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# reclamation matters

Spring 2021

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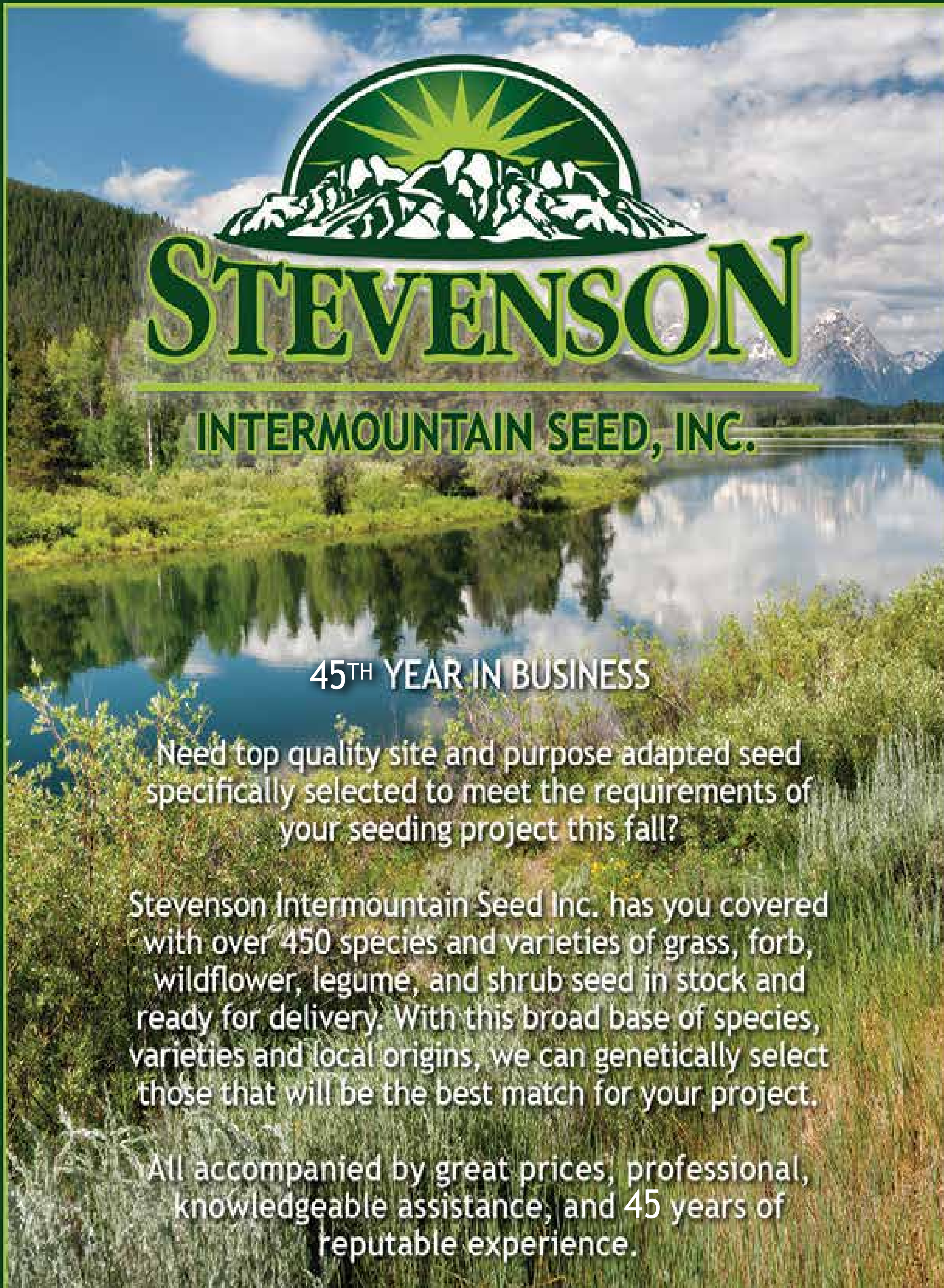
Stream quality in a mixed-use watershed

Bee visitation preferences on mined lands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PRESIDENT / PUBLISHER
**David Langstaff**

MANAGING EDITOR
**Lyndon McLean**
lyndon@delcommunications.com

SALES MANAGER
**Dayna Oulion**
dayna@delcommunications.com

SALES REPRESENTATIVES
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PRODUCTION SERVICES
S.G. Bennett Marketing Services

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**Kathleen Cable**





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Email: david@delcommunications.com

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# Let's count our winnings

BY DUSTIN WASLEY, P.E., PRESIDENT OF ASRS

Hello everyone! Wow, 2020 was a year like no other; our thoughts go out to our family and friends that have been and continue to be impacted.

For years, the heart of our society has been focused on our Annual Meeting, connecting with old friends and colleagues, meeting new ones, sharing a beverage and occasional toast, and presenting our technical accomplishments. I have missed that, as I am sure you have. In 2021, we are launching new ways to keep us connected. In February, we began hosting a series of bi-monthly webinars, giving members a platform to share technical insights and to recruit new members. These webinars will continue until June, culminating at our Virtual Annual Meeting. The National Executive Committee (NEC) is actively planning to resume our Annual Meetings in 2022 in Duluth, Minnesota, and the following year in Boise, Idaho.

As we look to the future, we should celebrate our society's accomplishments in 2020 and the start of 2021. We:

- Expanded our working subcommittees on the NEC to also include: Membership/Marketing, JASMR, ECPs/Students, and Technical Divisions (TDs). These subcommittees enable us to do more focused work outside of the NEC meetings.
- Began revamping membership, including new categories (e.g. retirees), new membership fee structures, different corporate levels, etc. We did not adjust membership dues in 2021; we are planning to roll out the new membership structure and fees for 2022 (note that we have not increased our membership fees in 30 years – you read correctly).
- Established a new Journal name. The NEC considered multiple options, and, ultimately, decided on Reclamation Sciences, which aligns with our new society name and brand, and with our sister publication Reclamation Matters. A huge thanks to Dick and Lela Barnhisel for their years and years of tireless service to the society and for making our journal a success. We are in the process of building out a new editorial board and are searching for a new editor-in-chief that can lead Reclamation Sciences into the future. If you are interested in participating, please reach out.
- Updated our Technical Divisions. Our TDs have not changed in many years, and the TD subcommittee has been discussing better ways to align these with our society's new direction. We are planning to roll out the new TDs at our Virtual Annual Meeting, stay tuned!
- Lived our Strategic Plan. Each of the items above are a direct result and outcome of the Strategic Plan we set forth in 2019, thank you all for your help and participation!

I've been reflecting on 2020 and how we've already hit the ground running in 2021. During a recent chat with my 14-year-old son, he said, "Dad, 2020 wasn't all bad, we got to spend more time together, we played more games, we watched more movies, we spent more time at the lake…" This resonated with me. So, let's count our winnings in 2020 and continue building on that in 2021.

It continues to be an honor to serve as your president, and I look forward to seeing everyone in Duluth in 2022. First round is on me! If you have any questions, thoughts, comments, concerns, or anything at all, please reach out to me at dwasley@geoengineers.com.

Be well!

# Challenging questions

BY JEFF SKOUSEN, WEST VIRGINIA UNIVERSITY

Several years ago, while teaching my Reclamation class, I had a student named Matt who seemed to know everything and wanted me and the class to know it. He was quite confrontational, spoke out in class, and defied me during my lectures. For instance, I was talking about land disturbances and I said that about five percent of the land area in Appalachia had been disturbed by surface coal mining. He yelled out, "Well, I'm going to challenge you on that!"

The other students, who were lounging on their seats and looking at their phones, suddenly awakened, looked at him and then at me. They wondered how I would respond. Surprised, I asked, "Why? How much land do you think has been disturbed?"

"Oh, much less than that. I'd say that less than one percent has been surface mined."

"I don't think I'm mistaken," I countered, "but I will check the research literature and have a definite answer by next class." And I went on with the lecture.

The next class period, I showed the class a map from one study.[1,2,3] I then said, "From this map, you can see that about six percent of the land area had been surface mined in Appalachia. When we look at the entire United States, the number drops to about 0.25% of the land area being surface mined."

"Oh," he said, "I meant in the United States."

"Well, OK," I said, nodding my head, "now we know." And I let it go.

The next challenge was a discussion about the reasons for declining coal production in the US. I mentioned that electricity prices from gas-fired power plants were lower on average than the electricity prices from coal-fired power plants. He nearly exploded off his seat and exclaimed, "That's not true! Electricity prices from coal plants have always been lower than gas plants."

"I'm fairly confident that what I said was true," I answered. "I don't have the data right now, but I will by next class."

And I did. Across the United States in 2019, gas-fired power plants provided electricity at an average cost of about \$0.06/kWh, while electricity from coal-fired plants averaged \$0.08/kWh.[4]

So, on it went with every class having a challenging question from Matt. The other students were dismayed, and I could hear a distinct "sigh" or "groan" when Matt spoke up. One of the students who sat by Matt and who I knew was in Matt's major came to my office to ask me a question about an assignment. His visit gave me an opportunity to ask about Matt's behavior.

"What is the deal with your classmate's outbursts in class," I asked.

"He is the same way to professors in all of our classes. We are all so sick of it. He really is a nice guy and pretty smart, but he just can't control his mouth."

The next class, Matt's challenge was on methane gas in underground mines. I said that methane was toxic.

"No, it isn't," he called out loudly. So, I checked again, and he was right on this one.

"Methane gas is relatively non-toxic, and its health effects are associated with its being a simple asphyxiant that displaces oxygen in the lungs.[5] But, of course, it is extremely flammable," I explained. "Matt was correct in saying that it is non-toxic."

After two weeks of these challenges (which caused me to be much more careful in my lectures), I finally talked to Matt after class. He was very pleasant and told me how much he liked my class.

"I know I'm annoying with my questions. Most professors do not respond the same way you do. They tell me I'm only a student, they know their topic, and that I must quit challenging them and disrupting class. No professor comes back to class to answer the questions with data and facts as you do."

The disturbances in class were rare after that and instead he came to me after class if he had a question. Our conversations were friendly and usually quite interesting. We became good friends, and after the semester, he visited me several times in my office even though his major was housed in a building across campus.

Several lessons could be learned from this story, but I'd like to focus on this student's initial attitude of distrust. Most people believe those who are well-known or considered experts in a particular discipline, and we pay attention to those who are schooled and experienced. Professors are generally at the top of the trustworthy list, and students can assume

Others believe information and opinions from untrustworthy sources, who may provide unsubstantiated material to confuse an issue or to promote a certain agenda.

that a professor has years of study and experience and, therefore, can speak authoritatively on a subject.

Others believe information and opinions from untrustworthy sources, who may provide unsubstantiated material to confuse an issue or to promote a certain agenda.

Some people, like Matt, don't trust information they receive from anyone. They defy authority figures (referred to as oppositional defiant disorder) or they contest information just to be contentious (called contrarians). We all should cultivate a healthy attitude of skepticism, but it should not make us distrustful of everybody and reject everything we're told. There is a balance along the scale of trust and distrust.

My response to Matt was probably the best I could do, not knowing which attitude he had. Rather than feeling disrespected or attacked, I think my method to clarify and to provide facts concerning his challenging questions was an appropriate response. And with time, he eventually realized that I was knowledgeable and experienced, and that he could trust the information I gave in class.

During this time of contrary individuals and opposing opinions, you and I should consider where we are positioned on the "trust" spectrum, how we accept statements and opinions of others, how we judge truth from falsehoods, and whether we believe reliable or untrustworthy sources.

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https://nevadanano.com/methane-gas-poisoning-and-exposure/

*Special thanks are given to Dr. James Thompson for helpful comments and editing.*

# Early Career Professionals

## *Meet two ECPs: Grace Mobley and Kari Lagan*

### GRACE MOBLEY

Grace Mobley graduated with a master's degree in environmental science in 2017 from Lincoln University of Missouri. Since then, she has been employed by the Missouri Department of Natural Resources, working in the Missouri Geological Survey's Land Reclamation Program. Her background in microbiology and biochemistry provided a solid starting point for understanding the environmental impacts of mining, and the importance of the state regulations that are in place to protect Missouri's natural resources. Grace is one of four environmental specialists in the Land Reclamation Program responsible for overseeing the reclamation of every site from small open pit sand and gravel sites to 300+ acre limestone quarries throughout the state. The greatest part about the position is the wide variety of day-to-day activities. With approximately 800 clay pits, granite mines, sandstone sites, in-stream sand and gravel mining operations, and lead tailings impoundments, there is a lot to see. Grace and her coworkers are responsible for ensuring the mined land is appropriately reclaimed to the best possible end land use. This involves permitting, inspections, public meetings to mediate public concern regarding new and transferred operations, bond-release presentations to the Missouri Mining Commission, and occasional court hearings when a concern between the public and a mining company is not able to be resolved with a meeting. Grace considers herself to be an environmentally conscious business advocate, supporting the industry by working with mine operators and helping to preserve affected lands for years to come. Read more about her work and that of her colleagues online at https://dnr.mo.gov/geology/lrp/mineralsandmining.htm.

### KARI LAGAN

Kari is a senior at Saint Francis University, majoring in environmental engineering with a concentration in ecological engineering and a dual major in chemistry. Kari has conducted undergraduate research in the areas of microbial fuel cells and drainable limestone beds. At the ASRS conference in 2019, she presented a poster on her research on optimizing drainable limestone beds for acid mine drainage remediation. The ASRS conference was the first one Kari attended, and she values her time spent at the conference, where she was able to expand her understanding of reclamation sciences, network with professionals in the field, and foster an interest in graduate-level education.

# *Case Study* Pennsylvania State: Route 219

Pennsylvania Department of Transportation (PennDOT) constructed a new 10 mile section of highway as part of State Route 219. A portion of the construction included the expansion of an existing wetland area. The plan called for willows to be planted in the wetland area and the entire area seeded with a native seed mix. When construction began, the wetland area was excavated and the topsoil was removed for construction, but was not replaced on the site.

Because a plan had not been in place for preserving the topsoil , the soil on the site was lacking the nutrients needed for successful plant growth and sustainability. Willows were dotted around the site, but struggled due to the poor quality soil. PennDOT seeded the area three times with inadequate results. The Engineering Architecture Design Services (EADS) Group asked Triton Environmental of Pittsburgh, PA for assistance.

*1*

A soil test showed the site was significantly lacking in nutrients. To further complicate matters, the organic composition of the soil was less than 1% and the pH was between 4 and 5. The obvious solution was to amend the topsoil with the nutrients and organic matter required to make it sustainable for re-establishing vegetation.

Upon receiving the soil test results, the team at Triton Environmental recommended Biotic Earth, a Biotic Soil Amendment or BSA. In addition, they used pH adjusters and fertilizer. Biotic Earth was utilized to provide the necessary organic matter to the soil. All the amendments, except for the fertilizer, were applied topically through a hydroseeder with no tilling required. A hose was run from the hydroseeder over 100 feet away, taking care of the accessibility issues. This method allowed complete coverage of the area without having the need for equipment that could damage the existing plantings. The fertilizer was applied by hand separately. The initial application, which was applied in late October, was germinating within two weeks. Even more impressively, the area was fully vegetated by early spring. The mix of amendments provided the necessary nutrients to establish and sustain vegetation, with an efficient application process. This is a process that can be used on even the most challenging sites. The next summer the vegetation far exceeded areas not treated with Biotic Earth. The site continues to thrive today.

*2*

*3*

ECBVERDYOL

***Image 1: Before***
***Image 2: 2 weeks later***
***Image 3: One year later***

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# Utilizing unmanned aerial vehicles to predict surface runoff

BY MICHAEL P. STRAGER, PAUL KINDER, AND SHAWN GRUSHECKY, SCHOOL OF NATURAL RESOURCES, DAVIS COLLEGE OF AGRICULTURE, NATURAL RESOURCES AND DESIGN, WEST VIRGINIA UNIVERSITY

## *Introduction*

Drones are everywhere these days. Drone technology ranges from high-tech toys for hobbyists to elaborate coordinated displays at sporting events. The unmanned aerial vehicles provide birds-eye views for action scenes in movies, real estate listings, and much more.

Drones or unmanned aerial vehicles (UAVs) have been used in military applications including the Gulf War in 1991; however, the technology has only been allowed for civilian use since 2006. The DJI Phantom (Figure 1), developed in 2013, was instrumental in expanding the commercial use of UAVs for civilians due to the ability to take pictures and videos with a GoPro camera. Today, many different styles of UAVS are available to fit different interests and needs with various camera options and longer flight times.

As UAV technology has improved greatly in the past several years, so has the proliferation of research performed with UAVs. This is due to the advantages of the technology such as the ability to collect information quickly and at a high spatial resolution to complement intensive field sampling. UAVs have additional advantages over traditional methods including the ability to fly below cloud cover, target features of interest, and ease of monitoring remote or inaccessible areas. Researchers can program flight paths (Figure 2) using GPS to capture overlapping photos and use photogrammetric and remote sensing principles to generate orthophotos. Orthophotos are aerial photos that are corrected for elevation and referenced to real world locations.

Along with creating orthophotos, the overlapping photos captured by drones can be used to generate surface measurements using a technique called Structure from Motion (SfM). SfM works by creating a point cloud of elevation values that can be used to create a digital surface model. The process is similar to the use of stereo-pairs of overlapping images that identify the same feature on multiple images (Figure 3). The resulting point cloud contains x, y, and z values which can be used to construct a three-dimensional surface. The three-dimensional surface can be used in applications to better understand the terrain at a high resolution (usually less than a meter).

In our experience, the orthophotos and structure from motion surface model show great utility for mapping and analysis. In this study, we demonstrate an application of a UAV to map and

*Figure 1. DJI Phantom Quadcopter UAV piloted by co-author Paul Kinder.*

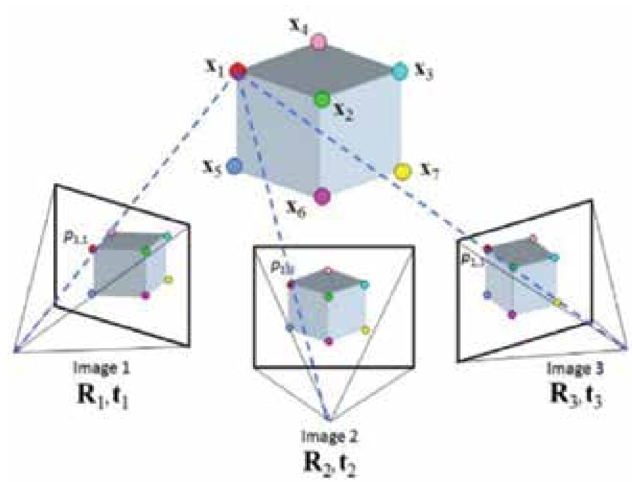



*Figure 3. Structure from motion conceptual capture of locations (Xiao et al. 2019).*

*Figure 2. An example of user-defined flight paths with the UAV altitude following the terrain.*


analyze the runoff from an unconventional gas well constructed in West Virginia.

We wanted to capture spatial information from the well pad in West Virginia to help identify potential water runoff issues at the site. Locations of permitted unconventional oil & gas well drilling sites are available on a daily basis from the West Virginia Geologic and Economic Survey (WVGES, 2020). This information was used to identify permitted sites and contact operators for permission to analyze the well pad and drilling site.

Our decision to use UAVs for the project followed the work by Morton (2018), who listed six main considerations for the use of UAVs in a project:

1. Is there a need for complex data or detailed measurements?
2. Is the study area located in a challenging area?
3. Is there a requirement for very high-resolution imagery?
4. Are frequent acquisition cycles desired?
5. Are there any safety concerns for manned operations?
6. What are the time and cost saving opportunities on the project?

As for project size, Morton (2018) found that the cost-effective area to use most UAVs is up to 1,000 acres in size. For larger areas, the costs become more effectively spent on manned aircraft.

Following the framework by Tokarczyk et al. (2015), we designed our study to use imagery gathered using UAVs to delineate the impervious and developed areas surrounding unconventional well pads and subsequently predict runoff flow paths. The well pad is a cleared area that is enforced with heavy rock to support large drilling rigs on the site. The size of the drilling pad itself is of interest because the impervious surface can reduce the infiltration of water into the soil and lead to higher runoff rates. The amount of impervious surface can directly impact many environmental processes, including surface runoff volume, peak discharge, soil moisture compensation, and groundwater recharge (Tokarczyk et al., 2015). Moreover, increased peak runoff volumes together with an inefficient drainage network may lead to an increased hydraulic stress and increased risk of loading streams with sediment and associated constituents (e.g. nutrients, contaminants and micro-pollutants) (Tokarcyyzk et al., 2015).

## Methods

The unconventional oil & gas (UOG) study site was located approximately 40 km west of Morgantown in Monongalia County, West Virginia (39.6216, -80.2786). The site is operated by Northeast Natural Energy, an independent oil & gas exploration and production company based in Charleston, WV (Figure 4). The proposed well for this site was located at 430 meters above sea level with the Marcellus Shale as the target formation at an approximate depth of 2.5 kilometers. The lateral bore for the UOG well was planned for 2.2 kilometers. The site plan in the well permit documentation included a total of 117 hectares of disturbed area, which includes all roads, soil stockpile areas, pits, and other infrastructure.

*Figure 4. Location and aspect of planned well pad site before construction.*

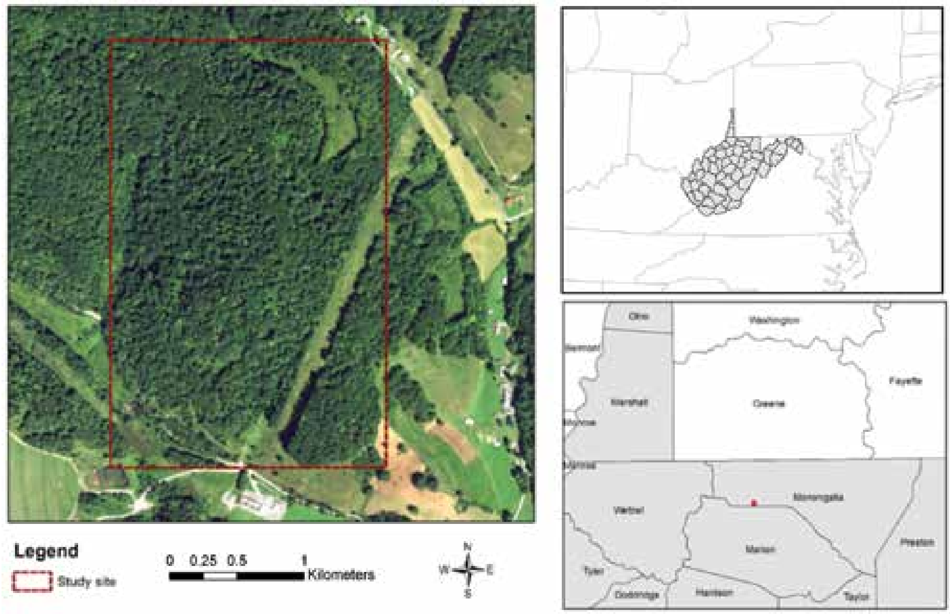



*Figure 4. Location and aspect of planned well pad site before construction.*

## UAV imagery acquisition and processing

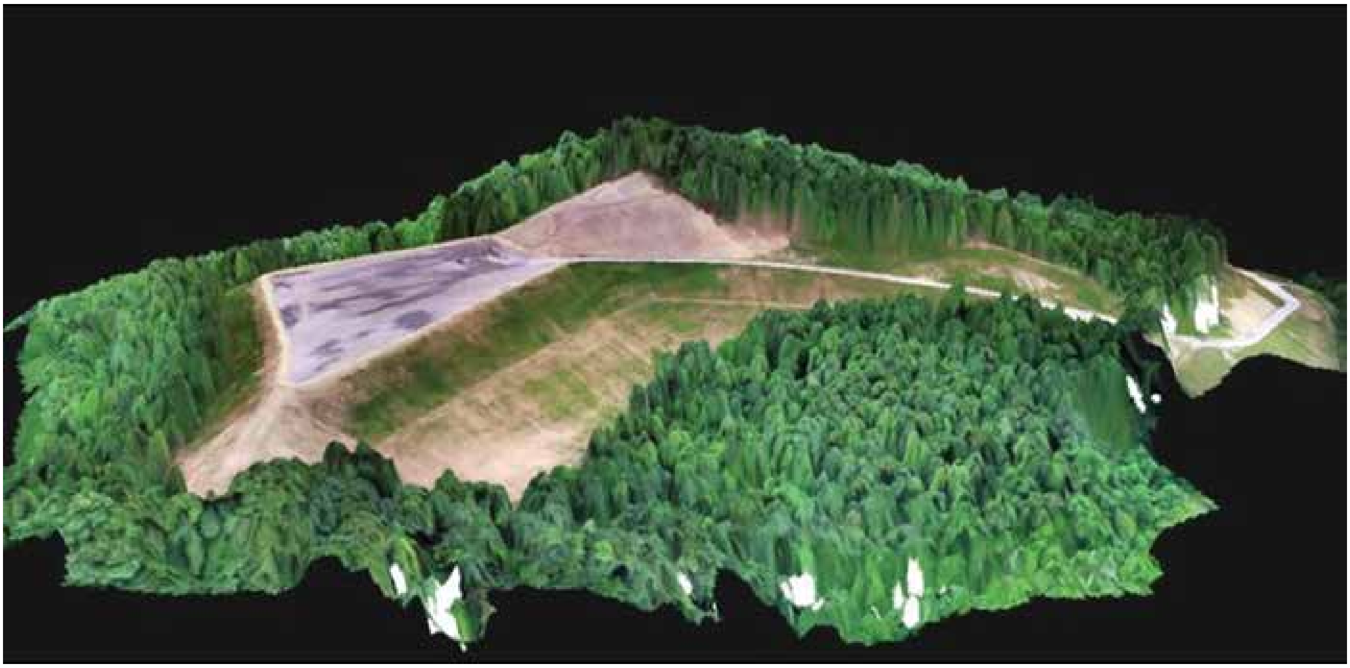
Once the location had been permitted and cleared for equipment setup, we visited the site and collected the UAV imagery using a DJI Phantom 4 Pro with an RGB (red, blue, green) camera to collect the images with 80 percent overlap, at approximately 80 meters above ground. A total of eight targets were placed around the well pad before the flight, and target coordinates were collected using a Spectra SP80 GNSS Global Positioning System receiver (Figure 5). The targets are critical for georeferencing the images and creating the orthophotos. We spaced eight targets at the perimeter and center areas of the study area. After the data collection, we used Agisoft Photoscan (Agisoft LLC, 2018) software to align the photos, create a density point cloud, orthophoto, and a digital surface model. The target coordinates were used in Agisoft as Ground Control Points, allowing the correct external registration of the derived products.

A component of the UAV image processing included a technique for estimating three-dimensional structures from two-dimensional image sequences noted earlier as structure from motion (SfM) (Granshaw, 2016). Based on Smith et al. (2015), the SfM processing workflow consists of feature detection, matching points in different images, point filtering, scene geometry reconstruction, densification, and interpolation to create a surface from the point cloud.

The produced surface elevation model is timely to capture the disturbance at the site and has a high spatial resolution (sub meter) to benefit water resource management. This surface elevation model is also necessary in the orthorectification process. The process of creating an orthomosaic is important because it is possible to measure angles, distances, positions, and area on the images since the objects are represented orthogonally (meaning, with adjusted angles) (Wolf et al., 2014).

*Figure 5. Global positioning system receiver for targets placed in study area.*

Figure 6 shows the created orthomosaic and digital surface model for the study area shown in a 3D perspective for a visual interpretation of terrain and land cover.



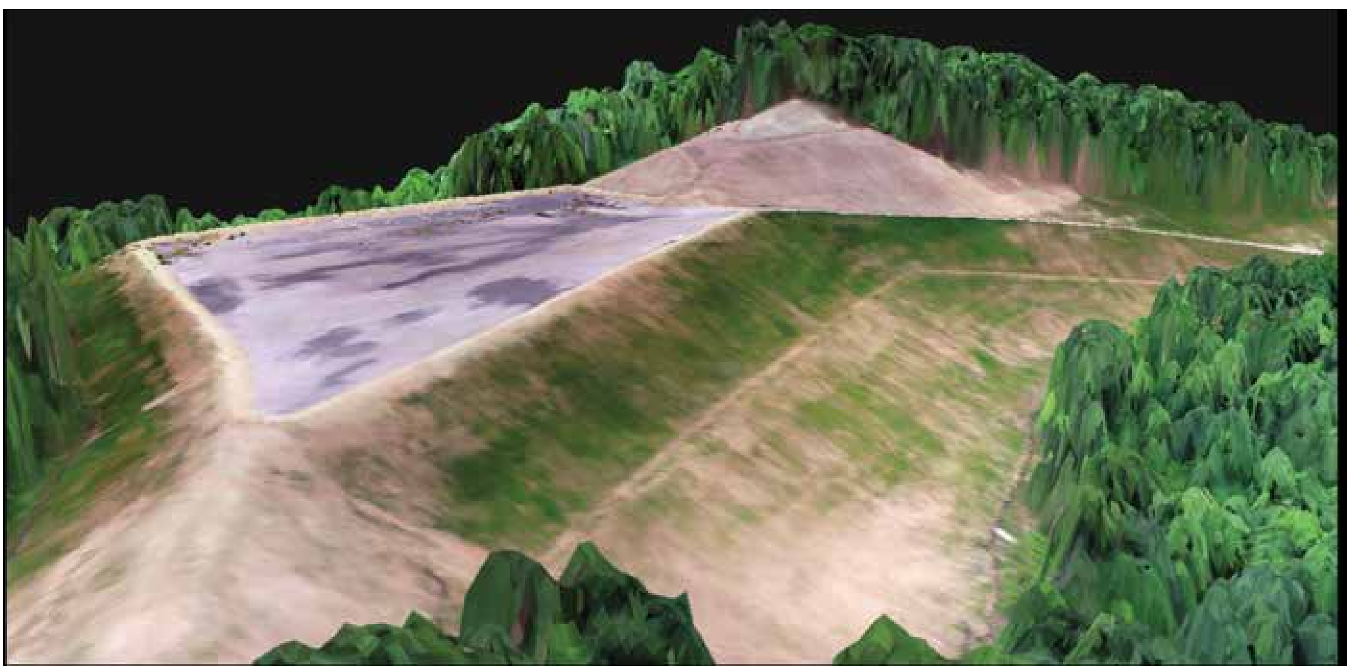


*Figure 6. Study site with orthophoto draped over digital surface model.*

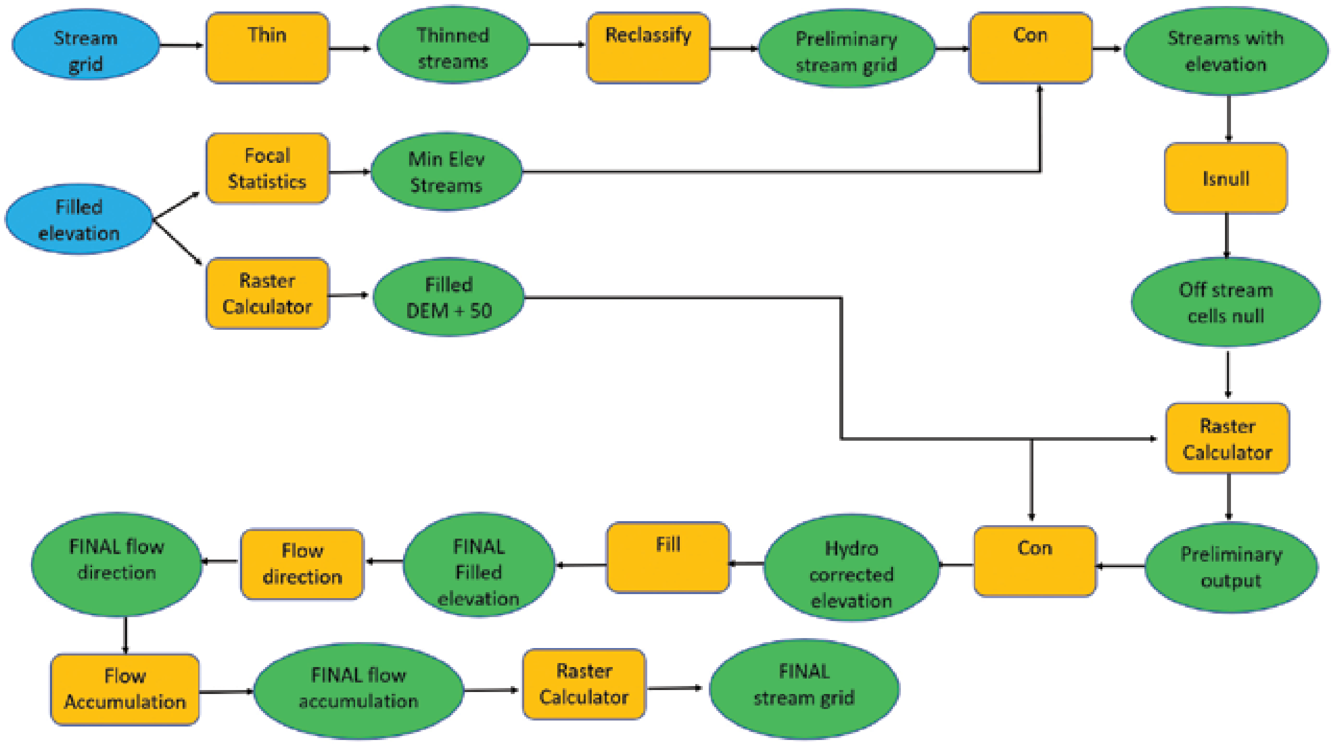
## Preparing the elevation surface for hydrological processing

An early use of digital surface models was to automatically map the stream channel and diversion or flow paths in a watershed. Band (1986) referred to elevation as a topographic skeleton. Surface elevation data provide the basis for a model of overland flow in which stream segments are used to track connected flow paths within watersheds.

Many of the functions in overland flow modeling rely on surface elevations and their derivatives, including flow direction and accumulation (Greenlee, 1987; Jenson and Domingue, 1988). Creating a surface runoff model to estimate total suspended solids first requires hydrological "correction" or conditioning of the elevation surface for hydrological modeling. The process of hydrological conditioning ensures that cells provide a path to the lowest point in the watershed when a flow direction algorithm is performed. Sinks or "pits" in the elevation surface are "filled" to prevent interruptions in the flow path.

Once hydrologically corrected surfaces are created, accurate flow direction and flow accumulation rasters are derived (Jenson and Dominque, 1988). These rasters assure that

*Figure 7. Creation of hydrologically corrected surface runoff models.*




overland flow estimates and watershed boundaries can be delineated efficiently. This method is explained in more detail and demonstrated in West Virginia by Morris et al. (2008) and Strager et al. (2010).

In this study, we used ArcGIS (ESRI, 2019) hydrological commands to create a hydrologically corrected elevation and surface runoff model, as shown in Figure 7.

## Results

The results include the surface runoff flow paths across the well pad site. Locations where runoff should be managed with remediation and sediment control are indicated by the flow paths. Results are shown in Figures 8 and 9.

Locations to focus on managing runoff were selected based on the results of the flow pattern analysis. These locations are noted by stars in Figure 9. These sites capture the most accumulated drainage contribution across the site which can be found as the highest values from the weighted flow accumulation command (ESRI, 2019). We suggest sediment control devices at these sites to mitigate the potential runoff of the well pad and minimize downstream impacts.

## Summary

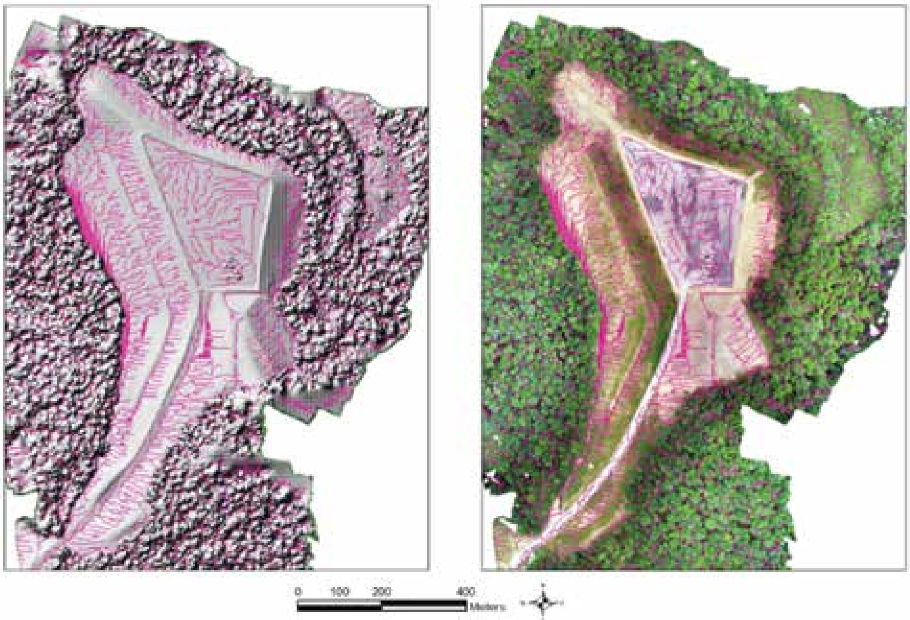
Using drones specifically for natural resource management is a growing area that has been shown to have some key advantages over more traditional sampling approaches. Some of the main advantages have to do with the unique deliverables that are possible beyond the traditional imagery product.

UAVs can be applied to collect valuable information during the construction of oil and gas well pads. The aerial photos from a UAV provide high spatial and temporal information and, when built as orthomosaics and digital surface models, can map the sources and paths of runoff for better sediment management. We collected true-color images with a Phantom 4 Pro and processed the imagery to create an orthomosaic and a digital surface model. We were able to identify three locations that could be detrimental to downstream aquatic systems and suggest the use of mitigation activities at these sites to prevent potential impacts. The use of UAVs in the oil and gas industry proved to be a viable option for better sediment management during pad construction.

The submeter high-resolution elevation surface in this study proved to be a critical input into hydrological modeling for small, localized study sites. This finding reinforces the work by DeBell et al. (2015) that noted that UAVs are set to become a key component of water resource management due to the growing need for fine-scale data. We found that combining imagery with high-resolution surface models can be a valuable approach to assist in water resource decision-making. UAVs provide a way to quickly respond to capture disturbance events and potential polluting sources and the water paths and flows throughout the landscape (DeBell et al. 2015).

UAVs have many future applications in watershed and overland flow runoff modeling due to the higher image resolution, quick deployment, access to hazardous areas, robust software, cost effective, fast data turnaround, GPS autonomous flight, and built-in safety features (Morton, 2018). Also, as noted by Tokarczyk et al. (2015), we found that UAV imagery represents a valuable alternative data source for drainage model applications

*Figure 8. Runoff grid showing stream flow paths (magenta) across the well pad displayed over digital surface (left) and orthomosaic aerial photo (right).*



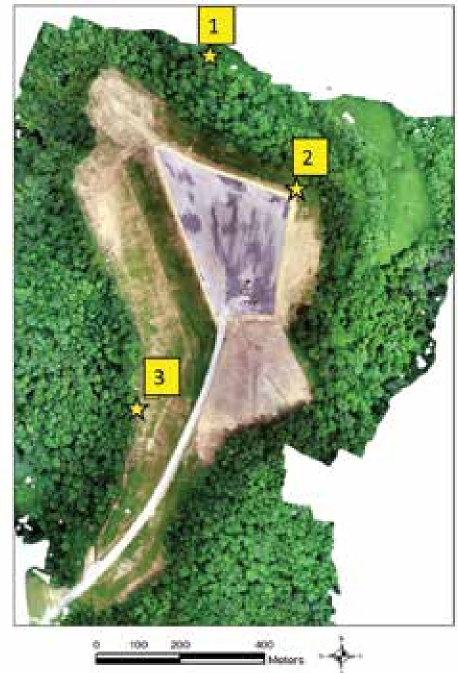




*Figure 9. Surface flow modeling indicates locations where surface runoff should be actively managed (locations 1, 2, and 3 above).*

due to the possibility of flexibly acquiring up-to-date aerial images compared with off-the-shelf image products. Imagery collected using UAVs has the potential to greatly increase the level of spatial detail available for localized drainage analyses.

Based on the results from this study, we concluded that the UAV technology can be a valuable tool in water management and mitigation of mining activities due to its extremely high spatial resolutions, allowing a quick and effective response to any aquatic problem related to such anthropogenic activities.

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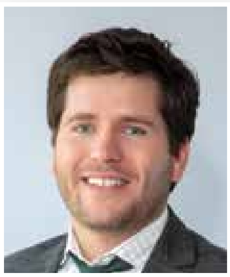
# ASRS WEBINAR SPEAKERS

## March 18, 2:00 p.m. Central
## Innovative Use Cases: Drones for Reclamation Monitoring



***Mike Rawitch*** is a geologist and geographer specializing in the implementation of geospatial technologies to optimize environmental problem solving. At Ramboll, his focus is on remotely sensed data analysis, collection and visualization applied to environmental monitoring. Mike's team at Ramboll uses aerial imagery and image analysis to understand site conditions, reduce uncertainty and help efficiently characterize and monitor environmental sites. Mike is an Interstate Technology and Regulatory Council (ITRC) team member and is a co-author on the ITRC Chapter for Advanced Site Characterization Tools. He is also a certified Federal Aviation Administration (FAA) Remote Pilot, is a senior Unmanned Aerial System (UAS or drone) operator within the Ramboll's global drone practice group and serves on industry advisory boards at Kansas State University and the University of Kansas for his expertise in UAS.


## April 1, 2:00 p.m. Central
## Reclamation in Teaching

***Kenton Sena*** is a lecturer in the Lewis Honors College at the University of Kentucky, where he teaches the honors foundations seminar (HON 101), as well as Restoration Ecology in the Commonwealth (HON 152) and The Ecology of Middle-Earth: Environmental themes in Tolkien's The Lord of the Rings (HON 301). His research engages in forest restoration in both reclaimed surface coal mines in Appalachia and reforested urban sites in central Kentucky.

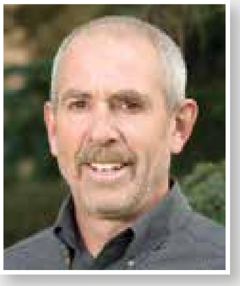
***Jennifer Franklin*** is a Professor in the Department of Forestry, Wildlife and Fisheries at the University of Tennessee. She teaches courses in ecosystem restoration, tree physiology, and prescribed fire management, and directs the Restoration and Conservation Science concentration within the Forestry major. Since 2003, her research has focused on restoring native hardwood forests to reclaimed surface mines of the eastern US, identifying factors important in the successful establishment of native plant communities.

***Brad Pinno*** is an Assistant Professor – Silviculture in the Department of Renewable Resources, University of Alberta. He has conducted extensive research in forest land reclamation and silviculture collaborating with industry, academic and government partners. His forest land reclamation research focuses on re-establishing forests after oil sands mining in the boreal forests of northern Alberta. He teaches Introductory Field School, Silviculture, and Forest Operations with a focus on field experiences and connecting operational treatments to management objectives.

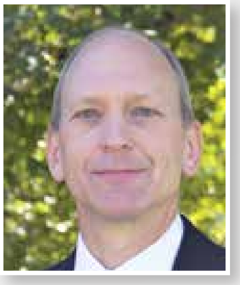
# ASRS WEBINAR SPEAKERS

## April 1, 2:00 p.m. Central
## The Four Rs – What Is It?

***Brenda Schladweiler*** is the president and owner of BKS Environmental Associates, Inc. which has been in business since 1981. She has been the recipient of the Wyoming Women of Influence Award in the Energy & Utilities category and received the Reclamationist of the Year Award from the American Society of Mining and Reclamation, where she served as president in 2015. Educational background includes PhD in Soil Science, University of Wyoming; Master of Science in Soil Science University of Wyoming; and Bachelor of Science in Range Management (Land Rehabilitation), Colorado State University.



***Peter D. Stahl*** (B.S. Oklahoma State University, 1978; M.S. and PhD, University of Wyoming, 1989) is an ecologist and soil scientist appointed to the Department of Ecosystem Science and Management at the University of Wyoming in 2000. Before returning to Wyoming, he completed a Postdoctoral Fellowship at the U.S. National Science Foundation Center for Microbial Ecology at Michigan State University and worked as a soil microbiologist at the USDA/ARS National Soil Tilth Laboratory. He, his students, and colleagues have published more than 100 peer-reviewed scientific papers on Soil Microbial Ecology and Ecosystem Recovery on restored lands.



***Jeff Skousen*** is a Professor of Soil Science and the Reclamation Specialist at West Virginia University. He received his Ph.D. from Texas A&M University, and M.S. and B.S. degrees from Brigham Young University. Jeff has more than 40 years of experience in coal mining and reclamation. He teaches courses in Soil Science, Environmental Science, and Reclamation of Disturbed Soils. Dr. Skousen's research areas include acid mine drainage control and treatment, overburden and soil analyses, oil and gas site reclamation, revegetation of disturbed lands, remediating contaminated soils and water, reforestation, native plant restoration, biomass for bioenergy, and post-mining land use development. He has published over 350 articles in journals, proceedings, books, extension publications, and other media outlets. He works with other faculty, directs graduate student research, publishes results in journals and proceedings, and presents findings at professional meetings. He also organizes the annual Acid Mine Drainage Task Force Symposium, conducts seminars and workshops on mined land reclamation, and consults with state and federal agency personnel, landowners, coal operators, and consultants. He edits the magazine Reclamation Matters and travels overseas to work on land reclamation issues in Asia and Europe. In 2020, he and a colleague published the book Appalachian Coal-Mined Landscapes: Resources and Communities in a New Energy Era.

# Detection of burning coal waste piles and their ecological restoration in China

BY ZHENQI HU, CHINA UNIVERSITY OF MINING AND TECHNOLOGY, BEIJING, CHINA;
AND JEFF SKOUSEN, WEST VIRGINIA UNIVERSITY, MORGANTOWN, WV, USA

## *Introduction*

Coal is the most important energy source in China. Coal production in China is almost half of the total production in the world. In 2019, about 8 billion metric tons of coal were produced worldwide with 3.8 billion metric tons of that total produced in China. Coal waste is produced in the process of coal mining and washing, which accounts for about 10 to 30 percent of the raw coal output. The coal waste is normally placed in piles on the landscape (Figure 1). Open-air coal refuse piles are weathered with wind and rain, and the particles are easily eroded causing air, soil, and water pollution. With rainfall leaching and flushing, these piles can release heavy metals into surface water and groundwater.

*Figure 1. Coal waste pile in China.*

Coal refuse containing pyrite, sulfur, and gases like methane can spontaneously combust and release a large amount of toxic and harmful gases, such as $SO_2$, $CO_2$, CO, and $H_2S$ (Figure 2). The large amount of coal waste and its potential for spontaneous combustion lead to serious environmental issues, including air, water, and soil pollution in mining areas, as well as a threat to human health and safety (Figure 3). For example, about 25 percent of $SO_2$ pollution comes from spontaneous combustion of coal waste piles in Yangquan City, Shanxi Province. Thus, it is important to identify coal waste piles on fire, extinguish the fire, control pollution, and reclaim the numerous coal waste piles in China.

*Figure 2. Example of spontaneous combustion of coal waste.*

## *The technical process of detection of burning and reclamation*

Based on almost 20 years of research, a new technology was proposed for identifying burning coal waste piles, extinguishing the fire, controlling pollution, and reclaiming the piles (Figure 4, following page). Following are four key steps for the technology.

### *1. MAPPING SURFACE TEMPERATURE DISTRIBUTION AND LOCATING FIRE POINTS OF SPONTANEOUS COMBUSTION*

Close-range photogrammetry was used to determine position, size and shape of coal waste piles and then reconstructing the piles in 3D images (Figure 5, following page).

Infrared thermography was used to detect surface temperature of coal waste piles by measuring its emitted electromagnetic radiation (Hu and Xia, 2017). Once the dimensions of the pile were determined, temperature values and spatial coordinates

*Figure 3. Burning coal waste pile near to homes presenting a health and safety hazard to residents.*

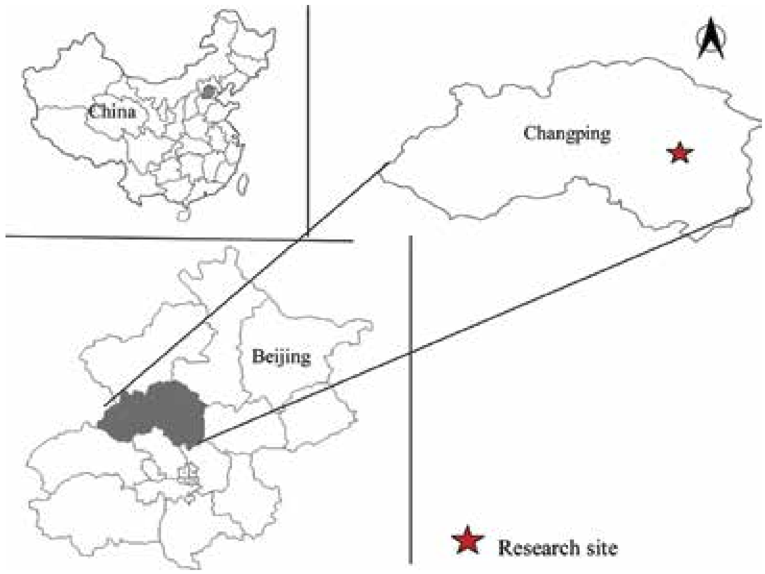



*Figure 4. Location in China where the technology for identifying burning coal waste piles, extinguishing the fire, and reclamation was developed and tested (Hu and Xia, 2017).*

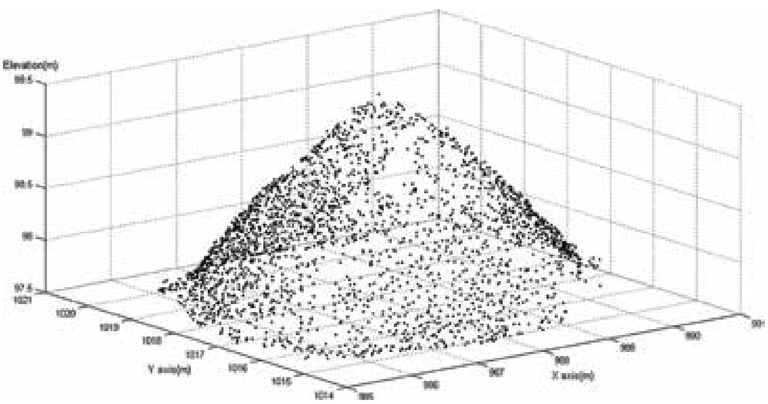



*Figure 5. Example of reconstruction of coal waste pile in 3D imaging using close-range photogrammetry data (Hu and Xia, 2017).*

were implemented to construct a 3D visualization model of temperature. Examples are shown in Figure 6. Temperature profiles of piles show hotspots where fires are located. The deep temperature field is inverted based on the surface temperature field to effectively determine the location of the ignition point.

## 2. EXTINGUISHING THE FIRE

After determining the locations of hotspots and the areas emitting the highest temperatures, a fire extinguishing technology was developed that combined shallow slurry spraying and shallow hole grouting. Improvements to the fire extinguishing slurry were made by the addition of refractory fiber and polyacrylamide type blocking agents. The slurry material was optimized by selecting liquid-solid ratios that encourage enveloping and sealing properties, but still allow mobility of the slurry. The concentration of solids in the slurry can be increased from the traditional 10 to 20 percent to 30 to 50 percent, which is more effective in extinguishing fires. The material can either be pumped down into grouted holes (cannot get too close to the hot material) or can be applied at the surface (Figures 7 and 8, following page).

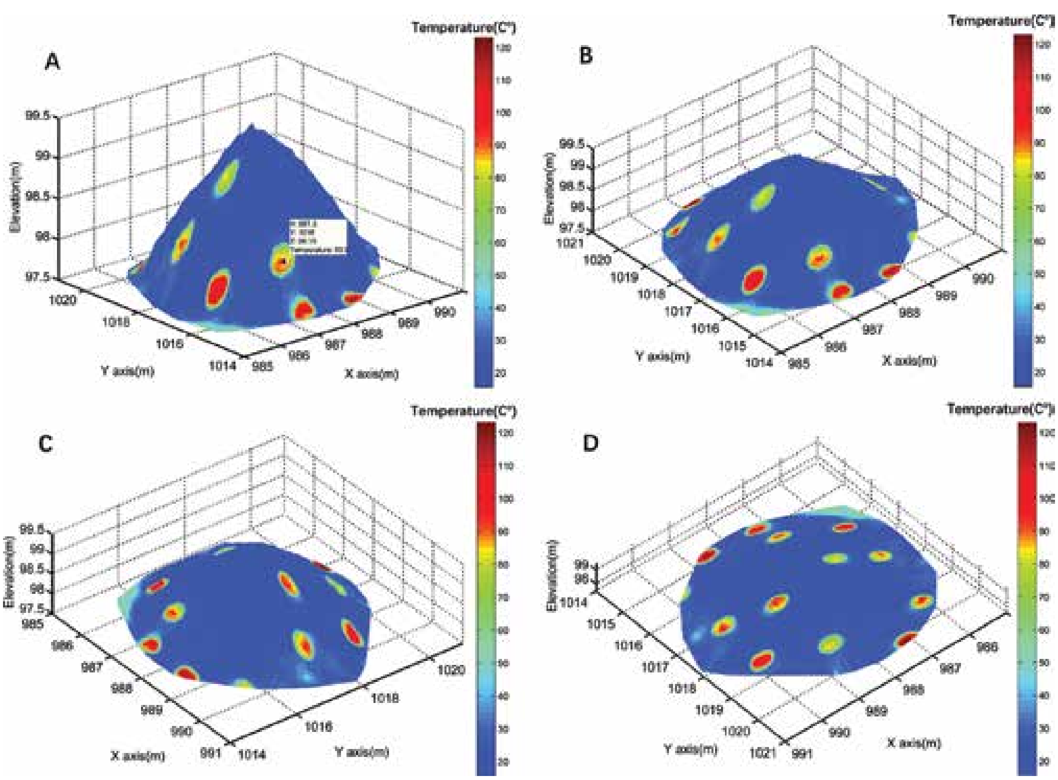



*Figure 6. Different views of the 3D visualization model for determining hotspots in coal waste piles. Image A is a full view with detailed temperature and spatial coordinate information; Images B, C, and D are different elevation views (see scales on y axis) (Hu and Xia, 2017).*

*Figure 7. Fire extinguishing technology for coal waste piles: grouting with slurry.*

*Figure 8: Fire extinguishing technology for coal waste piles: surface spraying of slurry.*

## 3. TREATMENTS FOR COVERING COAL WASTE PILES TO PREVENT SPONTANEOUS COMBUSTION

Fire protection methods and materials were studied to determine suitable methods for preventing spontaneous combustion of coal waste piles. The methods included the use of bactericides to control sulfur-oxidizing bacteria and sulfate-reducing bacteria, as well as covering the waste piles with laminated fireproof soil layers to restrict oxygen infusion into the coal waste pile.

The catalytic oxidation caused by oxidizing bacteria such as *Thiobacillus ferroxidans* (T.f bacteria) in coal waste (which increases the oxidation rate of coal waste by $10^6$ times) is the main driving force of oxidative spontaneous combustion. In our studies, two common bactericides – namely sodium dodecyl sulfate (SLS) and sodium benzoate (SBZ) – were tested and found to effectively kill T.f bacteria and inhibit $Fe^{2+}$ oxidation by more than 75 percent.

Through indoor geo-mechanical experiments and air percolation simulation tests, along with outdoor rolling experiments, the laminated fireproof soil material to cover waste piles was optimized (Figure 9, following page). Parameters such as cover thickness and level of compaction by rollers were evaluated. A model of the cover layer thickness was derived based on the principle of seepage motion and critical seepage velocity ($4.4\times10^{-5}$m/s). The study showed that the best soil cover to retard combustion was a combination of silty soil over silty clay soil of 70 cm and 20 cm, respectively (Figure 9, following page). Compaction of the soil layers to about 150 kJ/m$^3$ was found to be optimum. The laminations of the two soils and their degree of compaction were important for minimizing air percolation.

Since large amounts of silt and silty clay soil are not always available, cover materials were also tested by mixing these soil types with fly ash to see if the mixtures changed the air percolation rates. For example, we found the best effect was when the silty soil was pulverized and mixed with 40~50 percent fly ash, and the cover thickness was 70~80 cm. For the silty clay soil, the best effect was when it was mixed with 20~30 percent fly ash and the cover thickness was 15~20 cm.

The most cost-effective amount of compaction was between 100~150 kJ/m$^3$. When the moisture content of the coal waste material was close to the optimum moisture content (around 30 percent and the difference is not more than ±2 percent) and the thickness of soil cover was 30~40 cm, the compaction degree reached 85 percent with 3~5 times of rolling by a four-ton roller.

## 4. REVEGETATION OF COAL WASTE PILES

In response to the lack of suitable soil for covering coal waste piles for revegetation, we used the following techniques. (1) Loess soil material with the addition of coal-based biological soil was used as a topsoil (Figure 10). This topsoil mix retained water and promoted vegetation establishment. This topsoil mix of loess and coal-based soil was applied at a thickness of 20-30 cm as the vegetation growth medium. (2) After the topsoil was placed, spraying seeds on the surface with an adhesive helped to hold the seed in place for germination. The biologically active topsoil enhanced rapid establishment of plants to prevent erosion, improve soil agglomeration and structure, and enhance plant growth and biomass production. Seeding onto this topsoil mix increased seed germination rates by five to 10 percent and vegetation cover increased by 10 percent over seeding on conventional soils.

We also proposed a new model of mixed planting of trees, shrubs, and herbs, which is different from the traditional ecological restoration methods of seeding on coal waste piles. The results show that an herbaceous-shrub community should be built on the side slopes of coal waste piles and trees can be planted in areas with thicker soil cover.


*Figure 9. Covering coal waste piles with laminated fireproof soil layers and compacting them with a four-ton roller.*


*Below: Figure 10. Coal waste pile undergoing regrading and placement of topsoil material composed of loess and coal-based biological soil. A mixed herbaceous-shrub vegetation community was established on coal waste piles.*


Figure 11. The process for detecting and extinguishing coal waste piles and revegetation has been awarded second prize.

### 5. APPLICATION EFFECTS AND ACHIEVEMENTS

The methods briefly outlined in this paper have been used at several mines in the Provinces of Shanxi, Ningxia, and Inner Mongolia. A total of 27 coal waste piles at 14 mines have been treated with a greening area of $2.937 \times 10^6$ $m^2$. The reclamation success demonstrated on these coal waste piles was awarded the second prize by the National Science and Technology Progress (CN) in 2020 (Figure 11).

## References

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# Effects of legacy coal mining in contemporary watersheds: A West Virginia case study

BY JASON A. HUBBART AND JEFF SKOUSEN, INSTITUTE OF WATER SECURITY AND SCIENCE, WEST VIRGINIA UNIVERSITY

## *Introduction*

The Appalachian region of the USA consists of complex geographic, climatological, and ecological characteristics (Dykeman, 2019). Water quality is a primary concern in rural Appalachia as many residents are exposed to contaminated streams from surrounding legacy mine sites, inadequate treatment of household wastewater, and trash. Specific water quality problems are related to acid mine drainage (AMD), oil and gas spillage, suspended sediment, and microbial contamination. Understanding water quality and their changes across seasons and years is a necessary first step that can then be used to inform policy makers and resource managers to implement best management practices and remediation actions in watersheds. The purpose of this paper is to determine water quality characteristics in a mixed-land use watershed and to evaluate the effects of land use on stream water quality.

## *Advancing Appalachian watershed research: A case study*

In 2016, a study including 22 permanent monitoring sites was implemented in the West Run Watershed (WRW), a 23 $km^2$ mixed-land use watershed located in Morgantown, West Virginia, USA (Figure 1). WRW monitoring sites (numbered in downstream order) were located in West Run (locations 3, 4, 6, 10, 13, 18, 19, 21 and 22) and its first and second order confluence tributaries (locations 1, 2, 5, 7, 8, 9, 11, 12, 14, 15, 16, 17 and 20), with contributing sub-catchments characterized by land use practices (Table 1; Figure 1). Both field surveys and GIS were used to identify study site locations and related sub-catchments. Monitoring sites 1, 15 and 20 are primarily mixed development land use, whereas monitoring sites 11 and 16 are primarily agricultural (Table 1). Site 17 (86 percent forested) serves as a reference site (control) for the current work (also contained nine percent agricultural and five percent mixed development land uses).

As a result of land use impacts, West Run was listed as a 303d impaired stream in 2012 and 2014. In 2012, the stream was listed because of aluminum concentrations, fecal coliform counts, and a generalized "condition not allowable (CNA)-biological." Total Maximum Daily Loads (TMDLs) were developed in 2012 for West Run, which targeted load reductions for pH, iron, aluminum, chloride, and fecal coliform (WVDEP, 2012). However, since 2014, West Run has remained 303d listed as CNA-biological (WVDEP, 2014).

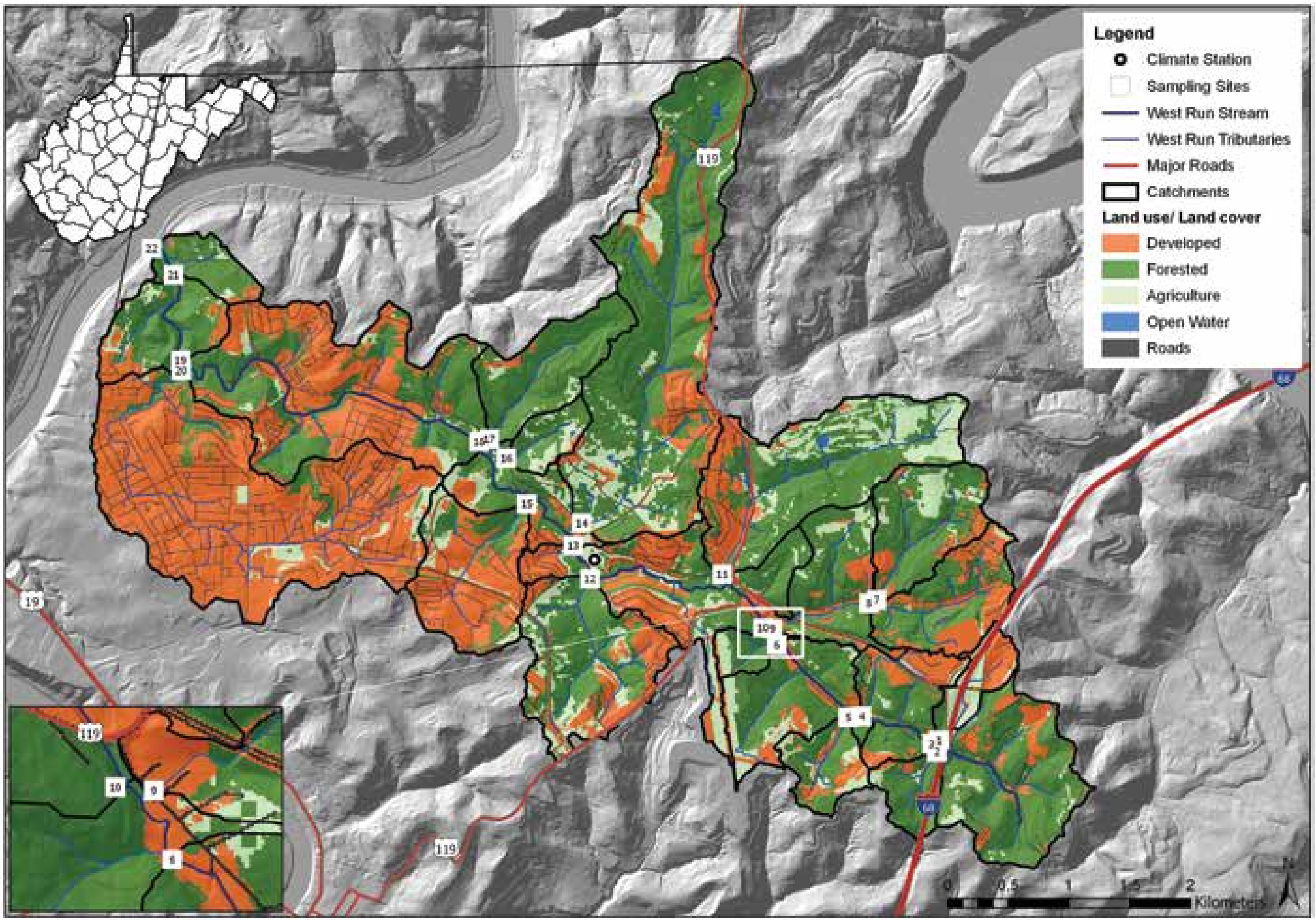
West Run is a third order tributary of the Monongahela River (Petersen and Hubbart, 2020a). Based on the 2018 National Agriculture Imagery Program (NAIP) land use and land cover data, WRW includes 43 percent forested, 38 percent mixed development (urban and commercial areas), and 19 percent agricultural land use practices, in addition to more minor categories (e.g., mining, open water, etc.). West Run is a narrow, moderately entrenched stream with multiple small floodplains. The change in elevation from the headwaters to the confluence of the Monongahela River is 180 m (420 and 240 m above mean sea level) (Horne and Hubbart, 2020).

The watershed includes relatively rugged terrain, featuring numerous Paleozoic era rock outcroppings (Petersen et al., 2018), and also has a history of surface and underground coal mining (Upper Kittanning and Pittsburgh coal seams), particularly in the headwaters of the watershed, peaking in the 1930s to 1950s (WVWRI, 2008). Mining practices ceased by the late 1950s but evidence of those operations remains apparent by means of acid mine drainage (Figure 2).

During the 1940s, the Morgantown area population increased from 16,000 to 24,000 individuals and mixed development areas such as the Morgantown Municipal Airport was constructed in West Run. Population has remained relatively flat since 1960 at approximately 30,000. However, since the 1970s, mixed development areas (stores and housing) in WRW increased from 18 percent in 1992 to 38 percent in 2018, replacing forested (54 percent in 1992 to 43 percent in 2018) and agricultural land uses (27 percent in 1992 to 19 percent in 2018). WRW receives approximately 1,060 mm/yr (41 in/yr) precipitation.

## *Data collection*

All 22 monitoring sites in the WRW included a Solinst Levelogger Gold pressure transducer that logs water temperature (°C) and stage (water depth, cm). Precipitation was recorded with a Campbell Scientific TE525 Tipping Bucket Rain Gauge, and air temperature (Campbell Scientific HC2S3 Temperature Probe) at three-meter height at a climate station located within approximately 30 m of Site 13 (Figure 1, Figure 3, respectively).




*Above: Figure 1. Land use and land cover of West Run Watershed (WRW) located in Morgantown, West Virginia, USA, including 22 nested gauging sites and corresponding sub-basins.*

*Left: Figure 2. Monitoring sites 1 (confluence left), 2 (confluence right), and 3 (middle, culvert) of the West Run Watershed study shown in Figure 1.*

*Right: Table 1. Land use/land cover characteristics (percent cover) and total drainage area (km²) of 22 monitoring sites (and associated sub-catchments) in West Run Watershed (WRW), West Virginia, USA. Land use percentages may not sum to 100 percent, as not every category is included (e.g., wetland, open water). Some categories are combinations of others (e.g., mixed development = urban + residential). Final row (Site 22) indicates the total values for the entire watershed. Shading denotes dominant land use practice by site.*

| Site | Mixed Development (%) | Agriculture (%) | Forested (%) | Drainage Area (km$^2$) |
|---|---|---|---|---|
| 1 | 53 | 39 | 8 | 0 |
| 2 | 14 | 12 | 74 | 0 |
| 3 | 22 | 16 | 61 | 2 |
| 4 | 26 | 15 | 59 | 2 |
| 5 | 23 | 26 | 51 | 0 |
| 6 | 24 | 17 | 59 | 4 |
| 7 | 16 | 29 | 55 | 1 |
| 8 | 31 | 16 | 52 | 2 |
| 9 | 28 | 19 | 53 | 2 |
| 10 | 25 | 18 | 56 | 6 |
| 11 | 18 | 42 | 40 | 2 |
| 12 | 32 | 34 | 35 | 2 |
| 13 | 27 | 26 | 47 | 11 |
| 14 | 16 | 26 | 57 | 3 |
| 15 | 70 | 10 | 19 | 1 |
| 16 | 5 | 59 | 35 | 0 |
| 17 | 5 | 9 | 86 | 1 |
| 18 | 26 | 25 | 49 | 16 |
| 19 | 29 | 22 | 48 | 19 |
| 20 | 89 | 4 | 7 | 3 |
| 21 | 38 | 19 | 42 | 23 |
| 22 | 38 | 19 | 43 | 23 |

Figure 3. Stream flow monitoring site 13 located in West Run, Morgantown, West Virginia, USA. Left, precipitation gauge. Right, data logger housing for stream monitoring.

Figure 4. Stream flow monitoring with a Sontec Flowtracker2®, during a runoff event in West Run, Morgantown, West Virginia, USA.

As often as weekly, stream water grab-samples were collected from each monitoring site. At the time of sample collection, a calibrated YSI Pro-Series DSS handheld water quality sonde was used to collect the following in-stream parameters: water temperature (°C), dissolved oxygen (percent saturation), specific conductance (μs $cm^{-1}$), and pH. Stream water samples were analyzed for an array of geochemical variables, nutrients, suspended sediment, and fecal contamination. *E. coli* and *Enterococci* colony forming units (CFU) were enumerated using the U.S. Environmental Protection Agency approved Colilert and Enterolert tests, respectively (IDEXX Laboratories, 2019). Periodic stream cross sections were conducted (Figure 4) to develop a rating curve for each of the 22 monitoring sites for flow and pollutant loading estimations.

## Recent Results

Results from data collected in 2018 (Kellner et al., 2018) showed significant ($p< 0.05$) relationships between chemical parameters such as Ca and Sr with specific conductance, a measure of ion concentration in water. Specific conductance concentrations are normally higher at low flow periods because higher flow dilutes the concentrations. These relationships varied more widely at mixed-land use sites compared to predominately urban, agricultural, or forested sites (Figure 3, Figure 5).

Stream water temperature was lower in water from forested land uses, indicating that increased forest cover decreased stream temperature (Horne and Hubbart, 2020). Agricultural land use

Figure 5: Left, site 12 (Figure 1) agriculture. Right, site 18 (Figure 1) looking towards forested reach 17.

was positively correlated to maximum stream water temperature except during the spring. Increases in mixed development land uses showed higher stream water temperature at quarterly and monthly timescales. Correlation trends in some reaches were reversed between the winter and summer seasons. During the winter, increasing mixed development showed lower minimum and mean stream temperature. As expected, summer showed the highest maximum and mean water temperatures, but also the most variation.

In a study on stream chemistry and bacterial composition in the WRW, Martin et al. (2020) found that sediment bacterial community richness was not affected by increasing urban land use, but the microbial communities from agricultural land uses were more resilient than those from urban land uses. These differences in microbial community resilience suggests differences in community function based on land use practices.

## AMD and an Emergent pH – Fecal Coliform Story

Recent research in the WRW indicates that agricultural land use practices are commonly associated with increased *E. coli* relative to other land use types (Petersen et al., 2018; Petersen and Hubbart, 2020a, b). However, AMD from legacy mined sites is hypothesized to impact microbial populations in streams, especially those that flow in urban settings. A follow-up study in 2020 further clarified the effects of AMD on in-situ *E. coli* and *Enterococci* populations in West Run.

Data from all 22 monitoring sites from March through November 2020 (monthly sampling, n = 198) indicated highly variable pH in WRW (Table 2, Figure 5). Lowest mean pH was observed at sites 8 and 12, both tributaries containing distinct outlets from AMD-contributing mined sites, which both displayed mean pH of 4.1. Sites 20, 21, and 22, near the mouth of West Run, showed the highest mean pH of 7.9. Generally, lower pH was observed in the upper portions of the watershed, and higher pH was observed in the lower portion of the watershed. From Figure 6, stream water pH varied widely at several sites (2, 5, 7, 9 and 12), all of which were tributaries and strongly affected by precipitation patterns and land surface activities.

Highest mean concentrations of *E. coli* (CFU) were observed at sites 8, 14, 16 and 19 with mean values of 1027, 820, 849 and 837 CFU, respectively. Highest mean concentrations of *Enterococci* (CFU) were observed at sites 4, 14, 15, 16, 20, and 21 with values ranging from 463 to 1555 (Table 3, Figure 7, following page). Values at site 22 may also reflect backwatering from the Monongahela river, which notably is 303d listed for high concentrations of Fecal coliforms.

In general, *Enterococci* concentrations were highest at monitoring sites 14, 15, 16, and 20, with average values over the period of study of 975, 1358, 1555, and 874 CFU per 100 mL, respectively. Lowest average *Enterococci* concentrations were observed at monitoring sites 2, 5, 8, 9, and 10, with values ranging from 1.3 to 6.0 CFU per 100 mL. Monitoring sites with the highest *Enterococci* concentrations had different land use practices: forest (14), mixed development (15), agriculture (16) and mixed development (20). Importantly, the sites with lower *Enterococci* values tended to correspond to sites with historic mining practices and AMD, which evidently suppressed microbial populations. These findings are supported by corresponding average pH values of 5.7, 5.5, 4.1, 4.7, and 5.3, respectively, at these sites (Table 2, Figure 6). Results of various

**Site Number and Mean pH**

| Site #1 | Site #2 | Site #3 | Site #4 | Site #5 | Site #6 | Site #7 | Site #8 | Site #9 | Site #10 | Site #11 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 6 | 6 | 7 | 5 | 6 | 5 | 4 | 5 | 5 | 6 |

**Site Number and Mean pH**

| Site #12 | Site #13 | Site #14 | Site #15 | Site #16 | Site #17 | Site #18 | Site #19 | Site #20 | Site #21 | Site #22 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 5 | 6 | 7 | 8 | 8 | 7 | 7 | 8 | 8 | 8 |

*Table 2. Water pH by sampling location (n = 22) during the study period (March 3 – November 3, 2020) in West Run Watershed, WV, USA. Shaded cells identify tributaries to main-stem West Run (unshaded). pH values reflect weekly sampling during the study period.*

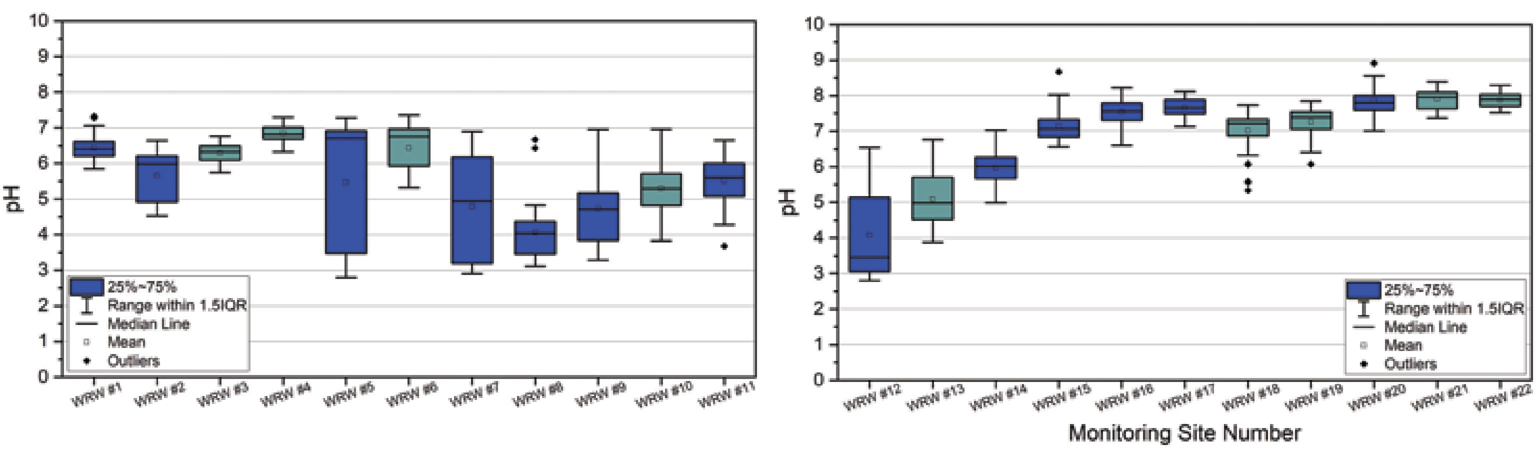



*Figure 6: Box and whisker plots reflecting pH sampled weekly at 22 stream monitoring sites during the period of March 3 – November 3, 2020 in West Run Watershed, Morgantown, West Virginia, USA. Blue shaded boxes denote tributaries. Olive green shading denote main-stem West Run.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***E-coli* - Site Number** | | | | | | | | | | |
| | Site #1 | Site #2 | Site #3 | Site #4 | Site #5 | Site #6 | Site #7 | Site #8 | Site #9 | Site #10 | Site #11 |
| Mean | 176 | 288 | 411 | 269 | 15 | 268 | 348 | 1027 | 348 | 294 | 56 |
| | ***E-coli* - Site Number** | | | | | | | | | | |
| | Site #12 | Site #13 | Site #14 | Site #15 | Site #16 | Site #17 | Site #18 | Site #19 | Site #20 | Site #21 | Site #22 |
| Mean | 345 | 115 | 820 | 622 | 849 | 110 | 524 | 837 | 703 | 727 | 476 |
| | **Enterococci - Site Number** | | | | | | | | | | |
| | Site #1 | Site #2 | Site #3 | Site #4 | Site #5 | Site #6 | Site #7 | Site #8 | Site #9 | Site #10 | Site #11 |
| Mean | 154 | 3 | 154 | 463 | 1 | 70 | 32 | 6 | 1 | 2 | 31 |
| | **Enterococci - Site Number** | | | | | | | | | | |
| | Site #12 | Site #13 | Site #14 | Site #15 | Site #16 | Site #17 | Site #18 | Site #19 | Site #20 | Site #21 | Site #22 |
| Mean | 36 | 25 | 975 | 1358 | 1555 | 538 | 251 | 695 | 873 | 792 | 339 |

*Table 3. E. coli and Enterococci concentrations (CFU per 100 mL) at each sampling location (n = 22) during the study period (March 3 – November 3, 2020) in West Run Watershed, WV, USA. Shaded columns identify tributaries and unshaded columns are main stem West Run.*

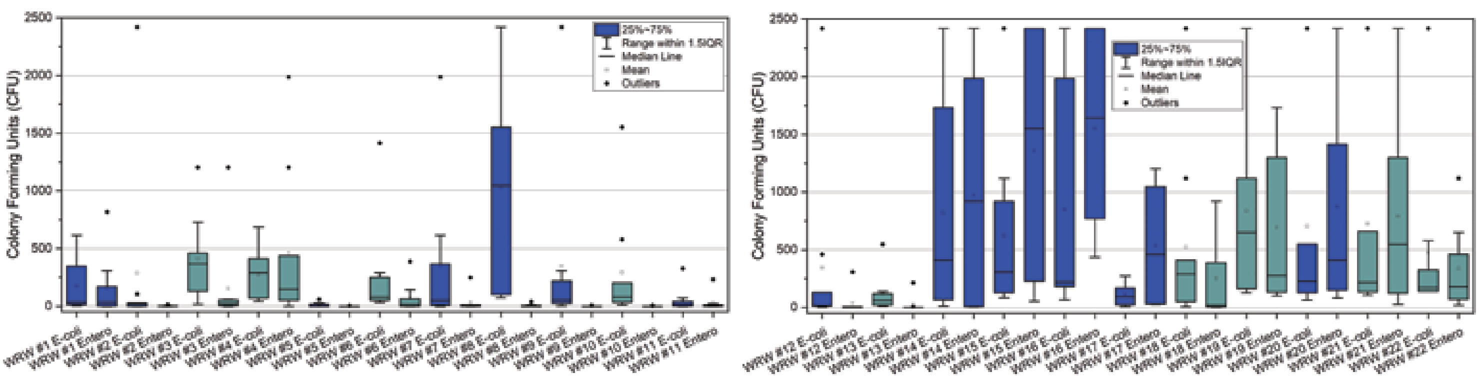



*Figure 7. Box and whisker plots of E. coli and Enterococci (CFU) at 22 stream monitoring sites during the period of March 3 – November 3, 2020 in West Run Watershed, Morgantown, West Virginia, USA. Blue shaded boxes denote tributaries. Olive green shading denote main-stem West Run.*

statistical tests support the conclusion that pH is exerting a limiting influence on fecal indicator bacteria concentrations in WRW that would not be observed in watersheds lacking AMD. In addition, inputs of fecal indicator bacteria concentrations from sites 14 to 17 don't appear to increase the concentrations in West Run downstream.

There are additional interesting relationships in these data that are worth mentioning. Site 14, for example, drains a large sub-catchment of 3.4 km$^2$ that includes 57 percent forested and 26 percent agricultural land uses, and has high concentrations of *E. coli* and *Enterococci*. It is assumed that agriculture is the likely source of *E. coli* and *Enterococci* (livestock). Site 16 with a similar high concentration of bacteria is much smaller but includes 59 percent agricultural land use. Site 15 is dominated by urban development (70 percent), yet it also shows high concentrations of bacteria. Since there was little agriculture, the only contributions of fecal coliform(s) would presumably be from small mammals (pets, urban wildlife) and humans. This may be of particular relevance considering that sewers are largely combined (i.e., human sewage and stormwater runoff) in this portion of Morgantown, WV, and system leakages or overflows during periods of high precipitation may contribute these sewage indicators to receiving waters in spite of detention facilities.

This study was conducted during the COVID-19 pandemic of 2020. It may be of interest to note that average *E. coli* concentrations from 2020 generally exceeded those of the data collected in 2018 (Petersen and Hubbart, 2020c; Petersen and Hubbart, 2020d). For example, in 2020 sites 15 and 20 (mixed land-use/urban by majority) were characterized by average *E. coli* concentrations of 623 and 704 CFU per 100 mL, respectively. These results represent increases of 89 percent and 70 percent over the average annual values for 2018 (330 and 415 CFU per 100 mL) (Petersen and Hubbart, 2020c; Petersen and Hubbart, 2020d). These increases may (in part) be attributable to more runoff carrying bacteria to the stream or deteriorating sewer/stormwater pipes and connections.

Recent results indicate that AMD may account for lower *E. coli* and *Enterococci* concentrations in the upper WRW (as discussed above) and the decreased fecal indicator diversity. However, in the lower elevations of WRW, land use practices may be the predominant factor influencing higher *E. coli* and *Enterococci* concentrations. For example, in West Run at sites 14 through 21, there was a notable increase in cumulative *E. coli* and *Enterococci* concentrations and a simultaneous increase in agricultural and mixed development land use practices.

## *Synthesis and Future Directions*

This WRW study approach (Hubbart et al., 2019) and the high spatial resolution sampling design (n = 22 monitoring sites) facilitates the collection of a globally unique data set, and moreover a collaborative research and education outdoor laboratory (Figure 8). Most watersheds lack such infrastructure and the opportunities facilitated by instrumented watersheds close to a university campus. An important discovery to date is the complexity of understanding the highly varied results from so many monitoring sites, the complex interrelations of land use practices on water quality, and the often forgotten, yet ongoing intermingled impacts of legacy land use practices (such as coal mining and AMD).

In WRW, increased instream fecal indicator bacteria concentrations were typically observed at study sites characterized by pH >7 and with high percentages of either mixed development or agricultural land use types. These results have important implications. First, pH may exert a limiting influence on instream fecal indicator bacteria concentrations in WRW and as such, may be masking the influence of sewage inputs in upper portions of the watershed. This interpretation is supported by a comparison of fecal indicator bacteria concentrations at sites 12 and 16. Both catchments are characterized by livestock production. However, water pH was higher at site 16 than site 12, which supported higher fecal indicator bacteria concentrations at site 16. Therefore, in watersheds characterized by variable pH, investigators and managers should interpret fecal indicator bacteria concentrations very carefully, to avoid overlooking a potential misleading result such as the masking-effect of low pH. Moreover, since *Enterococci* appear to be more sensitive to low pH, investigators and resource managers should exercise caution when utilizing this genus of bacteria as an indicator of land use impacts. Finally, pH is presented in the current work as an independent environmental variable, alongside land use characteristics. However, past mining activities are not fully captured/quantified in land use datasets utilized for the study, given reclamation and reforestation/vegetative succession of past mine sites. Thus, pH could be considered a proxy variable for such historic land use impacts and should be understood to represent an integration of past and contemporary land use influences.

## *Acknowledgements*

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*Figure 8: A 2019 community and collaborator meeting event in the West Run Watershed (Site 13, Figure 1), Morgantown, WV, USA.*

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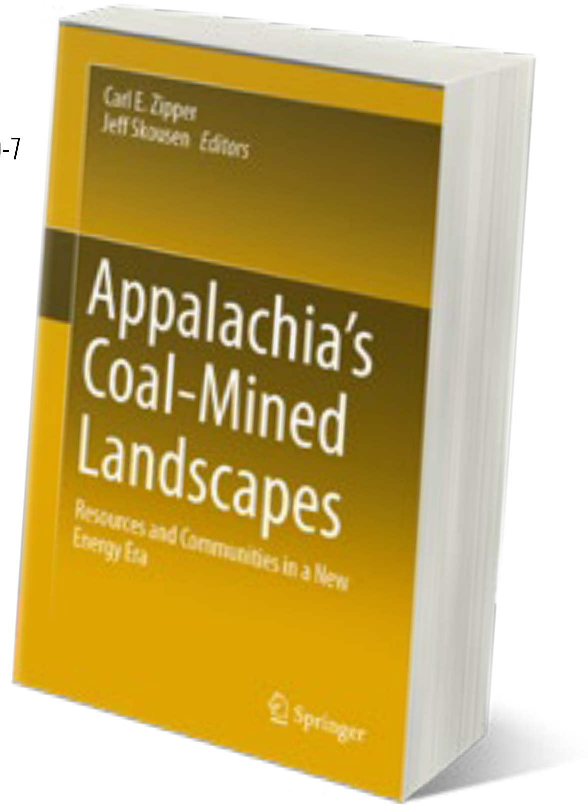
# Appalachia's coal-mined landscapes: Resources and communities in a new energy era

BY CARL E. ZIPPER, JEFF SKOUSEN (EDS.) SPRINGER, 2021. ISBN 978-3-030-57779-7
https://www.springer.com/gp/book/9783030577797




This book collects and summarizes current scientific knowledge concerning coal- mined landscapes of the Appalachian region in eastern United States. Containing contributions from authors across disciplines, the book addresses topics relevant to the region's coal-mining history and its future; its human communities; and the soils, waters, plants, wildlife, and human-use potentials of Appalachia's coal-mined landscapes.

The book provides a comprehensive overview of coal mining's legacy in Appalachia, USA. It describes the resources of the Appalachian coalfield, its lands and waters, and its human communities – as they have been left in the aftermath of intensive mining, drawing upon peer-reviewed science and other regional data to provide clear and objective descriptions. By understanding the Appalachian experience, officials and planners in other resource extraction-affected world regions can gain knowledge and perspectives that will aid their own efforts to plan and manage for environmental quality and for human welfare.

*Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era* will be of use to natural resource managers and scientists within Appalachia and in other world regions experiencing widespread mining, researchers with interest in the region's disturbance legacy, and economic and community planners concerned with Appalachia's future.

## *Table of contents*

# Planting native willows to conserve bee species diversity on a reclaimed coal mine

BY A. MOSSELER, J.E. MAJOR, D. P. OSTAFF, AND J.S. ASCHER, NATURAL RESOURCES CANADA

## *Introduction*

We have been field-testing the use of native North American willow (Salix) species for the rapid reclamation of former coal mine sites in eastern Canada. Willows are useful in reclamation efforts because they are easily and cost-effectively propagated from dormant stem cuttings; they grow fast on the harsh and infertile conditions of exposed former mine sites; and they are attractive to many forms of wildlife as food and cover (Photo 1). Of special interest was the use of willows by native bees as sources of pollen and nectar for raising their offspring. As flower pollinators, bees are important to agriculture and food production. However, the health of native bee populations has become a worldwide concern because of various threats to both natural and domesticated bee populations. These threats include intensive agronomic and monoculture practices, displacement of native floral hosts by exotic plants, and the impacts of several pests and infectious diseases. By purposely using flowering plants attractive to bees in our landscapes and mine site reclamation efforts, we can have a positive effect on native bee populations and simultaneously boost agricultural production in areas where native populations of flowering species such as willows can be promoted.

*Photo 1. Willow is being used to reclaim mined areas in Canada.*

Willows produce flower catkins very early in the growing season when few other plants are in bloom (Photo 2). This is important for many bee species as they emerge from the ground early in spring after their winter dormancy period, looking for pollen and nectar to provision their nests and developing broods. North America has over 108 native willow species to choose from for landscape reclamation activities. Willows have the relatively uncommon feature among plants of bearing male and female flowers on separate plants (dioecy). Our studies on native bees visiting willows were aimed at assessing foraging preferences among different bee species: whether they favored one willow species over another, whether they preferred plants with male flower catkins or female flowers, and whether they preferred a particular sampling date or time of day for their foraging activities. Our ability to identify bees to the species level (Table 1) allowed us to assess some aspects of the biological diversity of bees foraging on willows. Conservation of biological diversity, including bee species diversity, may be an important objective in reclamation of highly disturbed areas such as former mine sites.

*Photo 2. Male flower catkin production on a coppice of Salix cordata used in pollinator studies.*

*Table 1. Native bees collected while foraging on flower catkins of three native willow species (Salix spp.) at the former Salmon Harbor coal mine site near Minto, NB in 2017 (mine site study).*

| Apoidea (Subgenus) | Salix species cordata | eriocephala | interior | Total |
|---|---|---|---|---|
| **Andrenidae** | | | | |
| *Andrena* | | | | |
| *(Andrena) frigida* Smith, 1853 | 26 | 48 | 287 | 361 |
| *(Andrena) clarkella* (Kirby, 1802) | 39 | 27 | 53 | 119 |
| *(Thysandrena) bisalicis* Viereck, 1908 | 23 | 72 | 6 | 101 |
| *(Euandrena) algida* Smith, 1853 | 5 | 10 | 20 | 35 |
| *(Trachandrena) sigmundi* Cockerell, 1902 | 10 | 13 | 4 | 27 |
| *(Melandrena) dunningi* Cockerell, 1898 | 4 | 8 | 6 | 18 |
| *(Micrandrena) salictaria* Robertson, 1905 | 0 | 1 | 6 | 7 |
| *(Euandrena) nigrihirta* (Ashmead, 1890) | 0 | 4 | 1 | 5 |
| *(Holandrena) cressonii* Robertson, 1891 | 1 | 0 | 2 | 3 |
| *(Melandrena) carlini* Cockerell, 1901 | 1 | 1 | 0 | 2 |
| *(Plastandrena) crataegi* Robertson, 1893 | 0 | 0 | 1 | 1 |
| *(Tylandrena) erythrogaster* (Ashmead, 1890) | 0 | 0 | 1 | 1 |
| *(Melandrena) nivalis* Smith 1853 | 1 | 0 | 0 | 1 |
| *(Melandrena) regularis* Malloch, 1917 | 0 | 0 | 1 | 1 |
| *(Andrena) rufosignata* Cockerell, 1902 | 1 | 0 | 0 | 1 |
| *(Thysandrena) w-scripta* Viereck, 1904 | 0 | 0 | 1 | 1 |
| *Andrena* sp. | 0 | 1 | 0 | 1 |
| **Andrenid Totals** | **111** | **185** | **389** | **685** |
| **Colletidae** | | | | |
| *Colletes* spp. | 3 | 6 | 10 | 19 |
| **Halictidae** | | | | |
| *Lasioglossum (Dialictus)* spp. | 9 | 3 | 3 | 15 |
| *Lasioglossum* spp. | 6 | 1 | 0 | 7 |
| *Augochlora* | | | | |
| *(Augochlora) pura* (Say, 1837) | 7 | 0 | 0 | 7 |
| Halictus | | | | |
| *(Protohalictus) rubicundus* (Christ,1791) | 4 | 1 | 0 | 5 |
| *(Seladonia) confusus* Smith, 1853 | 0 | 1 | 3 | 4 |
| **Apidae** | | | | |
| *Bombus* | | | | |
| *(Subterraneobombus) borealis* Kirby, 1837 | 0 | 0 | 1 | 1 |
| *(Pyrobombus) vagans* Smith 1854 | 1 | 0 | 0 | 1 |
| **Non Andrenid Totals** | **30** | **12** | **17** | **59** |
| **Grand Totals** | **141** | **197** | **406** | **744** |

## Methods

To examine foraging preferences of natural bee populations, we used three native willows: *Salix cordata* (COR), *S. eriocephala* (ERI), and *S. interior* (INT) (Photo 3). These willows were artificially established in both a common garden field test located at our research facilities near Fredericton, New Brunswick (NB), Canada and on a former coal mine site managed by NBPower (the local power utility) near Minto, NB, approximately 80 kilometers east of Fredericton. The common garden test included approximately 25 clones from each of seven native willow species that were collected from across central and eastern Canada. Hourly counts of *Andrena* bees (andrenids) visiting several male-female clonal pairs of ERI and INT on three consecutive days during May 2015 were used to identify foraging preferences on different willow species (as well as male versus female willow plants [Fig. 1]) and to assess the presence of diurnal patterns in *Andrena* bee visits (Fig. 2). In 2017, our field observations on Apoidea bees (andrenids plus other non-andrenid species) visiting willow flower catkins were expanded to a former coal mine site near Minto, NB, where we had been planting COR, ERI, and INT, among other willow species, over several years as part of ongoing mine reclamation efforts (Fig. 3). For more details on materials, methods, and statistical analyses, please see the reference in the journal Annals of Applied Biology cited at the end of this article.

*Photo 3. Three native willow species were tested for pollination by bees.*

## Results

In both field studies (tree research nursery and mine site), we found a strong preference by bees for visits to male willow plants, which produce both pollen and nectar (Photo 4). This preference for male plants ranged from about 70 to 90 percent of total bee visits in favor of male plants across the three species tested (Figs. 1 and 3), a result that might be expected given that pollen is the main food source for their offspring. Bee foraging preferences for different willow species were relatively unimportant indicating that most bees seem to be opportunistic in their foraging behavior and don't seem to need to differentiate in favor of one willow species over another. On the mine site study, plant sex preferences accounted for over 30 percent of total variation among the four factors affecting bee visitation activity that were studied. In contrast, bee visits to female willow flowers showed little diurnal variation and had a more subdued, uniform visitation pattern throughout the day (Fig. 2).

Sixteen species of *Andrena* bees and eight other bee species were identified in our collections, showing that many different bee species were foraging on willows. Despite this bee species diversity, bees belonging to the genus *Andrena* represented 92 percent of the bees foraging on the three willow species (COR, ERI, and INT) used in this study. Others, working further south in Illinois, USA, identified 59 bee species visiting several willows including INT. We also found differences in the numbers and types of bees visiting willows between the urban environment of our research facilities in Fredericton versus the more rural environment of the former coal mine site. Nevertheless, the dominance of *Andrena* species (92 percent of bee visits) indicates the potential importance of andrenids as natural pollinators of both native and domestic crop plants.

Andrenids tend to be smaller, darker, and less conspicuous than the larger, more charismatic and familiar bumble bees or honeybees, but our data show that these less conspicuous andrenids can play a major role in pollination of both native plants and commercially important crop species such as blueberries.

Some of the bee species visiting our willows are known to be important pollinators of fruit crops such as berries and apples. Fruit crops such as blueberries and cranberries represent major commercial industries across central and eastern Canada. Large-scale supplemental pollination of these crops using commercially imported insect pollinators represents a large portion of the costs of fruit production. These production costs could probably be reduced by promoting populations of native willows as alternative forage for bees, especially early in the growing season when pollen and nectar may be in short supply and necessary for sustaining native bee populations. Promotion of naturally existing willow populations in the vicinity of crop plants—or artificial establishment of willow populations on sites unsuited to crop production—may be useful in increasing and promoting pollinators capable of shifting their foraging activity to commercial crop plants. In addition, the establishment of largely male, or male-only, willow populations would have the added benefit of avoiding unwanted willow seed dissemination and potentially harmful vegetative competition into agricultural fields.

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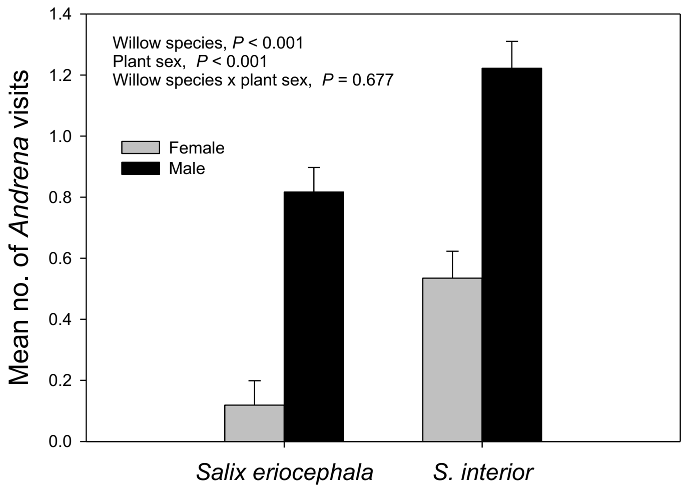
*Photo 4. Andrenid bee collecting pollen from a male willow catkin of Salix interior.*

*Fig. 1. Mean (+ S.E.) number of visits by Andrena species to male and female flower catkins of Salix eriocephala and S. interior observed during five-minute periods at hourly intervals from 0800 to 2200 h over a three-day period (diurnal study).*



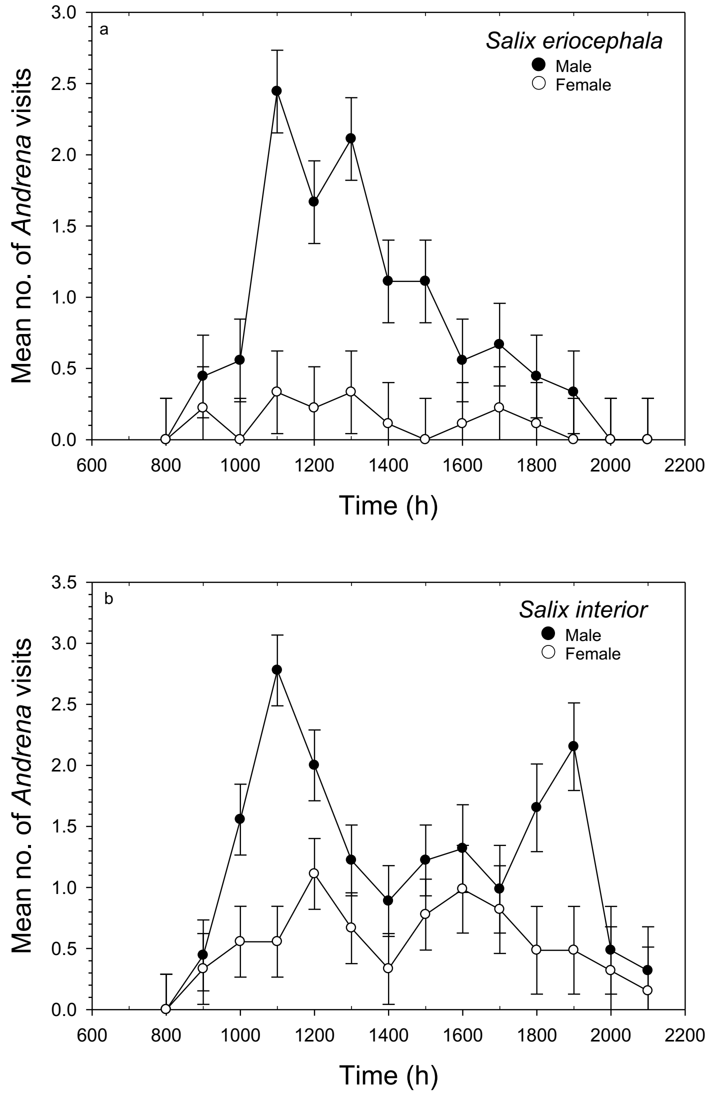



*Fig. 2. Mean (+ S.E.) number of visits by Andrena species to (a) Salix eriocephala and (b) S. interior separated according to plant sex (male or female). Counts were made during five-minute periods at hourly intervals from 0800 to 2200 h over a three-day period for each willow species (diurnal study).*

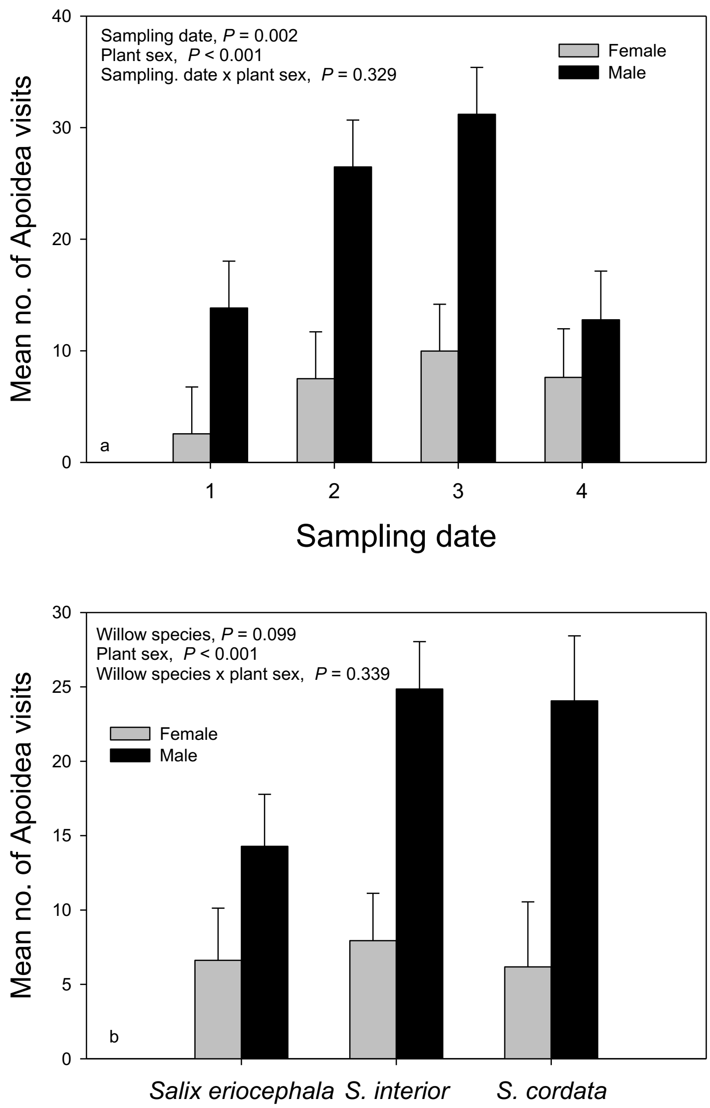



*Fig. 3 (a) Mean (+ S.E.) number of visits by Apoidea bees to male and female flower catkins of Salix eriocephela, S. interior and S. cordata separated according to day of observation, and (b) separated according to willow species. On each day, counts were made during two 15-minute periods (mine site study).*

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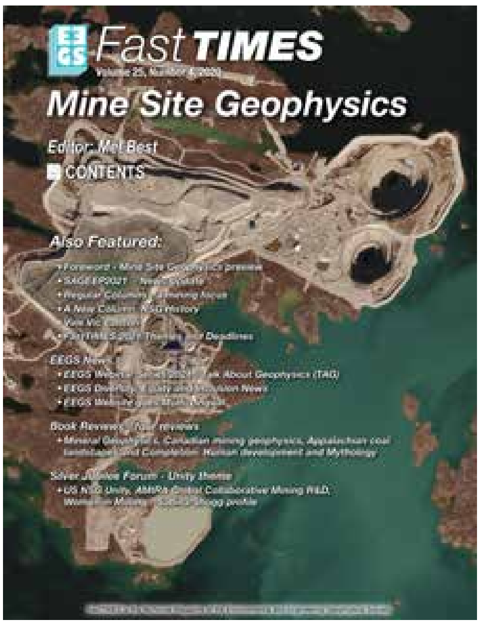


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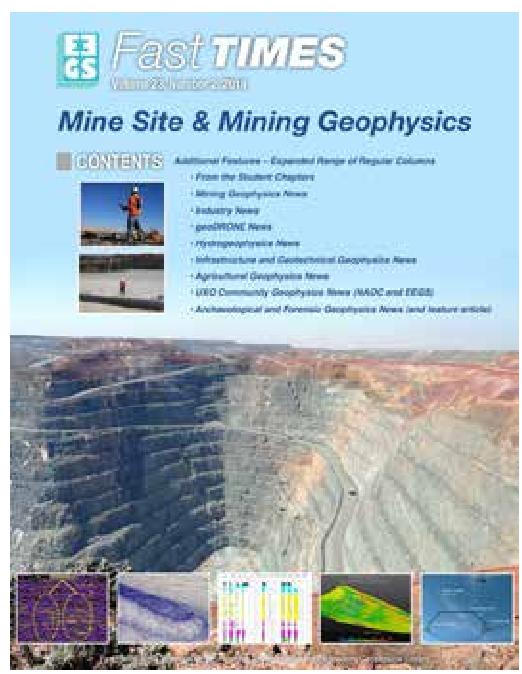



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