous planting started the second week in June and was completed by mid-August each year. Bulrushes were planted first to give the maximum time to establish healthy root systems and minimize potential damage by geese. Herbaceous plants were installed by hand, starting with bulrushes in areas of standing water. Sedges and rushes were planted in patches

Herbaceous planting

Establishing Herbaceous Vegetation

of appropriate hydrology, and remaining grass species were planted in moisture conditions suitable for their establishment and long-term survival.

Revegetation Results

We measured plant survival by establishing circular plots in representative patches within each planting zone immediately following installation. A stake was placed in the center of each plot, the location was recorded using a handheld global positioning system (GPS) unit, and the number of installed plants within each plot was recorded.

The results of the monitoring show that herbaceous and bulrush plantings are rapidly spreading and increasing in density. Shrub and willow survival is 80% after two full growing seasons and plant densities are well within the long term shrub spacing goals. Many of the shrubs are also sprouting from the ground and increasing in density of stems per acre above the planted density. The created wetland area is seeing heavy use by waterfowl and big game. Ducks, geese, phalaropes, avocets and long billed curlews are all common. Whitetail deer and moose are using the site and even a mountain lion has been observed.

Monitoring and Maintenance

We continue to monitor and maintain the site. Documenting observations of wildlife, especially any state-listed sensitive species, will provide needed information in determining the wildlife habitat value of the site, which is critical to meeting the wetland functional objectives. Collection of yearly data from established shrub survival plots and reporting shrub survival rates and visual assessment of herbaceous vegetation (seeded and planted) will also be valuable in showing the development of vegetation. Continuing to take yearly photos of established photo points will provide visual documentation. Based upon monitoring and observations, areas of poor vegetation establishment will be mapped (with GPS) and the resulting maps will guide actions to remedy problems and re-establish healthy vegetation on the problem areas.

Lessons Learned

We learned a number of important lessons in the implementation of this project. Most are related to the fact that re-


Establishing Shrub Vegetation

vegetation projects have a multitude of uncontrollable variables, and it is critical to invest in quality control and quality assurance of those which can be controlled.

- We could not control where the actual hydrology of the site would equilibrate, but could control where we placed the planting unit boundaries to match on-the-ground hydrology. Plants were initially placed in planting zones according to the design, but there were many areas where water levels differed from the design. To ensure optimum plant survival, we worked with the agency oversight and the planting contractor to revise plant placement based on current hydrologic conditions rather than the designed water levels.
- We knew form previous experience that bulrush establishment would be a challenge, especially along the edges of larger ponds where geese tend to congregate. Although we planned the bulrush plantings as early as possible to give plants time to establish before the midsummer flocks of geese appeared, we still observed significant goose damage. We modified the plan, requiring bulrushes to be grown in larger containers which helped establish root systems that could withstand goose browse. In future wetland restoration projects, we may concentrate bulrush plantings along smaller inundated and permanently saturated areas and away from larger water bodies.
- During the first week of planting, there was a cold spell with temperatures below 20 degrees F. Many of the shrubs in the holding area and staged on the site were damaged. This caused reduced survival. For the next year's plantings we moved planting dates later in the spring and provided protection for staged plants to protect them from frost damage. ■

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Moose cow and calf


Long billed curlew

Trompe Technology for Mine Drainage Treatment

B.R. Leavitt, T. Danehy, R. Mahony, B. Page, C. Neely, C. Denholm, S. Busler, M.H. Dunn

Introduction

At many mine water treatment facilities, aeration is needed to oxidize ferrous iron or to remove dissolved carbon dioxide from the water. Many methods have been used to accomplish this throughout the years including surface diffusion, cascade aeration, or in some cases oxidation has been accomplished using chemical reagents such as hydrogen peroxide. The trompe is an ancient technology which has recently been applied to mine water treatment to provide the benefits of mechanical aeration without the need for electricity, motors, or any moving parts. Trompes may also be utilized at many other sites where compressed air is needed.

Figure 1. Bruce Leavitt measuring air velocity using an anemometer.

Figure 2. Aeration using a trompe at the North Fork Passive Treatment System.

Trompe Background

A trompe (Figure 3) is a device that uses falling water to compress air. Water is directed through an airhead (Figure 4) where the effect of falling water draws air into a vertical downpipe. The velocity of falling water in the pipe is high enough that entrained air is carried down the pipe along with the water. A chamber located below the discharge elevation separates the air from the water. The compressed air is then captured for use while the water is discharged from the trompe. The trompe contains no moving parts.

History of the Trompe

Trompe-based technology has been used for many applications, with the earliest known dating back to the Catalan Forge developed in the 17th century. In Figure 5, water falling down a pipe (most likely a hollow log) carries air that is separated in the air box. Compressed air was then directed to the forge, replacing the bellows.

During the late 19th and early 20th century the trompe reached its zenith. Mr. Charles Havelock Taylor rediscovered the working principle of a trompe inde-

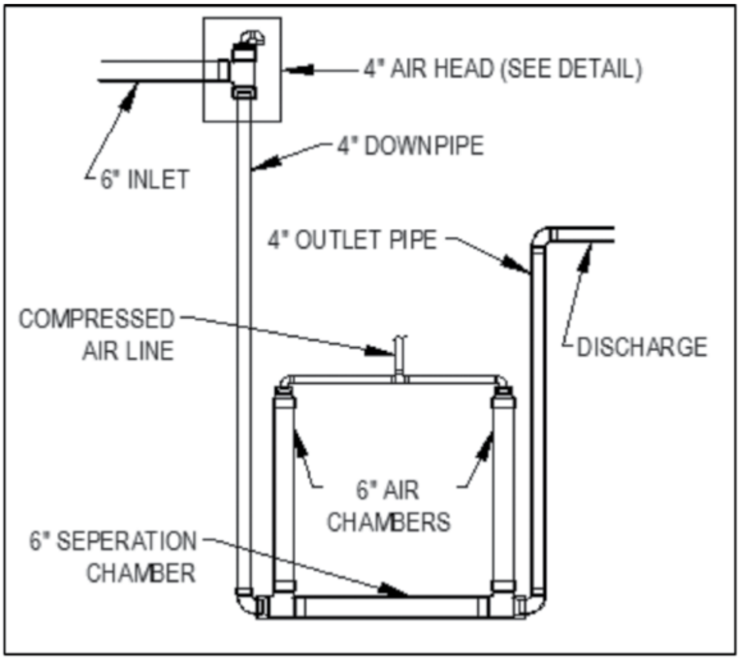

Figure 3. Trompe Section View

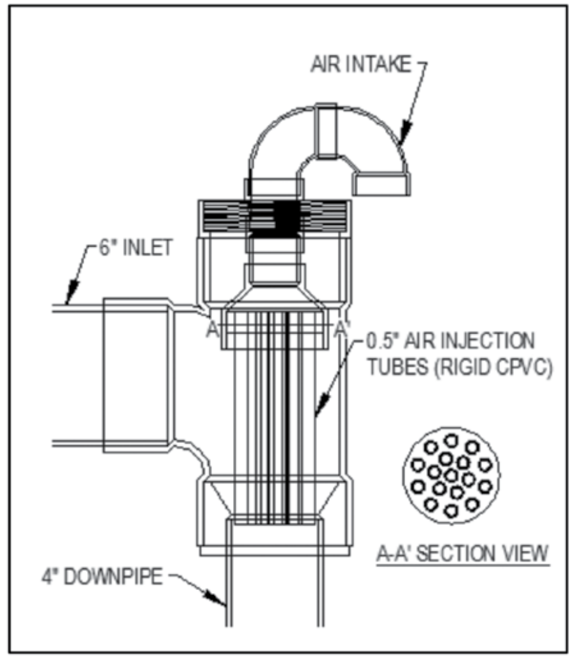

Figure 4. Trompe Airhead Detail

pendently. In 1896 a compressor was built at Magog, Québec, to supply compressed air to a cotton mill. This method of air compression became very well known at the time and Mr. Taylor built a number of trompe-style compressors in the United States (Washington, Michigan, Connecticut), Canada, Peru, and Germany. These compressors became so associated with Mr. Taylor that they became known as Taylor Compressors. In 1910, Mr. Taylor designed and built a compressor called Ragged Chute near Cobalt, Ontario, Canada. Figure 6 is a diagram of the Ragged Chute facility. This unit was in nearly continuous operation from 1910 until the headworks were destroyed by fire in the 1980's. The compressed air generated at Ragged Chute was used to operate rock drills in nearby mines.

Basic Trompe Installation Requirements

Approximately 4 feet of drop is needed as measured from the difference of elevation between the inlet head and the discharge pipe. The air pressure that can be generated is controlled by the height of the discharge pipe and can vary based on the depth at which the separation chamber can be buried. Trompes have been recently installed for flow rates ranging from 25 – 400 gallons per minute and we have designs developed for flow rates greater than 3,000 gallons per minute. Approximately 1 cubic foot per minute of air can be produced for every 25 gallons per minute of available flow. If site conditions allow, multiple trompes can be installed in series. Variable flow rates can be accommodated by installing trompes with multiple airheads and downpipes.

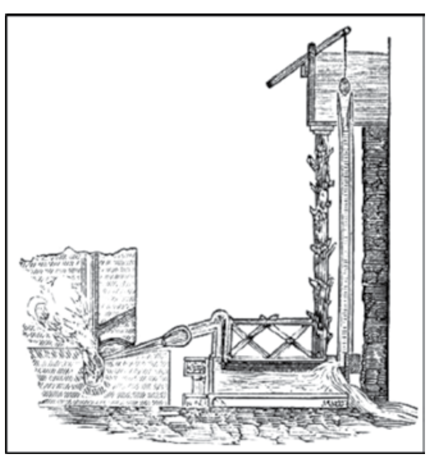

Figure 5. Catalan Forge

A trompe can use water from any appropriate point in the treatment process, or from any other available water source. However, clean water from the final discharge helps minimize iron deposition within the trompe and associated maintenance requirements. In addition, the variation in discharge flow is proportional to the need for compressed air in the treatment process. The compressed air that is generated in the trompe can be piped to any point in the treatment system.

Trompe Applications in Water Treatment

In recent years, trompes have been installed for multiple applications with successful results. Trompes have been

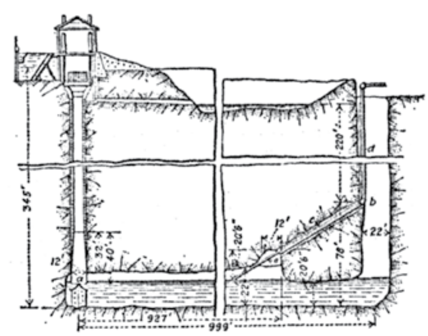

Figure 6. Ragged Chute Trompe

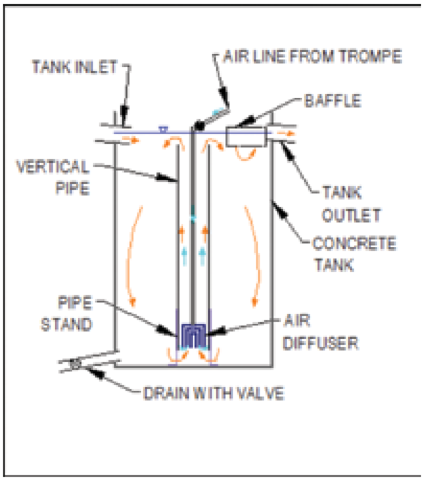

Figure 7. (above left) Diagram of the "A-Mixer".

installed in both passive treatment and semi-active mine drainage treatment systems.

Trompe technology powers a device called an "A-Mixer" (pat. pend.), which is similar to an air-lift mixer, located at the Manor Treatment System in Clearfield County, PA. This device consists of a tank which provides residence time for pebble quick lime dissolution. In the center of the tank is a vertical pipe suspended off the bottom of the tank and rising to just below the water level in the tank. An air pipe, with an air distributor (diffuser), is suspended in the middle of the vertical pipe and is connected to a trompe. In this case, compressed air from the trompe is used to increase chemical utilization efficiency of pebble quicklime at the site.

Trompe-powered aeration helps remove carbon dioxide and increase dissolved oxygen in order to enhance the oxidation and precipitation of ferrous iron. Sites currently using trompes for this purpose include the Curley Passive Treatment System in Fayette County, PA, and the North Fork Passive Treatment System in Allegheny County, PA. Both of these sites utilize fine bubble disc diffusers to aerate the mine water shown in Figure 9. ■

Figure 8. (above right) Manor "A-Mixer" used to enhance lime mixing and dissolution.

Figure 9. Fine bubble disc diffusers used at the Curley Passive Treatment System.

Selected References

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Second Annual WRRC Land Reclamation Symposium and the 30th Annual Meeting of the ASMR

– Northeast Wyoming Post-Conference Tour

Friday, June 7th, 2013

The post-conference tour through Northeastern Wyoming began the morning of Friday, June 7th. A jam-packed day began with an early morning departure from Laramie, WY. The first stop was the Rolling Hills Wind Farm northwest of Glenrock, WY. Chet Skilbred, long-time environmental coordinator for the previous coal mine at that site, provided a historical perspective of reclamation in the southern part of the Powder River Basin (PRB). Despite varying precipitation and years of drought, successful sagebrush establishment was viewed.

From there, we traveled to Cameco Resources Smith Ranch in-situ uranium mine/processing facilities located about 45 minutes north of the Rolling Hills Wind Farm. Cameco graciously provided lunch to tour participants while an overview of in-situ mining was presented. A tour of the main processing plant provided participants with an overview of the chemical complexity of producing yellow cake or the final product at the facility.

We then continued onto North Antelope Rochelle Mine (NARM) near Wright, WY. Paul Griswold and Scott Belden, two of ASMR's Reclamationist of the Year award recipients, were tour guides of the reclamation throughout the expansive mine, as well as an overview of pit operations. Despite the lateness of the day, Paul and Scott were enthusiastic tour guides and didn't mind the group overstaying its original departure time. Innovative techniques were viewed.

After that was completed, we continued on to Wright to dine at the relatively new hotel/steak house in this small northern Wyoming industrial based town. The group ended the first day of the Northeastern Wyoming Tour in Gillette and spent the night at the Arbuckle Lodge near the Camplex (Campbell County's large fairground facility).

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