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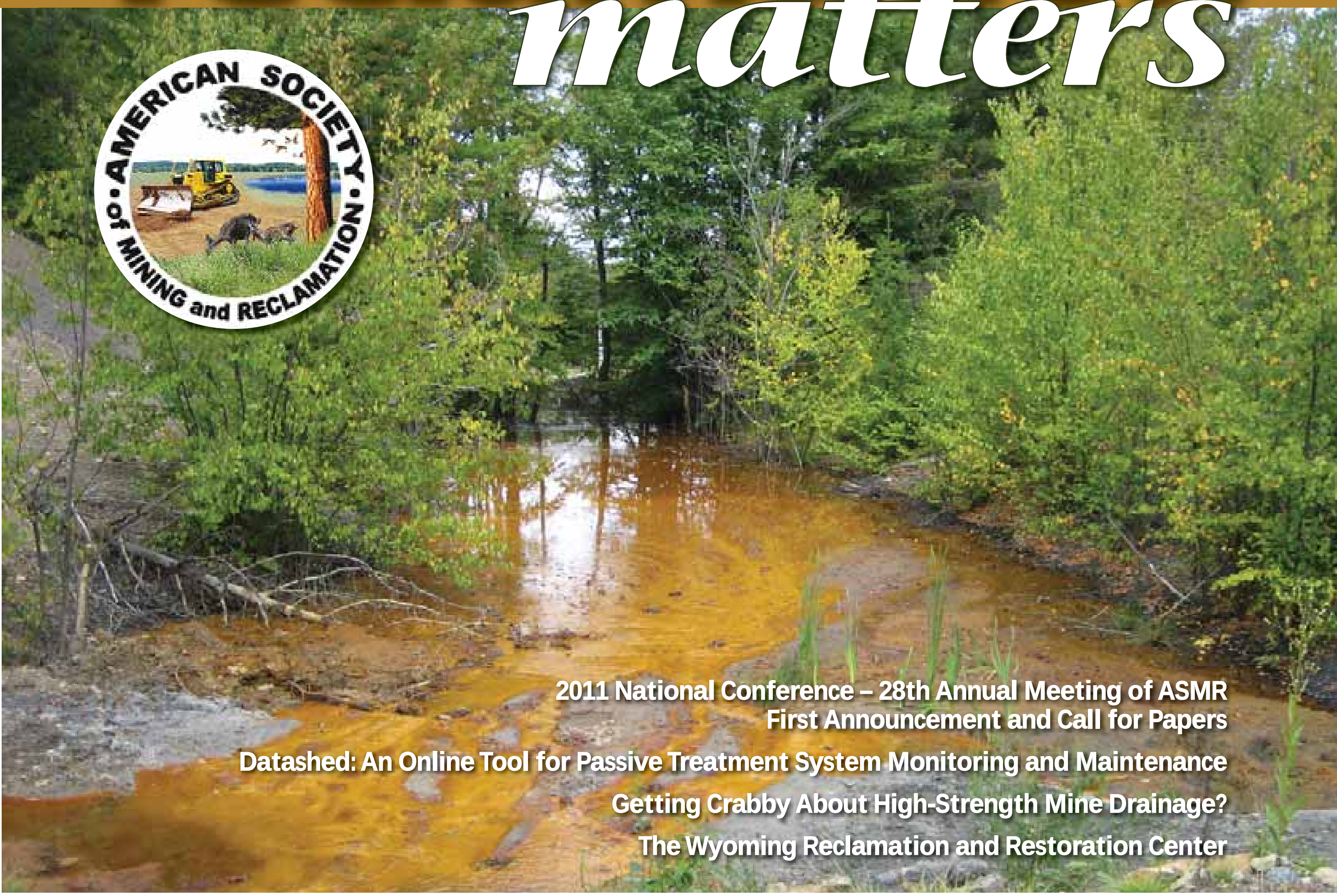
reclamation *matters*



2011 National Conference – 28th Annual Meeting of ASMR First Announcement and Call for Papers

Datashed: An Online Tool for Passive Treatment System Monitoring and Maintenance

Getting Crabby About High-Strength Mine Drainage?

The Wyoming Reclamation and Restoration Center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reclamation matters

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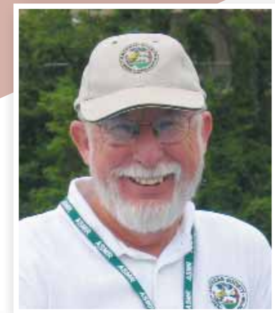


Generational Challenge

Kimery Vories, ASMR President

The challenges of the last generation (those who came of professional age during the '60s and '70s) were to apply science and technology to prevent major industrial processes from having detrimental impacts on human safety, health, culture, and the environment. This generation lived through major changes to environmental laws, both in the United States and worldwide, protecting clean air and clean water, managing wastes and properly disposing of materials, identifying and protecting archeological resources, and promoting land use capability. They created professional organizations like ASMR, whose members bring the knowledge, skills, and experiences of numerous natural resource disciplines, engineering, and the sciences that are needed to protect our land, air and water from the tragic side effects of the industrial age.

In the long run, the next generation of professionals involved in environmental reclamation and restoration will find a totally new challenge. Although the technological achievements of the last century have allowed us to live in comfort and abundance, the raw materials these technologies depend on are no longer abundant and cheap. The energy resources that drive these technologies are no longer abundant and cheap. The environmental impacts of the technologies that sustain our civilization now transcend local, state, and national boundaries to the extent that they could impact global ecosystem functions. The challenge for each of us, and for ASMR collectively, is to discover our part in making mineral extraction technologies compatible with the natural systems that sustain our country and our world. If we are successful, we may produce a model to show the world how the same can be done elsewhere.

In the short run, each one of us needs to improve our professional skills and abilities and communicate our solutions and challenges to a world that is largely unaware of us make ASMR an easy to use and effective umbrella organization for professionals in the field. There has been an increasing sense of urgency and purpose within the ASMR NEC, shown by the leadership of Vern Pfannenstiel and Dennis Neuman who have preceded me, in directing the energy and resources of ASMR to meet some of these challenges. Efforts by Abbey Wick in the formation of the Early Career organization must be supported and expanded to reach, coach, and challenge the next generation. Modernization of our website and other challenges of the electronic age must be improved and adapted to better communicate with other professionals and the world at large. The development fund being created by the NEC must be supported and expanded so that ASMR has the resources to respond and implement solutions to the challenges ahead. Relationships need to be built between the reclamation scientists of ASMR and the reclamation practitioners who are often in government agencies that do not have access to the latest scientific discoveries. They frequently need assistance from the scientific community to investigate exactly how and why their field efforts succeeded or failed.

Personally, I am asking each of you to make this next year as productive as possible by directly contacting me or any other member of the NEC with your ideas on how to make ASMR more effective and productive. Then I would ask you to be willing to roll up your sleeves and work with the NEC to make those ideas a reality. I am looking forward to hearing from you. ■

How Are You Changing the World?

Jeff Skousen, West Virginia University

Recently, I watched an old science-fiction movie made in 1980 called *The Final Countdown*. The story involved the captain and crew of the USS Nimitz, a huge Navy aircraft carrier, being transported back in time to December 6, 1941, and magically deposited near the Hawaiian Islands. Finally realizing that they were in 1941, the Captain, Kirk Douglas, decided they must defend U.S. soil and attack the Japanese fleet that was moving toward Pearl Harbor. Their aircraft of the 1970s (F-14 Tomcats) could easily wipe out the Japanese Zeros and save Pearl Harbor preventing the United States from entering World War II. An efficiency consultant, Martin Sheen, argued that annihilating the Japanese fleet and changing history in such an astonishing way would have unimaginable consequences. The dilemma was obvious: averting a world war by killing a group of people now who had lived before and saving another group now who had died then would dramatically change thousands of lives and completely alter world events during the ensuing 40 years. The paradox left the captain and senior officers on the ship pondering the inconceivable possibilities and innumerable changes their attack would bring about. I'll let you rent the video to see the ending.

Upon reflection (which is dangerous after viewing a sci-fi movie), I realized that the lives of each individual and the things we do and accomplish in life have quite a significant effect on others and can have a large impact on the course of history on a local and broad scale. This concept was also depicted during the classic film *It's a Wonderful Life*, when George Bailey was able to see how the world evolved without him. His thinking, "the world would have been better off without me and I wish I had never been born," was illustrated and the small, seemingly insignificant things he had done and his personal interactions with others on a daily basis resulted in the quiet, wholesome village of Bedford Falls instead of the landlord slum of Pottersville.

Some of you may feel that you are pretty insignificant with little to offer, going nowhere in your job, making no momentous decisions, and producing nothing. I counter with the argument that the daily routine of your life and the decisions you make are having a larger impact than you can imagine and your realm of influence is broader than you may think. Even if you are not breaking new ground in scientific research and making new discoveries, which many of you are, and even if you are not producing new policies and laws to change the way things are done, which some of you are doing, I submit that you are changing history every day. Each of us can and should do our part, large and small, to make the world a better place. So keep doing your job, pushing boundaries, grinding through the daily turmoil, adapting old solutions to new problems (or vice versa), proliferating new ideas, publishing papers, promoting good policies and rules and, above all, being a productive, thoughtful, and caring person to your family, friends, and co-workers.

So, how are you changing the world today? ■

Getting Involved

Abbey Foster Wick

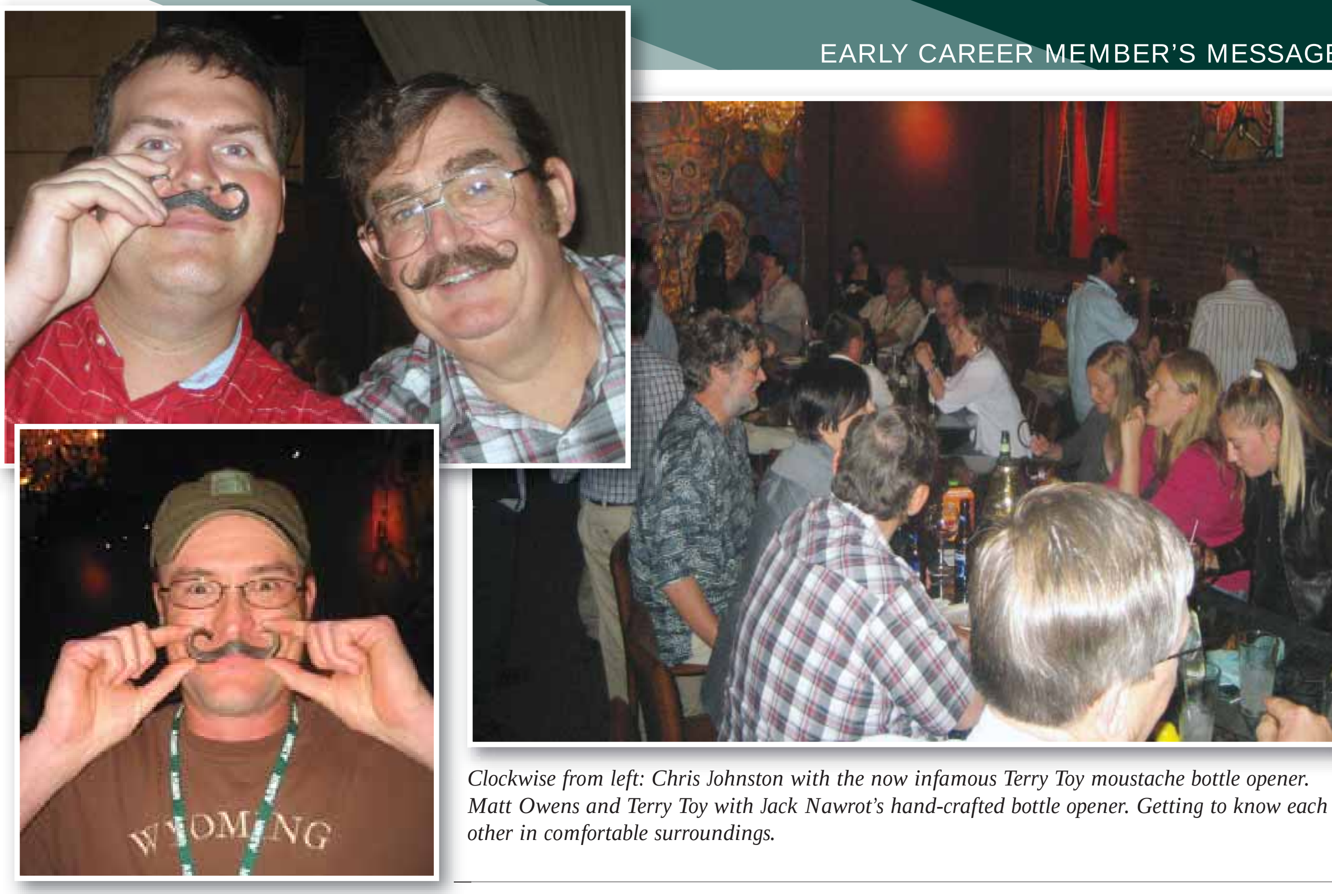
Right: Abbey Wick with Hines Ward autographed football from the auction.
Below: Caley Gasch-Salava showing off her receiving skills!

The first order of business came after several conversations at the meetings in Pittsburgh. We decided that a name change for the group was in order, so … (drum roll) … we are now the "Early Career" rather than "Young Professionals" group within ASMR. Other societies have similar divisions with this name, perhaps reducing some of the confusion about who should register for Early Career events, etc. I want to stress that we are not a "student group," but rather members and non-members who are new to ASMR and who are just starting their careers or further defining their career direction in graduate school. Of course students of any level are encouraged to attend our events, but, sorry guys; you're not the basis for the group.

Now for an update on the first annual Early Career social event.

I received a letter from Jessica Odenheimer shortly after the meetings in Pittsburgh (see excerpt below). To me, her comment not only reflects the overall consensus about the social event, but also ASMR in general. There is something about the atmosphere at ASMR meetings that keeps us "in love with our jobs" and inspires us to continue advancing reclamation science and practices. I think we can all agree that it is the interaction among those starting their careers, those who are wrapping up years of service, and those in between that makes this an effective and innovative professional society. As you can see in one of the event photos, the Early Career Social event created an environment conducive to that interaction … we had a mix of 60 percent early career, 20 percent sponsors, and 20 percent more established members in attendance (total of 75 people). We raised $2,500 through sponsorships and the auction, which gives us an excellent start

> *"The young professionals [early career] social was a hit; it was a great way to get to know people in a casual atmosphere. I have never met so many people who are in love with their jobs…"*
>
> — Jessica Odenheimer

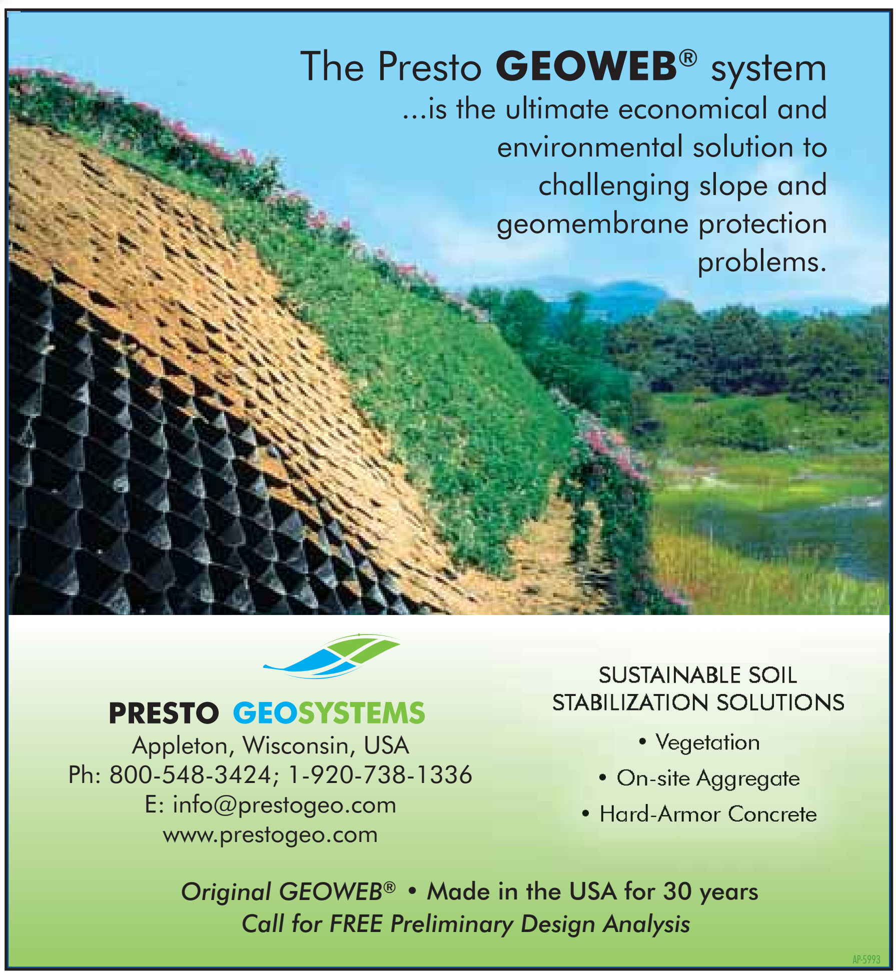


Clockwise from left: Chris Johnston with the now infamous Terry Toy moustache bottle opener. Matt Owens and Terry Toy with Jack Nawrot's hand-crafted bottle opener. Getting to know each other in comfortable surroundings.

to planning reduced-rate events geared towards Early Career members at the Bismarck meeting in 2011. Please keep in mind that we continue to look for monetary support to expand upon future activities.

Again, I want to thank all those who attended the social, our generous sponsors, those who donated auction items, and the Early Career committee (Caley Gasch-Salava, Matt Owens, and Chris Johnston; I've included pictures of them from the event). Next year, Caley will be planning the social event and I'll be working on a special session and field tour. Matt and Chris will be working on rounding up sponsors. Based on the response this year, I'm confident that the events planned for next year will be a huge success and the Early Career group will continue to grow and serve the society.

Please join us on Facebook. Just search "American Society of Mining and Reclamation" or email me (afwick@vt.edu) to get more involved. ■



June 12-16, 2011, Bismarck, North Dakota, USA

First Announcement and Call for Papers

Theme – Reclamation: Sciences Leading to Success

This conference will focus on, but will not be limited to, the technical areas identified below and will provide a forum for the dissemination of information through presentation of research findings, field tours, workshops, and open discussion of public policy relating to mining, reclamation, restoration, and land management issues.

Papers Categories

Three kinds of papers will be considered this year as a way of encouraging a greater number of submissions.

1) Research paper – three peer reviews will be obtained; must be reproducible lab or field research. Must submit a standard full-length paper if given orally or as an extended abstract if given as a poster.
2) Case Studies – two peer reviews will be obtained for the submitted manuscript; presentation of field case studies and examples of mitigation tactics that have been employed at a field site. May be given orally when a written paper has been submitted or as abstract or an extended abstract if given as a poster.
3) Demonstration project – two peer reviews will be obtained for the submitted manuscript; generally these are demonstrations of a new product, method, or technology of commercial value, but presented with defendable data and more than just a clever sales pitch. May be given orally when a written paper has been submitted or as abstract or an extended abstract if given as a poster.
4) Other – requires two peer reviews; e.g., policy paper. May be given orally when a written paper has been submitted or as abstract or an extended abstract if given as a poster.

Invitation:

The Program Committee invites the submission of abstracts for the above categories for both oral or poster presentations. Suggestions for workshops are welcome and are in the planning stages, as well as pre- and post-conference field workshops/tours.

Technical Sessions:

A 250- to 300-word abstract should be submitted for consideration within topical areas such as those given below (see Submitting an Abstract section below):

Forestry and Wildlife Topics
- Wildlife Habitat Replacement
- Wildlife Habitat Revitalization (maybe in joint session with Ecology)

Ecological Topics
- Channel Reconstruction
- Invasive Species
- Coal Bed Methane
- Saline Effects on Revegetation
- Managing Impacts to Species of Concern
- Active/Passive Water Treatment
- Impacts of Watershed Restoration Using Native Species

Geotechnical Engineering
- Innovative Reclamation Techniques Steep Slope Stabilization
- Geochemistry

Land Use and Design Topics

Soils and Overburden Topics
- Cold Climate Reclamation
- Liners, Covers and Caps – Design Succession – Plant Community Development
- Byproduct Utilization in Reclamation
- Ash Disposal – Coal Combustion Byproducts Plant Materials Development
- Land Revitalization Case Studies
- Dust Suppression for Air Quality

Water Management Topics
- Hydrology – Surface/Groundwater
- Wetlands
- Riparian Restoration (maybe in joint session with Ecology)
- Cold Climate Passive Treatment Systems
- Biochemical Rea.ctors

Refuse and Tailings Management Topic

Other Topics
- Geomorphic Approaches to Reconstructing Landscapes
- Equipment, Instruments and Software
- Uranium Mining and Reclamation
- Developing Appropriate and Achievable Success Criteria

Workshop Sessions:

Short Courses/Workshops will be presented in the following tentative areas: RUSLE2; Bond Release Procedures; Geo-Technical System Use on Mined Lands; 40 Years of Reclamation Work; and Reclamation of Oil and Wind Tower Pads. Other topics will be considered, as well.

Field Tours:

Potential Pre- and Post-Conference activities include unique field tours varying from power generating sources in North Dakota (including gasification, DryFining™ lignite, and wind power); alternative post-mine reclamation uses; AML highwall/subsidence reclamation techniques; and wetland restoration to Lewis and Clark's presence in the state and others.

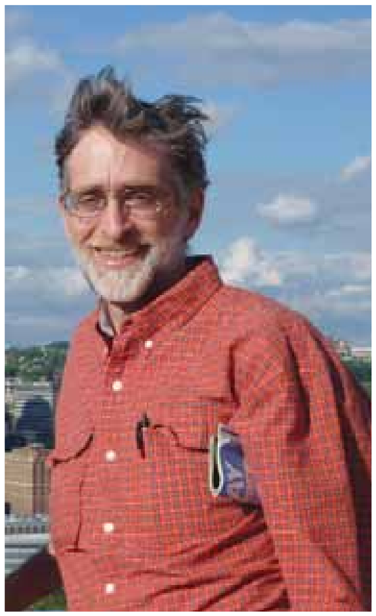
Submitting an Abstract:

Please submit your abstract electronically for oral or poster presentation by October 30, 2010. Abstracts will be reviewed for scientific content and relationship to the tentative Technical Sessions identified above. If accepted, oral or poster paper presenters who wish to publish their paper must submit a draft copy electronically of the full paper for review by January 17, 2011. Poster presenters have the option for submitting a full-length paper. Technical review of the paper will be conducted by appropriate ASMR Technical Divisions. If the draft paper is accepted, the authors must submit their final manuscript as an electronic copy by April 25, 2011. Final manuscripts must use either MS Word or WordPerfect PC software. The full-length paper will be published as a CD-ROM and distributed at the Conference. ■

Picture Award Winners

Robert Darmody

Richard and Lela Barnhisel Reclamation Researcher of the Year



Our recipient of the 2010 Richard I. and Lela M. Barnhisel Reclamation Researcher of the Year Award for 2010 has a long history of research relating to mining and its environmental and agronomic impacts. His research was some of the first of its kind in the U.S. At the time his research began, Illinois was considering banning long wall underground coal mining. His research provided evidence that the impacts of related subsidence could be mitigated. He also served as director of the University of Illinois Surface Mine Reclamation Program for several years, which documented the importance of soil compaction in mined land reclamation. Because of this research, the industry modified its soil-handling techniques and developed procedures to avoid or correct soil compaction in reclaimed mine soils. His research has led to many invitations to speak on the subject in numerous countries. He has published over 100 technical journal articles and other research publications over his distinguished career.

He received his graduate education in Soil Science at the University of Maryland. He received the Fellow from the American Society of Agronomy and the Environmental Achievement Award from the National Environmental Awards Council. He is also recognized for his outstanding teaching at the University of Illinois and received outstanding instructor rankings in 1985, 1986, 1988, 1996, 1997, 2001, 2002, 2006, 2007, 2008, and 2009. He is a long-time member of ASMR (18 years) and served as president of the society in 2006. We are pleased that the 2010 Richard I. and Lela M. Barnhisel Reclamation Researcher of the Year Award is presented to Dr. Robert Darmody, Professor of Pedology, at the University of Illinois. ■

James Luther

2010 Reclamationist of the Year Award

Our recipient of the Reclamationist of the Year Award for 2010 has had a prestigious career in the field of mined land reclamation for over 30 years. He has worked in regulatory, consulting, and in the mining industry. This man readily tries new ideas, in spite of the resistance from those who like the "old ways." But he has never let resistance discourage him. During his development and implementation of fluvial geomorphic principles on surface mines, he kept insisting that this was a more stable method of reconstructing landscapes. The new design was erosionally stable, diverse, and sustainable, and the technology was quickly adopted by his company. His other accomplishments include the first Phase 3 bond release in his state. One of his mine managers wrote: "He has always been an excellent representative for the environmental activities within the company." Another operations manager stated: "His drive for improvement was recognized this past year as we closed the LaPlata Mine after 20+ years of operation. The reclamation work led by him and his team has been recognized with such terms as 'world-class' and 'leading best practices.' All his effort and work culminated in the LaPlata mine winning the national OSM Surface Mine Reclamation Award for 2009 and the BHP Billiton Global Environmental Excellence Award in 2009. He is a life member of ASMR and serves on numerous public and civic organization boards in his home town. His nominator stated: "Jim is one of the nation's stellar reclamationists and no doubt one of Wyoming's proud graduates." ASMR's 2010 Reclamationist of the Year is James Luther, Manager of Health, Safety and Environment, New Mexico Coal. ■

George Vance

William T. Plass Lifetime Achievement Award

Our recipient of the William T. Plass Award for 2010 has spent over 20 years in research and teaching in the area of soil chemistry as it relates to mined land reclamation, coalbed methane water utilization/disposal, carbon sequestration, and industrial waste management and treatment. He received degrees at University of Illinois and Michigan State University in soil science. His research in selenium chemistry in soil and mined land overburden was used by Wyoming regulatory agencies to establish plant tolerance/toxicity guidelines. He has also been instrumental in developing selenium methodologies now being utilized as standard methodology in soil chemistry handbooks. His achievements in education are also very impressive. He has received special recognition for excellence in academic advising, distinguished graduate faculty mentoring, and three of his Ph.D. students won the outstanding dissertation award at his university. He also had a major role in the development and establishment of the Wyoming Reclamation and Restoration Center.

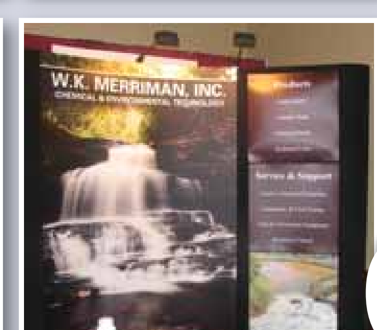
George has been very active in the Soil Science Society of America: serving as chair of the Soils and Environmental Quality Division, presiding over number of symposia sponsored by SSSA, and serving as president and secretary/treasurer of the Western Soil Science Society. George served as co-chair of the ASMR program committee for the 1995 conference and also served on the ASMR organizing committee of the 2005 and 2007 conferences. He served as president of ASMR in 2001-2002, and also served on the awards committee and scholarship committee. Awards received include Fellow in AAAS, Fellow in SSSA, Fellow in ASA, Reclamation Researcher of the Year Award in ASMR, and J.E. Warren Distinguished Professor of Energy and the Environment. ■

Exhibitors

2010 MEETING

Exhibitors

2010 Meeting



2010 Joint Mining Reclamation Conference – A Successful Team Effort

By Cliff Denholm, Biomost, Inc.

We congratulate and thank the organizing committee of the 2010 Joint Mining Reclamation Conference for putting together such a wonderful event. This year's conference combined the 27th Annual American Society of Mining and Reclamation Conference with the 12th Annual Pennsylvania Abandoned Mine Reclamation Conference and the 4th Annual Appalachian Regional Reforestation Initiative Conference into one unified meeting. Appropriately titled *Bridging Reclamation, Science and the Community*, people of different backgrounds, including governmental regulators, academia, research scientists, watershed groups, and reclamation practitioners from literally all over the world, came together in Pittsburgh, Pa., the City of Bridges, to discuss mining reclamation, which is so dear to the hearts of those of us from western Pennsylvania.

Coal mining has taken place in Pennsylvania for well over 200 years, and Pennsylvania was once the leader in the production of coal in the United States. As a large majority of the mining took place prior to the development of environmentally considered technologies, the Commonwealth has been faced with a legacy of over 250,000 acres of unreclaimed mine lands and over 5,000 miles of streams polluted by abandoned mine drainage. Much of the work to address these issues has been led by dedicated watershed groups and governmental agencies like the Pennsylvania Department of Environmental Protection. As a result billions of gallons of mine drainage are being treated every year by over 250 passive treatment systems and hundreds of miles of streams have been restored. Many of these streams now have reproducing fish for the first time in 50 years or more. These improvements in the headwater streams along with the implementation of industrial and residential wastewater treatment have significantly improved the water quality of the Three Rivers, so much so that in 2005, the BassMasters Classic Tournament was held in Pittsburgh – of all places!

Attendees of the this year's conference had the opportunity to experience one of the Three Rivers, the Monongahela, firsthand from a unique vantage point while riding aboard the Gateway Clipper's Empress ship. The cruise, which was modeled after the annual Ohio River Watershed Celebration Riverboat Cruise (now in its ninth year), gave the participants a guided tour of the river highlighting the history, use, and beauty of the river, as well as providing an opportunity to relax and listen to local musicians Mike Gallagher and Bob Banerjee.

In addition to the cruise and other social events, the conference was filled with opportunities for participants to share and learn from each other. There were tours, workshops, posters and of course presentations on a wide range of topics from growing trees on mine lands to passively treating severe mine drainage sources to utilizing an abandoned mine site for environmental and coal heritage education.

While we applaud all of the individuals who made this conference a huge success, we specifically recognize and thank Lois Uranowski and her team at the US Office of Surface Mining, Mike Bower of Appalachian Regional Reforestation Initiative, Andy McAllister of the Western Pennsylvania Coalition for Abandoned Mine Reclamation, Tom Grote of Stream Restoration Inc., and Dick Barnhisel of ASMR for all their hard work and many hours of volunteer service.

For further information about BioMost Inc., please contact Tim Danehy, BioMost, Inc., 434 Spring Street Ext., Mars, PA 16046; (724) 776-0161, bmi@biomost.com, www.biomost.com. ■

Evaluation of First 1.5 Years of Operation of a Passive Treatment System in S.E. Oklahoma

By J.A. LaBar and R.W. Nairn

Introduction

Typical coal mine drainage is characterized by elevated concentrations of dissolved iron, sulfate, and trace metals and generally exhibits an acidic pH (<4.5) (e.g., Watzlaf et al. 2004 and Younger et al. 2002). Conventional methods of treatment for these waters generally require large amounts of maintenance and can be very cost intensive to sustain. Passive methods of treating mine drainages, which utilize natural chemical, physical, and biological processes to remove contaminants from the water, are becoming more commonplace. These systems may be composed of a variety of unit processes, including oxidation/settling ponds, vertical flow cells, and anoxic limestone drains (Watzlaf et al. 2004; Ziemkiewicz et al. 2003).

Oxidation ponds are commonly used to remove iron from the water via oxidation, hydrolysis, and precipitation. These processes require the mine drainage to be net alkaline in order to sustain the chemical reactions (e.g., Nairn and Mercer, 2000). When addressing a net acidic discharge, an anoxic limestone drain (ALD) may be placed before the oxidation pond. ALDs consist of buried beds of high-calcite limestone in an anoxic environment. As mine water flows through an ALD under anoxic conditions, limestone dissolves, neutralizing proton acidity and producing dissolved carbon dioxide which further reacts with calcite to generate bicarbonate alkalinity (e.g., Younger et al. 2002; Cravotta 2003, LaBar et al. 2008).

In vertical flow cells, water flows down through a layer of organic matter atop a bed of limestone. The purpose of these systems is twofold: to anaerobically reduce concentrations of trace metals through bacterial sulfate reduction and subsequent sulfide precipitation and to generate alkalinity through bacterial sulfate reduction and limestone dissolution (Kepler and McCleary, 1994). The reducing environment in the compost also prevents the armoring of the underlying limestone due to $Fe(OH)_3$ precipitation by reducing Fe^{3+} to Fe^{2+}. If enough alkalinity is not generated to neutralize all of the acidity, the vertical flow cell may be followed by another series of oxidation ponds and vertical flow cells (Nairn and Mercer, 2000).

This paper presents the first 1.5 years of data collected from a site utilizing these three-unit processes. The system has consistently removed sulfate, iron, manganese, and trace metals effectively throughout the study period. In addition, the system has been effective at removing mineral acidity and now discharges a net alkaline effluent.

Methods

Site Background

The Rock Island Coal Company #7 Mine is located near Hartshorne, Pittsburg County, Okla. An artesian discharge from the abandoned (*circa* 1930s) mine was sampled periodically over several years in the late 1990s and early 2000s (Photos 1 and 2). Water quality fluctuated greatly over this period, as did discharge rates, ranging from <1 to approximately 75 L/min. Temperature, pH, and DO remained relatively consistent across sampling events, but metals and anions concentrations varied considerably (Table 1). The acidity of the discharge, as well as the elevated median concentration of iron made a plan for treatment imperative.

System Design

Through a cooperative effort between the Office of Surface Mining Reclamation and Enforcement, Oklahoma Conservation Commission, and others, a 12-cell passive treatment system was constructed in summer 2005 to treat the mine discharge. The system consists of a vertically oriented anoxic limestone drain (VALD)

Far left: Artesian mine discharge from abandoned fan shaft near Hartshorne, Okla.

Left: Covered abandoned fan shaft and surrounding area, pre-construction.

Below: Figure 1. Schematic of Rock Island #7 passive treatment system with discharge point shown in red. (BASE DRAWING COURTESY OF BURNS AND MCDONNELL, 2004)

Table 1. Summary data for untreated mine discharge near Hartshorne, Okla. from 1999 to 2002.

	Minimum	Maximum	Median	n
Temperature (°C)	17.4	22.3	20.9	18
pH	5.25	5.64	5.36	18
DO (mg/L)	0.1	0.8	0.2	17
Specific conductance (µS/cm)	2960	17100	11800	18
Alkalinity (mg/L as $CaCO_3$)	95	214	117	18
Acidity (mg/L as $CaCO_3$)	419	2402	1405	15
Iron (mg/L)	215	1311	765	15
Manganese (mg/L)	14	29	18	15
Sodium (mg/L)	1400	3437	1893	4
Chloride (mg/L)	197	381	225	9
Sulfate (mg/L)	5456	13620	7842	12

followed by an alternating series of three oxidation ponds and two vertical flow cells (Figure 1). The water discharges into a polishing wetland cell and then into an existing pond.

An abandoned fan shaft (total depth approximately 56 meters) from which the mine water discharged was converted into the VALD. The VALD was designed to perform akin to a traditional horizontally oriented ALD. The shaft was first filled with approximately 34 meters of local dolomitic stone (to provide long-term stability) which was then covered by 22 meters of high calcite limestone (to provide alkalinity generation capacity). Stone size was nominally 4 inches to 6 inches with larger cobble first used to establish a base. An effluent header pipe directs water from the VALD into the first oxidation pond, where the water is split into three discharge pipes (Photo 3).

Each of the three oxidation ponds in the system has an areal surface area of 1,214 m^2 (0.30 acres). The size of the ponds was determined using a removal rate of 20 g/d/m^2 of iron. The oxidation ponds are each split into three sub-cells by aeration berms built of dolomitic limestone. Each of the two vertical flow cells has a surface area of 647 m^2 (0.16 acres). Both cells contain an underdrain pipe system made of 4-inch perforated schedule-80 PVC-pipe laid into 0.3 meters of dolomitic limestone. This layer is covered with 1 meter of high calcite limestone and 0.5 meters of spent mushroom compost. These five cells are then followed by a small polishing wetland cell and then an existing pond (approximately 4,000 m^2); however, for the purposes of evaluating the performance of the system, analyses of data collected from the polishing wetland and pond are not discussed in this paper.

Sampling and Analysis

Although construction was completed in June 2005, the VALD did not begin to discharge into the system until January 2007, due to a prolonged regional drought. The entire system was sampled approximately monthly from January 2007 through June 2008. Samples were collected at the three VALD discharges, at the outflow of each oxidation pond and at the outflow of each vertical flow cell. Temperature, pH, DO, oxidation-reduction potential, total dissolved solids, conductivity, and specific conductance were determined *in situ* with a YSI 600QS multiparameter datasonde and YSI 650MDS display. Total alkalinity and turbidity were measured immediately after sample collection via titration with appropriate normality sulfuric acid using a Hach digital titrator (Method 8203) and via a Hach 2100P Turbidimeter, respectively. Samples were collected in 250-mL HDPE bottles for each sample location-event pair. One sample was preserved with trace metal grade HNO_3 to pH <1 for total metals analyses and a second sample was stored on ice at ≤4°C for anion analyses. Samples were then transported to the Center for Restoration of Ecosystems and Watersheds (CREW) laboratories at the University of Oklahoma for analyses.

Preserved samples for metals analyses were first nitric acid digested in a CEM MARSXpress Digestion System following

Right: VALD outflow into first oxidation pond.
Below: View of entire system with influent on the right and effluent at the bottom left.

EPA Method 3015 (EPA, 2006). Digested samples were then analyzed with a Varian Vista-PRO simultaneous axial Inductively Coupled Plasma-Optical Emission Spectrometer following EPA Method 6010b (EPA, 2006). Samples retained for anions analysis were filtered through 0.2µm nitrocellulose filters and analyzed with a Dionex 300 ion chromatograph following EPA Method 300.0 (EPA, 1993).

Results and Discussion

Due to the design of the VALD, sampling of the original mine discharge is currently impossible. The VALD effluent is considered the best approximation of the discharge water quality. Water quality and quantity data collected from the VALD effluent from January 2007 through June 2008 demonstrate that this mine discharge remains highly mineralized, containing elevated metals, base cations, sulfate, and chloride. Metal and anion concentrations and discharge rates were highly variable, remaining consistent with pre-construction data.

The purpose of the VALD is to generate alkalinity to sustain iron oxidation in subsequent unit processes. In this regard, the VALD is performing effectively. According to Watzlaf et al. (2004), a typical anoxic limestone drain can be expected to add up to 150-300 mg/L as $CaCO_3$ of alkalinity. Alkalinity concentrations in the VALD effluent averaged 470 ± 49 mg/L (mean ± standard deviation) as $CaCO_3$ during the period of study. As a result of alkalinity generation, as well as decreases in metals concentrations, the net acidity of the discharge decreased from a pre-construction value of 1,288 mg/L as $CaCO_3$ to 614 ± 498 mg/L as $CaCO_3$.

System effluent showed a marked improvement in quality over the course of the study, particularly with respect to iron concentrations (Table 2). As a result of water flowing through the system, total metals, sulfate, and alkalinity concentrations decreased, while pH increased. In addition, the water went from net acidic (571 ± 489 mg/L) at the VALD discharge to net alkaline (163 ± 74 mg/L) at the end of Cell 5.

Iron and Manganese Removal. This passive treatment system has been very effective at removing iron from the mine discharge. The maximum iron concentration in the VALD effluent during the period of study was 1,220 mg/L and the maximum total iron concentration leaving the system was 1.9 mg/L. On average, 11.4 tons/year (22,800 lbs/year) of iron entered the treatment system, while 31.9 lbs/year exited the system. This amounts to an average iron removal of 12.5 tons/year, with the majority of the iron being removed in the first oxidation cell.

In order for manganese to be oxidized and precipitated, nearly all of the iron must be removed first (Watzlaf et al. 2004). Although there was essentially a complete removal of iron (< 1 mg/L) from the water by the time it left the system (often by the time it left the second oxidation cell), only about half of the manganese, from 8.8 ± 4.7 to 4.4 ± 4.7 mg/L, was removed throughout the system. This was likely due to several factors, with lack of retention time in the system subsequent to iron removal apt to be the primary reason. The rate of abiotic oxidation of manganese is very slow at pH < 8 (Stumm and Morgan, 1996). The only instance in the system where mean pH was greater than 8 was at the outflow of Cell 5. This was also the cell where the manganese concentration decreased the most.

Alkalinity Generation. Alkalinity generation is necessary to sustain iron oxidation and neutralize acidity in passive treatment systems. In the first 1.5 years of operation, the VALD generated an average of 25.05 kg/d of alkalinity. However, Cell 1 used 24.7 kg/d of alkalinity in the neutralization of proton acidity. By including the two vertical flow cells in the system, enough alkalinity is produced to not only sustain iron removal in subsequent oxidation ponds, but also to produce a net-alkaline discharge from the system. The result of the water moving through cells 2 to 5, resulted in a net generation of 3.75 tons/year of alkalinity.

Conclusions

Although the Rock Island #7 passive treatment system was designed primarily for the removal of iron from the mine discharge, it has been very effective at removing other metals, as well. The system, on average, has exhibited iron removal and alkalinity generation rates that compare well to those found in the literature. However, these rates fluctuate widely due to the highly variable water quality and quantity entering the system. In order to understand the system more fully, more information must be gathered on the retention time of the water in the system and the unit processes themselves. This will aid greatly in resolving the issue of location-event sample matching. Also, a thorough evaluation of the biotic processes occurring in both the oxidation ponds and vertical flow cells is necessary to gain a better understanding of how the system treats this unique mine discharge. Gathering a wider array of data on this system will help in further determining the efficacy of treatment. Despite these gaps in data, it is evident that the treat-

Table 2. Mean data for RI#7 passive treatment system from January 2007 to June 2008

	pH	Alkalinity (mg/L as $CaCO_3$)	[Fe] (mg/L)	[Mn] (mg/L)	[Cd] (mg/L)	[Pb] (mg/L)	[Zn] (mg/L)	[Na] (mg/L)	[SO_4^{-2}] (mg/L)
VALD out	6.2	470	555	8.8	0.04	0.23	0.05	1346	5784
Cell 1 out	4.1	5.8	202	11.4	0.01	0.12	0.03	1378	5688
Cell 2 out	6.7	207	47	10.7	0.004	0.07	0.01	1310	5001
Cell 3 out	7.1	117	16	8.8	0.01	0.06	0.02	1277	4902
Cell 4 out	7.2	214	6.5	7.4	0.001	0.05	0.01	1177	4493
Cell 5 out	8.2	166	0.7	4.4	0.01	0.05	0.01	1106	4202

ment system is discharging water with much higher quality that the original mine discharge.

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Datashed: An Online Tool for Passive Treatment System Monitoring and Maintenance

Shaun Busler, Peter Drake, Bruce Golden, Andy McAllister, Cliff Denholm, Tim Danehy, Tom Grote, and Margaret Dunn

INTRODUCTION

For more than a decade, organizations have been installing passive systems to treat abandoned mine drainage throughout the Commonwealth of Pennsylvania. Through these activities, watersheds are being restored. According to an inventory of mine drainage treatment projects compiled by the U.S. Department of Interior, Office of Surface Mining (OSM), over 280 systems exist within Pennsylvania. Many of these restoration projects, however, must be maintained properly in order to have a lasting impact. To prevent streams from reverting to their polluted condition, these projects must continue to function.

Volunteers, non-profit organizations, and government agencies have spent numerous hours collecting valuable water quality data in order to determine the effectiveness of these treatment systems. Dependent upon the organization, these data have a variety of end uses. Some groups enter the data into a computer database for use in reports, newsletters, etc. Other groups do not have a database and only keep paper records. Many times, government agencies store their data in proprietary databases behind firewalls for security. As a result, the availability of these data to the general public and to researchers is limited.

Figure 1: An intern samples raw water entering a passive treatment system.

HISTORY

Stream Restoration Incorporated (SRI), a 501(c)(3) nonprofit, has assisted numerous watershed groups throughout Pennsylvania with assessment, restoration, and protection projects. These efforts have included all necessary reports, studies, designs and construction oversight for the installation of over 30 passive treatment systems throughout Pennsylvania, having a combined total of more than 200 components. With this experience, SRI understands the necessity of properly maintaining passive treatment systems and the need to make water quality data available to others.

In 2002, SRI began the development of the *Datashed* (www.datashed.org) Web system to aid in the operation, maintenance, and monitoring of these passive systems. Work began on *Datashed* under a small United States Geologic Survey (USGS) grant to SRI to assist interns from Grove City College in monitoring over a dozen passive treatment systems in the headwaters of the Slippery Rock Creek Watershed. The Slippery Rock Creek Watershed (Ohio River Basin) is located in western Pennsylvania, north of Pittsburgh, Pa. A small company, 241 Computer Services, offered to donate much of their time to create a simple interface for these interns to upload water quality data through the Internet and to provide downloadable information, such as schematics and inspection sheets, on the passive treatment systems. As funding was not readily available for *Datashed*, work was completed in small increments over time. Additional partners who have contributed to *Datashed* since its inception include: Western Pennsylvania Coalition for Abandoned Mine Reclamation (WPCAMR), Foundation for Pennsylvania Watersheds, BioMost, Inc., PA Department of Environmental Protection (PA DEP) – Bureau of

Figure 2:
Project searches can be based on multiple parameters and by name.

Abandoned Mine Reclamation (BAMR), U.S. Environmental Protection Agency, Greene County Watershed Alliance, Indiana County Conservation District, Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR), Indiana County Conservation District, Slippery Rock Watershed Coalition, and others. The pace of enhancements to *Datashed* has increased with contributions from these project partners.

FEATURES

As funding was limited, SRI decided to use applicable Free and Open Source Software (FOSS) where available to reduce costs while increasing the longevity, security, reliability and stability of the Web site. Using commercial software would have increased the cost by hundreds of thousands of dollars to meet the requirements. The FOSS alternatives have met these requirements and reduced initial and recurring maintenance costs of the project. The current configuration of *Datashed* uses PHP, MySQL, Mapserver, Apache, and Media-Wiki, as well as a host of open source functional libraries. *Datashed* can be viewed in most modern Web browsers without the use of any additional plug-ins other than Adobe Acrobat Reader. *Datashed* currently offers the following capabilities:

- Instant, 24/7 access to important documents such as Operation & Maintenance Plans, inspection sheets, directions to project sites, topographic maps, and aerial photos.
- Password-protected data submissions (i.e., field data).
- I-Map, an interactive GIS map depicting all known passive treatment systems at abandoned mine sites in Pennsylvania and other datasets.
- Multiparameter project searches.
- Printable monitoring reports and predefined graphs.
- Public access to all water sampling data.
- Wiki.

Downloads:

One of the primary functions of *Datashed* is to offer access to documents that will allow organizations, especially volunteer-based programs, to easily monitor their passive systems. *Datashed* provides downloadable operation and maintenance plans, site schematics, aerial photos, as-built drawings, etc. In addition, *Datashed* uses Bing Maps Web Services to allow users to view and print directions to the passive system based on their address.

Water Quality Data:

The data stored within *Datashed* can be viewed and downloaded from the Web by anyone in several different formats without the need of an account. The data are found by searching for the passive system or stream within a multiparameter query or by searching i-Map (Figures 2 and 4). Once the site is found, data can be viewed in dynamically generated reports or downloaded as a CSV (comma separated value) file, which is easily opened in Excel, Access or other tools to allow further calculations and data manipulations.

No data may be uploaded to *Datashed* without first having an account. Passwords are available to any organization that would like to upload their data and access is given only to their projects. Users must type in their password before being able to access the data submission interface. Passwords protect *Datashed* from potential vandalism and false data entries and provide a traceable path to the source of the data. A Web-based tool has been developed to import large datasets in an electronic format. This tool assists in matching the fields within the organizations dataset to fields within *Datashed*. This tool also checks the data to ensure it is within appropriate ranges (e.g., pH is between 0 and 14). Once an organization has imported the historic dataset, the organization could continue to use the import tool or they could use an interface where they simply type the data into an online form. For organizations that would like a comprehensive assessment of their passive treatment system, operation and maintenance forms can be created. Information, such as erosion, embankment stability, valve operability, etc., can be entered into an online form. In addition to water quality and operation and maintenance data, users may upload photos.

Once the data has been uploaded to *Datashed*, the data can be viewed or downloaded as stated previously. In addition, dynamically generated graphs are available (Figure 3). These graphs use the most up-to-date information stored within *Datashed* at the moment they are generated. As new data is uploaded to *Datashed*, these graphs are updated to reflect these changes.

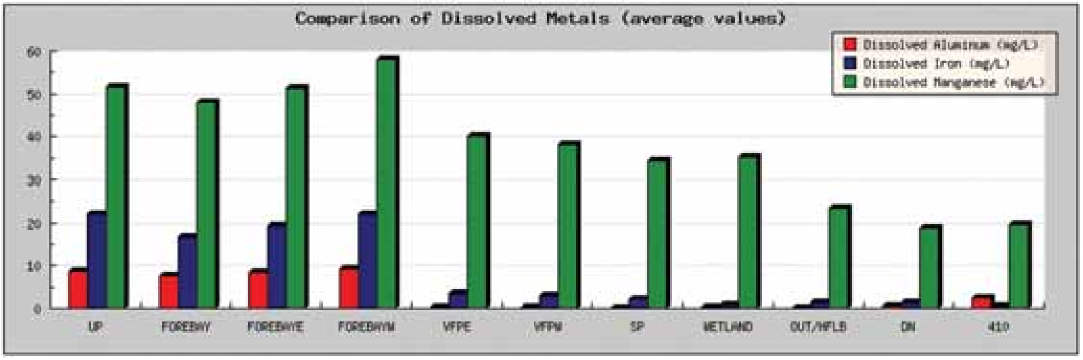

Figure 3:
Example of a dynamically generated graph.

i-Map – Geographic Information System (GIS):

An innovative GIS application called i-Map has been developed to spatially connect the data stored in *Datashed*. The spatial component of *Datashed* utilizes MapServer, a robust, free and open source GIS software originally developed by the University of Minnesota ForNet project in cooperation with NASA and the Minnesota Department of Natural Resources (DNR). A wide variety of government agencies, nonprofit organizations, businesses, and academia are actively involved in using and developing this software,including the U.S. Army Corp of Engineers, Minnesota DNR, U.S. Department of Agriculture Forest Service, and Canada Centre for Remote Sensing and Natural Resources Canada. A custom-designed JavaScript/HTML interface allows users to easily find sampling points and directs users to additional content on the site. Each passive system can be queried for average water quality data. Terrabytes of additional geographic data are made available using Web Mapping Services (WMS), such as NASA's Landsat 7 satellite and USGS topographic maps, and on-the-fly projections. Not only can i-Map serve as a WMS client, i-Map can provide spatial data to other Internet and desktop applications. In addition, customized GIS maps can be generated from parameters stored within the database, such as the topographic maps found in the download section of *Datashed*.

FACTS

Funding AMD Chemistry for Treatment Systems (FACTS) is a program of WPCAMR offering funding for chemical analyses to watershed organizations in Pennsylvania. In cooperation with WPCAMR, many new features have been incorporated to *Datashed* to create a powerful data management system and repository for data collected for the FACTS program. FACTS standardizes the process of establishing a sampling schedule and coordinates the analysis of water samples with the watershed organization and participating laboratories. Email "triggers" are sent to the appropriate organization to alert them of upcoming sampling events.

Wiki

A wiki is a collection of Web pages that is edited by users. *Datashed* uses wikis in several different ways. Administrators of *Datashed* are capable of adding and modifying content within the Help pages without having to learn HTML or other programming languages, which also prevents accidents with the code. In addition, any organization using *Datashed* can use the Community Wiki to generate content that may be useful to other organizations, such as instructions on how to use different types of field sampling equipment.

Snapshot

In order to assess the condition of passive treatment systems in the Commonwealth of Pennsylvania, a partnership effort was organized to conduct two water quality "snapshots" of all the publicly funded passive treatment systems located within the state. This snapshot consists of collecting water samples for laboratory analysis, as well as measuring selected field parameters. The samples have been collected for the raw untreated mine drainage, the final effluent of the passive system, and the influent and effluent of every alkalinity-generating component, such as anoxic limestone drains (ALDs), vertical flow ponds (VFPs), etc. The first snapshot took place in fall 2009, while the second snapshot took place in spring 2010, to represent both low flow and high flow conditions. Out of the 280 passive

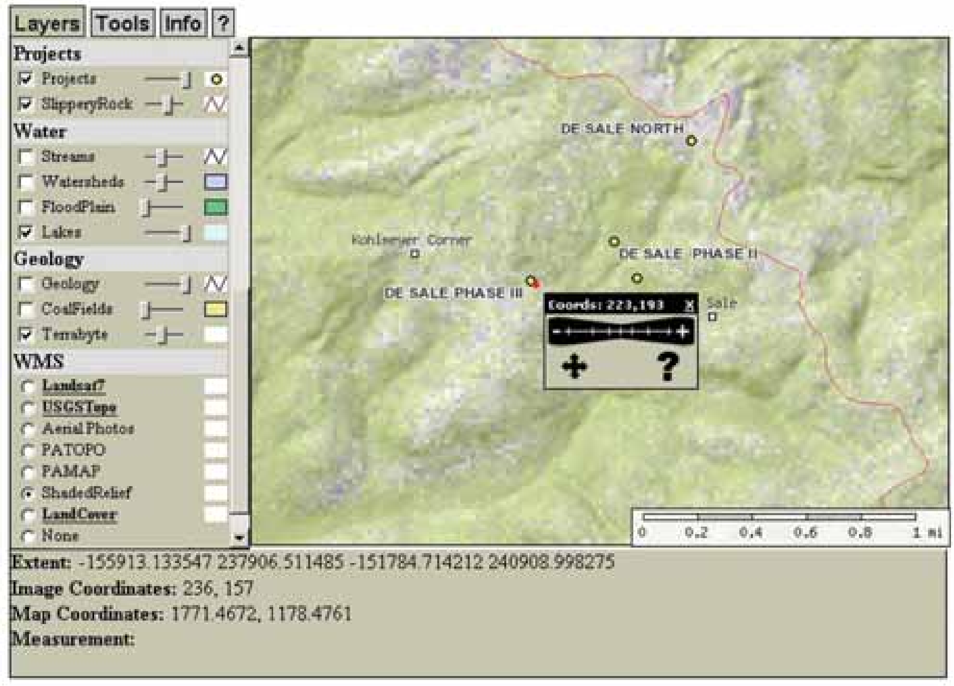

Figure 4: Screenshot of i-Map, the GIS component of Datashed.

treatment systems, approximately 50 systems were not sampled due to a variety of issues, such as the discharge was not flowing, the discharge was bypassing the treatment system, and the landowners have denied access. The monitoring has been completed by a team consisting of individuals from PA DEP BAMR, Stream Team, PA Senior Environmental Corps, Mill Creek Coalition, Babbs Creek Watershed Association, Broadtop Township, and Stream Restoration Incorporated. Data from the snapshot will be made publicly available via *Datashed*. These data complement the information provided within the Web site to provide an accurate account of the location, components, and current condition of these treatment systems. Once the data are posted, *Datashed* will become an invaluable tool for research.

CONCLUSION

It is the goal of SRI for local groups to be actively involved in the operation, maintenance, and monitoring of treatment systems. *Datashed* has begun to help us achieve this goal. Although a work in progress, many features are currently available to store and distribute data on passive systems. Additional features are being added to meet the needs of the project partners. Below is a list of a few of the more prominent feature requests, some of which are currently being implemented:

1. Tutorials on using *Datashed*.
2. Allow the user to define custom graphs and reports based on date, location, etc.
3. Modeling of passive treatment systems to determine the effectiveness of the system and when maintenance may be needed.
4. Management interface to add, modify, transfer, or delete data.
5. Develop online tools to calculate flows (multiple methods) and loading, unit conversions (ex. gallons to liters), etc.
6. Create a process to incorporate PA DEP data on a regular interval from their database management system.

Please send us any comments or suggestions to make the site even better! Anyone interested in opening an account on *Datashed* can email us at sri@streamrestorationinc.org.

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Andy McAllister is the current Regional Coordinator for the Western Pennsylvania Coalition of Abandoned Mine Reclamation, Greensburg, Pa. ■

Getting Crabby about High-Strength Mine Drainage?

The combination of chitin, protein, and calcium carbonate in crab shells may offer a passive treatment solution

By Rachel Brennan, Penn State University

Figure 1: From left to right: a Dungeness crab, one of the main sources of commercially available chitin; a handful of processed crab shell particles used in remediation projects; and the chemical structure of two chitin monomers (N-acetylglucosame, NAG) connected by a □-1,4-linkage.

The bad news: funding cuts expected for passive treatment systems. The new *AMD Set-Aside Program Implementation Guidelines* established by the Pennsylvania Department of Environmental Protection (PA DEP) in 2009 warn against the use of state grant money to implement passive systems for treating “high risk” AMD. They define high risk on a sliding scale based on metals concentration and flow rate, but it can be generally described as net acidic water with a combined metals (Fe + Al) concentration of greater than 50 mg/L. This restriction in funds for AMD remediation projects is understandable: High levels of metals loading often leads to premature clogging of the treatment substrate with metal hydroxide precipitates, essentially rendering the systems useless in a relatively short period of time. Our research, however, indicates that high-strength AMD can indeed be treated with proper design and substrate selection.

The good news: multifunctional substrates. Since 2005, we have been experimenting with using crab shells as an alternative substrate for AMD treatment (Figure 1). Crab shells are a sustainable and commercially-available waste product of the shellfish industry, composed of a complex matrix of chitin, protein, and calcium carbonate ($CaCO_3$). This unique combination has been shown to biologically reduce sulfate, chemically enhance alkalinity, and physically remove metals from mine impacted water (MIW) at the bench scale (Daubert and Brennan, 2007; Robinson-Lora and Brennan, 2009; Robinson-Lora and Brennan, 2010a; Newcombe and Brennan, 2010) and in field trials (Venot et al. 2008) without the addition of limestone. The secret? The crab shell contains a high percentage (~40 percent by weight) of biogenic calcite with a high surface area. The micro-porous structure of crab shells provides a surface area that exceeds that of powdered limestone, thereby enabling high neutralization capacity and the complete removal of metals as hydr(oxides) and carbonates under continuous-flow conditions (Robinson-Lora, 2009). The release of phosphates and organic compounds also work to increase the alkalinity of water in crab-shell treated systems. Of special significance is the ability of crab shells to induce the removal of manganese, a particularly recalcitrant metal in AMD, even under field conditions at circum-neutral pH (Venot et al. 2008). It has also been shown that the chitin, and to a lesser extent the protein, in crab shells can remove some of the metals in AMD through biosorption (Robinson-Lora and Brennan, 2010b).

Table 1 (below): Water quality characteristics of the Klondike-1 discharge. Figure 2 (right): Acid mine drainage seeps from abandoned coal mine tailings at the Klondike-1 site.

Parameter	Value
Hot acidity (mg/L as $CaCO_3$)	285
Alkalinity (mg/L as $CaCO_3$)	0
Design flow, maximum (gpm)	42
Typical flow, average (gpm)	15
Total Iron (mg/L)	93.2
Aluminum (mg/L)	4.5
Manganese (mg/L)	24.9
pH	3.9
Sulfate (mg/L)	692

Proof-of-concept research. In our initial work, we used crab shell as a sole substrate for enhancing AMD treatment. In batch tests with moderately strong AMD from a former bituminous coal mining area, crab shell increased the pH from 3.21 to 6.79, raised the alkalinity from 0 to 235 mg/L as $CaCO_3$, reduced dissolved Fe and Al concentrations by over 99 percent, and reduced Mn by 81 percent in just nine days (Daubert and Brennan, 2007). Subsequent testing has yielded even greater contaminant reductions. In columns with a hydraulic retention time of 11.2 h, 25 g of crab-shell chitin was able to completely remove Fe, Mn, and Al for 174, 234, and >268 pore volumes, respectively, while continuously supplying alkalinity at a rate of 50 mg $CaCO_3$/day (Robinson-Lora and Brennan, 2009).

So, how much does it cost? While the multifaceted capabilities of crab shell make it attractive for use in passive remediation systems, economic considerations are also important. Unrefined crab shell is a relatively inexpensive microbial substrate, retailing at $1.32/kg ($0.60/lb), but it is expensive in comparison to spent mushroom compost (SMC), which costs only $0.055/kg ($0.025/lb). We have demonstrated, however, that SMC is not as effective as crab shell for the removal of many metals, especially manganese (Robinson-Lora and Brennan, 2010a), which minimizes the importance of the initial capital cost savings it offers. A true economic benefit may be realized by adding fractional amounts of crab shell to SMC in order to improve the efficiency of the substrate with little, if any, added cost over traditional systems. By increasing the efficiency of the substrate, it should be possible to reduce the overall size and cost of passive AMD treatment systems.

Substrate mixtures may be best To evaluate different crab-shell/SMC mixtures for their ability to neutralize acidity, reduce sulfate, and remove metals in field-collected AMD, batch and continuous-flow column tests were conducted. Alkalinity generation and the removal of manganese and sulfate were strongly correlated to the fraction of crab shell in the substrate: The treatment capacity increased from 36.7 L/kg for the traditional 90 percent SMC/10 percent limestone substrate up to 428 L/kg for 100 percent crab shell (Newcombe and Brennan, 2010). The costs associated with adding crab shell to SMC were found to be minimal relative to the resulting improvement in water quality. Based on these data, it appears that a small fraction of crab shell (5 to 15 percent) does not provide a significant benefit over traditional compost and limestone substrates, but that larger fractions (50 to 100 percent) are more efficient than traditional SMC substrates, especially for the removal of metals. By adding fractional amounts of crab shell to SMC, treatment capacity and efficiency are improved, thus allowing for a smaller treatment system to remediate equivalent volumes of AMD.

Throwing down the gauntlet: finding a "high risk" discharge for a field demonstration. Over the past several years, we have been looking for a high risk discharge on which to test our crab shell mixtures at the field scale. After carefully considering the need for treatment, site accessibility, and level of cooperation of the local watershed groups, the site for our field demonstration was selected: the abandoned Klondike Mine in Cambria County, PA (Table 1, Figure 2). The U.S. EPA and other organizations have determined that restoration of this site is imperative to the health

Figure 3. Dr. Brennan and the continuous-flow column system that her research group uses to test different substrate combinations for the treatment of high-strength acid mine drainage. PHOTO CREDIT: SARA BRENNEN.

of downstream receiving waters in the Clearfield Creek Watershed and, as a result, have awarded in excess of $600,000 in grants toward its remediation. These funds have supported the design and construction of two nearly-identical treatment systems to treat the two discharges: Klondike-1 (KL-1) to treat discharge 32-R2 (93 mg/L Fe, 15 gal/min) and Klondike-2 (KL-2) to treat discharge 32-R2A (5 mg/L Fe, 166 gal/min). Although a series of large oxidation and vertical flow ponds are successfully cleaning the less-contaminated KL-2 discharge, the spatially restricted, smaller treatment system for KL-1 is removing only about 75 percent of the Fe and acidity. It is believed that the deficiency of the KL-1 treatment system is due in part to high concentrations of ferric iron (Fe^{3+}) clogging the SMC substrate in the vertical flow pond. In short, the KL-1 system was under-designed for the substrate selected and level of contamination present.

Restoration of the KL-1 site, and treatment of other similar discharges, presents a practical and intellectual challenge: How can we achieve a higher degree of treatment within a pre-existing small footprint? We believe the answer is through proper design and substrate selection. In side-by-side field tests with AMD from a former hard-rock mine in Colorado, crab shell has not clogged while other substrates have (Venot et al. 2008). We theorize that the non-clogging nature of crab shell is due to its ability to maintain low redox conditions, which keeps iron in a reduced, soluble state (ferrous iron, Fe^{2+}), allowing it to pass through the substrate without precipitating. Nevertheless, the application of crab shell substrates to high-strength water had not yet been tested, so during the past year, we evaluated different substrate combinations and retention times for treating the KL-1 discharge. Using a series of continuous-flow column tests (Figure 3), we observed that substrates containing 70 percent chitin by mass mixed with SMC offer the best balance of treatment effectiveness and cost, but that 100 percent chitin offers the greatest longevity (Grembi et al. 2010). With support from the National Science Foundation, the Foundation for Pennsylvania Watersheds, and the Clearfield Creek Watershed Association, a field demonstration of these substrates compared to the original SMC/limestone mixture used at the site is underway.

Pilot test design. The pilot field test at the KL-1 site consists of four replicate reactors (1,000-gallon plastic septic tanks, Figure 4) containing the following substrate mixtures: the original 90 percent SMC/10 percent limestone mixture currently used at the KL-1 site (negative control); 70 percent crab shell mixed with 30 percent SMC (Figure 5); and 100 percent crab shell (positive control). All of these substrates were placed over a limestone underdrain. An additional 70 percent crab shell/30 percent SMC reactor was constructed with a sandstone underdrain to see if the crab shell could provide enough alkalinity that the limestone underdrain could be omitted and costs reduced in future applications. A portion of the flow from the current primary oxidation/settling pond at KL-1 was diverted through a buried PVC-pipe network (Figure 6) and split into these four reactors to give a hydraulic residence time of ~16 hours. Aeration of the effluent water via cascades and aeration ponds (Figure 7) should allow Fe^{2+} to oxidize and precipitate out as Fe^{3+}, and simultaneously strip out residual ammonia that may be released from the crab shell at early times (Korte et al. 2008). Water sampling and analysis of the influent and effluent from the reactors will be conducted weekly for the first month, biweekly for the next month, and then monthly for the remainder of the year to determine the effects of the substrates on water quality. In addition, DNA and RNA samples (Figure 8) will be taken from the different reactors at these sampling times to examine the relationship between microbial community development and water quality, so that future optimization of passive systems for the treatment of high risk AMD may be enabled. This is the first pilot test of this technology for treating high-strength AMD at the field scale and is a necessary step toward validating the technology for full-scale application.

Future plans. Water quality analyses taken over the next year will help determine if a full-scale retrofit of the KL-1 site is warranted. This project is being supported in part by a multiyear grant from the National Science Foundation (CAREER Award CBET-0644983), which continues through 2012. If this pilot test is successful, then full-scale restoration of the KL-1 site will be initiated with partial support of this NSF grant. Dr. Brennan's design classes (Figure 9), research team, and the Clearfield Creek Watershed Association will monitor the system for as long as funding permits, and will seek new funds to continue evaluating the effectiveness of the system into the future. Fundamentally, the results of this project should provide insights into innovative passive treatment methods that can be used for remediating high risk AMD within small treatment footprints.

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Figure 4. Penn State Environmental Engineering graduate student, Jessica Grembi, guides one of the pilot reactors into position at the Klondike-1 site.

Figure 5. President of the Clearfield Creek Watershed Association, Earl Smithmeyer, and Penn State undergraduate Honors student, Sara Goots, add a mixture of crab shells and spent mushroom compost into one of the pilot reactors.

Figure 6. Influent to each of the reactors is provided through individual pipelines from the current primary oxidation/settling pond on site. After installation, the pipes were buried to prevent freezing in winter.

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Figure 7. Effluent from each reactor will cascade into a series of two aeration/settling ponds, and then be piped to the existing aerobic wetland on site.

Figure 8. Permeable substrate bags inserted into the pilot reactors for later microbial community analysis, arranged left to right: spent mushroom compost and limestone chips, crab shell and spent mushroom compost, and crab shell only.

Figure 9. Penn State Civil Engineering undergraduates Brad Sick, Gary Warren, and MacKenzie Muryn take water quality measurements at the Klondike site for their CE497B class. The course, Field Methods for Remediation Design, is taught by Dr. Brennan with the support of a Faculty Early Career Development (CAREER) award from the National Science Foundation.

The Wyoming Reclamation and Restoration Center

By Peter Stahl and Stephen Williams, University of Wyoming

Members of the ROaR Club (Restoration, Outreach and Reclamation) working on a reclamation project near Laramie. Left to right: Professor George Vance, Kyle Lily, Matt Allshouse and Lisa Cox.

The University of Wyoming (UW) has a rich history of applied research and outreach activities in rangeland ecology and management. Since the late 1950s, UW faculty members have worked with local communities, state government, and individual landowners to ensure that Wyoming's resources are available for future generations. Today, College of Agriculture faculty members are nationally and internationally known for their work with disturbed land and water resources. In fact, as an established center of excellence in reclamation and restoration, the UW College of Agriculture and its research consistently guide federal regulators.

The Wyoming Reclamation and Restoration Center (WRRC) is an interdisciplinary program housed within the College of Agriculture. Its mission is to develop, collect, and disseminate impartial scientifically-based information related to the reclamation, rehabilitation, and restoration of disturbed lands in Wyoming and the western United States. In 2009, Gov. Dave Freudenthal and the Wyoming State Legislature designated funds from the Abandoned Mine Land (AML) Program of the Surface Mine Reclamation and Control Act of 1977 to the University of Wyoming College of Agriculture for reclamation science purposes. The center trains students in land reclamation and restoration ecology, offering an undergraduate minor in Land Reclamation, as well as certification for graduate students. Faculty affiliated with the Wyoming Reclamation and Restoration Center, research best practices in reclamation of disturbed lands, and provides extension and outreach for practitioners of land reclamation in the energy industry, state and federal agencies, and other interested concerns.

Based in the Department of Renewable Resources, WRRC promotes interaction among numerous academic faculties and units at UW. Faculty affiliated with WRRC include economists, hydrologists, soil scientists, plant ecologists, rangeland managers, wildlife biologists, and weed scientists. The center works closely with the School of Energy Resources, the Wyoming Geographical Information Science Center (WyGISC), the Haub School and Ruckleshaus Institute of Environment and Natural Resources, the Wyoming Conservation Corps, the Wyoming Natural Diversity Database, and the cross-college program in Ecology. Off-campus, the WRRC has working relationships with energy companies in the gas, coal, wind, and mining industries, federal government units (e.g., the Bureau of Land Management, U.S. Forest Service, Office of Surface Mining), the Wyoming Department of Environmental Quality, the Wyoming Oil and Gas Conservation Commission, and the state forestry office. Projects conducted with these outside entities include funded research projects, employee training and outreach programs, and internships for students.

A great example of activities sponsored by the WRRC is the Wyoming Reclamation and Restoration Symposium held in Laramie last April entitled "Recent Successes and Current Challenges." This meeting was organized by the WRRC to bring together land reclamation professionals from all of the natural resource industries that disturb and reclaim lands in the state. Over 130 reclamationists attended the meeting and had a chance to discuss the state of the profession and share ideas on how to improve reclamation technology. The symposium included speakers presenting information on reclamation associated with oil and gas drilling, coal mining, bentonite mining, trona mining, wind energy, pipeline installation and power transmission. Experts from state and federal regulatory agencies also made presentations regarding their roles in land reclamation. ■

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Downstream Point	pH	Acid (mg/L)	Alk. (mg/L)	T. Fe (mg/L)	T. Mn (mg/L)	T. Al (mg/L)	SO_4 (mg/L)
21 (Pre Constr. Avg.)	3.0	498	0	51	21	27	1337
21 (2009 Average)	6.5	12	22	2	13	3	829

WATER QUALITY (AVERAGE)								
Point	Flow (gpm)	pH	Acid (mg/L)	Alk. (mg/L)	D. Fe (mg/L)	D. Mn (mg/L)	D. Al (mg/L)	SO_4 (mg/L)
Raw	n.m.	2.8	1390	0	243	18	113	2622
Phase 1	n.m.	5.0	62	10	4	10	9	1506
Final	44	7.3	-181	307	<1	8	<1	1170

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