33rd Annual David S. Snipes/Clemson Hydrogeology Symposium
April 3, 2025

High-temperature geothermal energy storage heater array on the Clemson University campus. In A, the borehole heat exchangers after grouting consisting of a central heat exchanger, six heat exchangers on the outside, temperature monitoring boreholes, and steam extraction wells. In B, the borehole heat exchanger array after being plumbed and insulated. A roofed structure overhead prevents rain infiltration from cooling the heat stored in the vadose zone.

Department of
ENVIRONMENTAL ENGINEERING
AND EARTH SCIENCES
Clemson University

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Zoom link:

https://clemson.zoom.us/j/94187409037?pwd=2H4UEOs5YfF9zHoIJzlBy2NHF2ZMcD.1

Webinar ID:
941 8740 9037

Passcode:
771705

Main Ballroom

Zoom Link:

https://clemson.zoom.us/j/99082670799?pwd=yQIQk26t6ksaSZ6kUAr5k2Pryhu307.1

Webinar ID:
990 8267 0799

Passcode:
811886

If you have a question for a presenter, please enter your question in the Q&A section of the Webinar rather than the chat to ensure it is seen.

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Meeting Rooms 1&2

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Webinar ID:
913 0051 0007

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270637

Meeting Room 4

Zoom Link:

https://clemson.zoom.us/j/99024718856?pwd=jLpwaX39gkbybAPusQwjx2gFuqbZT2.1

Webinar ID:
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380364

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SPEAKER SCHEDULE

Time	BellSouth Auditorium	Meeting Rooms 1&2	Meeting Room 4
7:15-8:00	**Registration**		
8:00-8:30	**Poster Session**		
	Remediation Moderator: Gary Birk	**Characterization, Site Model Development, and Artificial Intelligence** Moderator: Sarah Asher	**Geotechnical and Geophysics** Moderator: Andy Alexander
8:30	Bountiful Superfund Case Study – Eight Years of Successful Chemical Reduction in Low Permeability Soils aided by Permeability Enhancement **Kessel, Lowell**	Enhancing Environmental Project Workflows with OpenAI Custom Generative Pre-Trained Transformer (GPT) and Palantir Foundry Artificial Intelligence Platform (AIP) Models: Two Case Studies Demonstrating Innovation and Efficiencys **Asher, Sarah**	Overview of Borehole Geophysics Methods for Groundwater Investigations **Rebman, Nick**
8:50	Utilizing High Resolution Design Optimization (HRDO) for an Injection Remedy at Brookley AFB, Mobile, AL **Gerber, Michael**	Conceptual Site Model Development, Source Removal, and Soil Amendment Get a UST Site Closer to Closure **Thompson, Rob**	Geophysical Investigations in Support of Hydrogeologic and Geotechnical Assessments for Landfill Design in Karst Terrane **Bergstrom, Jorgen**
9:10	Passive and Solar-Powered Bioventing Implementation to Augment Natural Source Zone Depletion (NSZD) of Petroleum Light Non-Aqueous Phase Liquids (LNAPL) in the Subsurface **Wheeler, Kevin**	Leveraging Digital Processes to Streamline Complex Assessment Projects **Grant, Jeremy**	Geophysical Evaluation of the Line Street Cemetery, Melbourne, Florida to Locate Unmarked Graves for Cultural Heritage Preservation **Brantley, Duke**
9:30	Multi-Technique Remediation of Chlorinated Groundwater Plume: Heat-Enhanced Bioremediation, ISCR, Bioaugmentation, and Performance Monitoring **Birk, Gary**	Applications of Environmental Sequence Stratigraphy (ESS): Decision Making and Planning Field Work **Dunn, William (see abstract for Andrews, Trevre)**	Validation of Seasonal High Groundwater Levels for Earthen Structure Design **Blais, Riley**
9:50	Utilizing Blind Horizonal Wells for a Variety of Remediation Applications **Shinall, Brian**	High-Volume Sub-Slab Sampling is more than just a Vapor Intrusion Tool, it is an Effective Tool for Developing CSMs **Olver, Klynt**	Geotechnical Case Study of a Wick Drain System beneath a Constructed Soil Embankment **Vastag, Johnny**

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Time	BellSouth Auditorium	Meeting Rooms 1&2	Meeting Room 4
10:10	Multiphysics simulation of plume transport with viscous fingering in geomechanically sensitive aquifers **Jha, Birendra**	Using Machine Learning for Analyzing Important Hydrogeological Phenomenon from Building a Forward Model to Mapping Salt Intrusion in the Biscayne Aquifer **Arhin, Henry**	Geotechnical Analysis for Construction of a Subway in High Water Content Soils **Garcia, Ernesto**
10:30 - 11:00	**Poster Session**		
11:00 - 12:00	**Keynote Address: Main Ballroom** Advances in Geological Storage of Carbon Dioxide in Deep Geological Formations **Sally Benson,** Department of Energy Sciences and Engineering, Stanford University, Stanford, CA		
12:00 - 1:00	**Lunch: Main Ballroom**		
	PFAS Moderator: Bob Kelley	**Energy Storage, Strainmeters, and Carbon Sequestration** Moderator: Ron Falta	**Water Supply and Sources** Moderator: Simon Kline
1:00	Optimizing PFAS Remediation Strategies from Lab to Field **Smith, Jacques**	High Temperature Subsurface Thermal Energy Storage **Falta, Ron**	Reclaimed Limestone Quarries: Potential Groundwater Resource for the Future **Foldesi, Christopher**
1:20	Developing Equilibrium Removal Isotherms of Base Carbons for Colloidal Carbon PFAS Adsorption **Kelley, Robert**	Utilizing Distributed Temperature Sensing for Underground Thermal Energy Storage Monitoring **Grant, Josh**	Evaluating a Former Quarry for a Piedmont Raw Water Storage Site: Geological, Geochemical, and Hydrogeologic Insights **Kline, Simon**
1:40	Lights, Catalyst, PFAS: How Long Can the Magic Last? **Mason, Marc**	Subsurface Thermal Energy Storage and Removal of Steam During Initial Heating **Heyer, Mark**	Assessing Water Accessibility and Quality in Kagarama, Rwanda: A Field Study by Engineers Without Borders **Branch, Owen**
2:00	An Enhanced Look at EPA 1633 and PFAS Data Quality Objectives **Boone, Lindsay**	A Strainmeter Array Used to Evaluate Well Tests at a Deep Aquifer **Murdoch, Larry**	Decentralized Runoff Management **Evans, Andrew**

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2:20	Stormwater Runoff as a Pathway for Per- and Polyfluoroalkyl Substance (PFAS) Transport **Salawu, Omobayo**	Life Cycle Assessment of the Carbon SIRGE approach **Carbajales-Dale, Mik**	**No Show**
2:40 - 2:50	**Poster Session**		
	Bioremediation Moderator: David Freedman	**Iodine/Boron Removal** Moderator: Jacques Smith	**Foraminifera, Hurricanes, and Response** Moderator: Josh Bregy
2:50	Identification and Enhancement of Naturally Occurring In-Situ Aerobic Metabolic Biodegradation of 1,4-Dioxane **Robinson, Michael**	Innovative and Cost-Effective Boron Absorbent Media **Butler, Julia**	Grassroots Rapid Response to Hurricane Helene **Petitt, Destini**
3:10	High-Permeability Zone Volume Fraction and First-Order Rate Constant Effects on 1,4-Dioxane Degradation in Simulated Aquifer-Aquitard Systems **Romero, Juan**	Batch Sorption Analysis of Iodine in Selected Biochars and FerroBlack™ **Erard-Stone, Emily**	Foraminifera Fidelity to Environmental Settings: A Meta-Analysis of Foraminiferal Assemblages from the Southeastern United States **King, Abbegail**
3:30	Investigating Biodegradation of 1,4-Dioxane and Co-Contaminants by Pseudonocardia BERK-1 **McCourt, Kelli**	Sustainable Approach for Boron Stabilization in Coal Combustion Wastewaters **Oladipo, Olajide**	Examining Foraminiferal Microfossils to Provide Evidence of Prehistoric Hurricanes at Topsail Hill National Park in Florida **Diaz, Denise**
3:50 - 4:00			
	Bioremediation Moderator: Lowell Kessel	**Water Quality and Iron Chemistry** Moderator: Brian Powell	**Geochronology, Fractures, and Social Networks** Moderator: Alex Pullen
4:00	Evaluation of Strategies to Remediate Mixed Wastes at an Industrial Site in Brazil **Jimenez, Jimena**	Comparative Analysis of Water Quality Degradation in Streams Originating in Blue Ridge and Piedmont Watersheds in Upstate South Carolina and North Carolina **Gilfillan, Abby**	Petrographic and Geochronological Investigation of the Contact Between the Poor Mountain and Chauga River Formations in the Upstate, South Carolina **Duncan, Jackson**

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Time	BellSouth Auditorium	Meeting Rooms 1&2	Meeting Room 4
	Bioremediation Moderator: Lowell Kessel	**Water Quality and Iron Chemistry** Moderator: Brian Powell	**Geochronology, Fractures, and Social Networks** Moderator: Alex Pullen
4:20	Remediation of Emerging Heavy Metal Contaminants from Coal Ash, Including Li, Mo, B, and As **Kessel, Lowell**	Influence of Organic Matter on the Effectiveness of Iron Flocculation **Smith, Evelyn**	Comparison of Fracture Aperture Monitoring using Arduino Based Data Loggers versus Modified Hobo Temperature Loggers **Keesee, Rion**
4:40	Effective, Sustainable In-Situ Remediation Approach at Brownfield Site Using a Combination of Zero-Valent Iron and Emulsified Vegetable Oil **Robert L. Kelley**	Seasonal Variation of Iron Flocculation in Hunnicutt Creek, Clemson, SC **White, Crawford**	Influence of Social Networks on Retention and Recruitment of Geoscience Majors **Oliver, Aster**
5:15	**Mixer at Clemson Outdoor Lab**		

Workshop 3 PM – 5 PM: Main Ballroom

Developing a Basic Site Conceptual Model and Remediation Strategy

Workshop Facilitator: **Joe Rossabi**

Limited to Attendees who signed up prior to the event

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Posters

Location: North Hallway **Online Participants: Access Online Posters**

Multimodal and Multiscale Characterization of Hydrogeochemical Alterations in Carbonate and Clay-rich Sandstones due to Dissolution Reactions with Reactive Brine
Chukwuma, Tracy Amaka

Exploration of the use of iButtons to monitor temperature variations in a bioretention cell
Curl, Allison

Examining Foraminiferal Microfossils to Provide Evidence of Prehistoric Hurricanes at Topsail Hill National Park in Florida
Diaz, Denise

Petrographic and Geochronological Investigation of the Contact Between the Poor Mountain and Chauga River Formations in the Upstate, South Carolina
Duncan, Jackson

Applications of Environmental Sequence Stratigraphy (ESS): Decision Making and Planning Field Work
Dunn, William (see abstract for Andrews, Trevre)

Piedmont and Blue Ridge Stream Water Quality Comparison
Gilfillan, Abby

Organoclay Synthesis, Characterization, and Use in Iodate Sorption
Goellner, Bennet

Foraminifera Fidelity to Environmental Settings: A Meta-Analysis of Foraminiferal Assemblages from the Southeastern United States
King, Abbegail

Comparison of Fracture Aperture Monitoring using Arduino Based Data Loggers versus Modified Hobo Temperature Loggers
Keesee, Rion

Sustainable Approach for Boron Stabilization in Coal Combustion Wastewater
Oladipo, Olajide

Influence of Social Networks on Retention and Recruitment of Geoscience Majors
Oliver, Aster

Investigating Adsorption as a Mechanism for Perchlorate and Nitrate Removal in Planted Bioreactors
Oseni, Oyindamola

High-Permeability Zone Volume Fraction and First-Order Rate Constant Effects on 1,4-Dioxane Degradation in Simulated Aquifer-Aquitard Systems
Romero, Juan

Influence of Organic Matter on the Effectiveness of Iron Flocculation
Smith, Evelyn

Seasonal Variation of Iron Flocculation in Hunnicutt Creek, Clemson, SC
White, Crawford

Passive and Solar-Powered Bioventing Implementation to Augment Natural Source Zone Depletion (NSZD) of Petroleum Light Non-Aqueous Phase Liquids (LNAPL) in the Subsurface
Wheeler, Kevin

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Workshop

Developing a Basic Site Conceptual Model and Remediation Strategy
Leader: **Joe Rossabi**
Location: Main Ballroom

Goal

This workshop will provide you with the basic tools and strategies to assess and develop remediation plans for contaminated sites.

Overview

You will learn practical strategies for gathering, interpreting, verifying, and prioritizing site characterization data to help develop a useful conceptual model. You will use those data to develop site remediation strategies.

Modules

Site Characterization

Typical site characterization and monitoring data (e.g. well, direct push, historical, etc.) will be presented and provided to workshop participants. You will review these data, discuss advantages and limitations of each type as well as the ensemble, and determine if additional data are necessary for the terminal objectives (e.g., develop report for regulators, clients, and other stakeholders, develop remediation strategy or bid package, etc.).

Conceptual Model Development

Data from real world sites will be provided. You will work through the basic steps to achieve the most common objectives. Conceptual model development will involve using weight of evidence.

Remediation Strategy

The most appropriate and most common strategies for access and remediation (e.g., injection, soil mixing, redox manipulation, biological enhancement/augmentation, heating, etc.) will be reviewed and discussed based on likely effectiveness and cost. The overall goals of removal, destruction, isolation, or reduction of contaminants will be evaluated in the context of Stakeholder objectives.

How to sign up:

All Clemson Hydro Symp in-person registrants will be sent an email with a link to sign up on March 2. The workshop is limited to the first 25 respondents. You will be sent an email that serves as your workshop registration confirmation.

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Snipes Fund

Dave Snipes in Limestone Quarry, Kansas, 1954

Dr. David Snipes organized the first Clemson Hydrogeology Symposium (affectionately called the Sniposium) in 1992. After his death in 2005, a fund was created in David's memory to provide graduate fellowships in hydrogeology at Clemson. Since that time, generous donors have given over $30,000 and the fund has appreciated about $10,000, generating about $1,500 per year for graduate fellowships. Please make a gift to this fund to increase the amount we can award to graduate students and honor David's legacy.

Please consider matching other donations as an individual or a company. As a matching sponsor, you can set the terms of your match (how much you match; at what exchange) and you can remain anonymous if you desire.

To make a donation, visit this website and donate to the Dr. David S. Snipes Memorial Student Assistance Endowment (code B2949).

https://cualumni.clemson.edu/giving/snipes

Career KickStarter

In the Main Ballroom from 3:30 to 5:00

The Career KickStarter is a networking event designed to create an opportunity for students to experience professional development, receive career advice, and develop a lasting professional network with experts in their field based on shared interests.

Quotes from alumni who have attended the Career KickStarter in the past:

"My mentor helped me connect with valuable people from different companies I was interested in, how to handle conversations in interviews, what happens when you eventually get a job offer, and how to pick between multiple employment offers."
-Noelia Muskus, Clemson '17, Geosyntec Consultants

"Participating in the Clemson Career KickStarter gave me the opportunity to speak with individuals from a multitude of career paths in a relaxing setting. My mentor took the time to get to know me and connect me with a number of events in NC and SC, giving me the ability to gain interviewing and networking skills that still help me in my professional career today."
-Rachel Capps, Clemson '19, Terracon Consultants

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Keynote Presentation

Advances in Geological Storage of Carbon Dioxide in Deep Geological Formations

Benson, Sally, smbenson@stanford.edu, Department of Energy Sciences and Engineering, Stanford University, Stanford, CA

Capturing carbon dioxide and storing it in deep underground geological formations is one of the most important approaches for reducing emissions of greenhouse gases into the atmosphere. Recent studies indicate that globally about 10 Gt/year of CO2 storage may be required by the middle of the century, including about 1 Gt/year in the U.S. Managing subsurface storage of this much CO2 requires the ability to characterize the storage potential of geological formations, predict and manage CO2 plume migration and pressure buildup, and monitor the fate and transport of CO2 in the subsurface. This presentation will provide an overview of recent advances in CO2 storage science and engineering, including new results from the GeoCquest Field Validation Test being conducted in Australia.

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Abstracts

Ordered by last name of first author

Applications of Environmental Sequence Stratigraphy (ESS): Decision Making and Planning Field Work

Andrews, Trevre, trevre.andrews@jacobs.com, Jacobs Engineering Group, Minneapolis, MN; **William Dunn, Wyatt Nolan** and **Simon Kline,** Jacobs Engineering Group, Atlanta, GA

Knowing when to use which tool at an environmental site is one of the most important jobs of the environmental manager. Decision trees are useful to this end to identify sites where the practice of Environmental Sequence Stratigraphy (ESS) would benefit the conceptual site model (CSM) and/or inform additional site characterization when applied. In this presentation the ESS decision tree was used to decide how and to what degree to apply ESS to two site investigations with disparate data set sizes. The first application was to locations for additional soil borings and monitoring wells to better characterize groundwater and contaminant pathways with multiple release areas with highly soluble recalcitrant compounds spread over a large spatial area. The second application used ESS to develop preliminary site cross sections for use by field geologists at a catastrophic release site where no borings were available. The application of ESS helped identify likely depositional environments, preferential pathways, and maximum drilling depths. Each of the two applications were put through the ESS decision tree process to screen the applicability and extent of ESS application to the site, where it might provide benefit, and what level of effort should be applied to the site based on the data available and the site objectives.

For the first site the ESS decision tree was used to define the spatial extent of the ESS analysis and the number and type of borings which would be included in the updated ESS geologic model. Although more than 300 borings were available at the site, only borings with continuous logging data and with sufficient depth were utilized to update the geologic model. Taking these boring data, an interactive three-dimensional conceptual model was developed and used to update the hydrogeologic portions of the ESS CSM. This included identifying the likely presence of sand channels, lagoon, swamp, deltaic, and interbedded deposits that comprise the subsurface. The model identified likely separation of perched and regional aquifers based on the discontinuities in depositional sequences and identified the likely orientation of preferential pathways in channel deposits allowing more strategic placement of proposed future characterization borings as well as recommended installation depths for those borings.

For the second site, the decision tree was used to identify analogous regional depositional environments to briefly provide enough potential ESS characterization to identify the major expected soil types, their distribution in the overburden, and the extent and connection of any preferential pathways within the depositional environments. Using this information in combination with site topography, preliminary field cross sections were created that field staff could use to inform real time decision making.

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Using Machine Learning for Analyzing Important Hydrogeological Phenomenon from Building a Forward Model to Mapping Salt Intrusion in the Biscayne Aquifer

Arhin, Henry, harhin@g.clemson.edu, Clemson University, Clemson, SC

Advances in machine learning have enabled its application towards a wide range of hydrogeological phenomena. I developed a forward model using strain datasets that uses inversion to estimate subsurface permeability and its influence on fluid flow. Additionally, I applied machine learning techniques to investigate the key factors causing saltwater intrusion into the Biscayne Aquifer. By integrating data-driven approaches with hydrogeological modeling, I aim to enhance understanding of subsurface processes and their implications for water resource management.

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Enhancing Environmental Project Workflows with OpenAI Custom Generative Pre-Trained Transformer (GPT) and Palantir Foundry Artificial Intelligence Platform (AIP) Models: Two Case Studies Demonstrating Innovation and Efficiency

Asher, Sarah, sarah.asher@jacobs.com, Jacobs, Atlanta, Georgia; **Todd Kremmin,** Jacobs, Minneapolis, Minnesota; **Alex Mahrou**, Jacobs, Cleveland, Ohio; **Mike Brown**, Jacobs, San Diego, California; **Andrea Pearce,** Jacobs, Boston, Massachusetts; and **Kevin Murphy**, Jacobs, San Diego, California

The advent of large language models (LLM's) through OpenAI's Generative AI (GenAI) custom GPT models and Palantir Foundry's AIP, have ushered in a new era of efficiency and innovation in environmental project workflows. These GenAI-driven tools are designed to tackle a wide range of tasks, from data analysis and compliance checking to documentation review and report generation. This presentation explores the development and implementation of two applications, 1. An OpenAI custom GPT model tailored specifically for environmental projects and report review and 2. A data extraction tool pertaining to boring logs using Palantir Foundry AIP. Both highlight the transformative potential and practical applications of GenAI.

Case Study #1: The "Environmental Document Reviewer (California)" custom GPT exemplifies how GenAI can revolutionize regulatory compliance processes. This tool is capable of swiftly analyzing environmental documents to ensure adherence to California's stringent regulatory requirements. By automating the review process, it enhances accuracy, reduces time, and minimizes human error, thus ensuring that environmental projects meet all necessary criteria for approval and implementation, before being submitted to regulatory agencies. Upon reviewing the documents, the custom GPT generates a downloadable .xlsx file containing detailed feedback, comments, and recommended edits for compliance and improved defensibility. It also cross-references laboratory analytical data results with California state limits and provides notifications if any values exceed those limits.

Case Study #2: The "Log Extractor AI" application is leveraged to meticulously extract and compile data from historical environmental soil boring or lithology logs. The AI application intakes large text-based PDFs and parses out location name, depths, USCS classifications, and descriptions to a .csv file. This GenAI tool is beneficial primarily because it provides a comprehensive, consistent and automated process

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of extracting and compiling data from boring or lithology logs, significantly reducing the time and effort required compared to manual data extraction. This capability allows environmental consulting firms to allocate resources more efficiently and focus on higher-level analysis and decision-making, rather than routine data extraction tasks.

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Geophysical Investigations in Support of Hydrogeologic and Geotechnical Assessments for Landfill Design in Karst Terrane

Bergstrom, Jorgen, jbergstrom@colliergeophysics.com, Collier Geophysics, Marietta, Georgia; and **T.J. Daniel,** BLE, Greenville, South Carolina

Constructing landfills in areas with karst terrane requires detailed geotechnical and hydrogeologic assessments to ensure that the design includes elements to address structural stability and environmental competency.

The presence of karst features such as cover collapse and cover subsidence sinkholes, rock pinnacles, and cutters can pose potential risks to the structural integrity of landfill liner systems, stormwater collection systems, create site-specific safety hazards, and pose challenges to the design of an effective environmental monitoring system.

A combination of hydrogeological and geotechnical borings, piezometers, and electrical resistivity imaging (ERI) geophysical surveys are often used to investigate these sites and to identify key subsurface features such as perched and stabilized groundwater, depth to competent rock, and potential limestone dissolution features.

This presentation will focus on the geophysical techniques for the collection and evaluation of the data necessary to identify these subsurface features and align the findings with those from invasive hydrogeologic and geotechnical assessment methods.

Multi-Technique Remediation of Chlorinated Groundwater Plume: Heat-Enhanced Bioremediation, ISCR, Bioaugmentation, and Performance Monitoring

Birk, Gary, gary.birk@tersusenv.com, Tersus Environmental, Wake Forest, NC; and **David Alden,** Tersus Environmental, Worcester, MA

This study investigated the remediation of a groundwater plume impacted by chlorinated compounds, including carbon tetrachloride (CT), perchloroethylene (PCE), and their respective breakdown products, such as chloroform (CF), dichloromethane (DCM), trichloroethylene (TCE), cis-dichloroethene (c-DCE), and vinyl chloride (VC). The approach combined In Situ Chemical

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Reduction (ISCR) with Reductive Bioremediation, utilizing a bioaugmentation culture containing key dechlorinating bacteria (Dehalococcoides mccartii, Dehalobacter) and functional genes (CfrA, DcrA, TceA, VcrA, and BvcA) essential for the anaerobic reductive dechlorination of these contaminants. Additionally, Heat-Enhanced Catalyzed Reductive Bioremediation (HECRB) was evaluated to assess its effect on optimizing the dechlorination process, with a focus on maintaining optimal temperatures for microbial activity and dechlorination, as well as promoting Volatile Fatty Acid (VFA) production critical for contaminant transformation.

The remedial strategy included the use of direct push technology (DPT) for the targeted distribution of amendments, such as zero-valent iron (ZVI), electron donors, micronutrients, and pH buffers, which formed linear injection barriers throughout the plume. Large batch soluble amendments were also injected into permanent wells upgradient of the source zone to enhance treatment accessibility. Periodic performance monitoring was employed to assess both abiotic and biotic treatment progress through a suite of geochemical and molecular genetic tools. qPCR testing quantified populations of dechlorinating bacteria and associated functional genes, tracking the evolution of microbial cultures capable of transforming the constituents of concern. Next Generation Sequencing (NGS) was also used to provide a deeper understanding of microbial community dynamics, treatment effects, and ecological roles over time and across space.

The discussion will include project results, including key findings from performance monitoring, and provide conclusions regarding the effectiveness of the integrated remediation approach. Additional performance indicators, including Compound-Specific Isotope Analysis (CSIA) and Volatile Fatty Acids (VFA) analysis, are employed to track the progress of dechlorination and identify any potential inhibitory effects or incomplete degradation processes. CSIA, in particular, provides insights into the abiotic and biotic contributions to contaminant mass reduction by monitoring shifts in isotopic signatures (δ13C) of key target compounds, such as CT, CF, DCM, PCE, TCE, c-DCE, and VC.

Preliminary results from baseline and post-injection groundwater sampling events highlight the efficacy of combining ISCR with bioaugmentation and HECRB in promoting the breakdown of chlorinated contaminants. Findings will be presented, including changes in microbial communities, contaminant isotopic composition, and VFAs.

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Validation of Seasonal High Groundwater Levels for Earthen Structure Design

Blais, Riley, riley.blais@blecorp.com, **Zach Downes,** and **Andrew Alexander,** BLE, Greenville, South Carolina

Hydrogeological investigations are required as part of the design and permitting processes for earthen structures such as solid waste landfills in the United States. The investigations require many elements including characterization of the geology, depths to bedrock, depths to groundwater, hydraulic conductivity, and determination of groundwater flow direction, and other relevant parameters.

Design of a solid waste facility subgrade is controlled by the depths to bedrock and/or groundwater. Measurement of a seasonal high groundwater level is required for design purposes. The requirements for the length of time and quantity of measurements required to establish a seasonal high groundwater level vary from state to state. Some states require depth to groundwater measurements over a period of one calendar year, others only require measurements over a period of three months, or there may be no specification

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for a specific period, or for the quantity of measurements.

Seasonal high groundwater levels may be validated by many methods including comparison to historical local or regional groundwater levels, evaluation of drought conditions, and/or evaluation of precipitation records during the time of water level measurement. When historical local or regional groundwater levels are not available, the evaluation of drought conditions and/or precipitation records should be considered. If seasonal high groundwater levels are not validated or technically sound, the seasonal high water level surface utilized for design may be artificially low which could result in a compromised design unless a correction factor is applied.

This study will focus on the techniques to generate a seasonal high-water level, the collection and evaluation of drought indices and precipitation data, and statistical techniques to validate seasonal high groundwater levels for use in permitting and design. Techniques for calculation of a seasonal high correction factor will also be discussed.

An Enhanced Look at EPA 1633 and PFAS Data Quality Objectives

Boone, Lindsay, lindsay.boone@pacelabs.com, Pace Analytical Labs, West Columbia, SC

PFAS test methods continue to evolve. US EPA finalized EPA 1633 on January 31, 2024. This method is "performance-based," which means that modifications may be made without additional EPA review to improve performance (e.g., overcome interferences, or improve the sensitivity, accuracy, or precision of the results) provided that all performance criteria in this method are met. Performance based methods could vary from lab to lab on how certain samples are handled. For example, high TSS samples can cause issues with EPA 1633 and how the laboratory chooses to approach these samples can affect parameters such as reporting limits. This presentation will cover the pros and cons of EPA 1633 and how to ensure your data quality objectives are met when working with your analytical partner.

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Assessing Water Accessibility and Quality in Kagarama, Rwanda: A Field Study by Engineers Without Borders

Branch, Owen, ob@clemson.edu, and **Anna Hughey,** Clemson University, Clemson, SC; **Erin Kinsey,** Engineers Without Borders, Greenville, SC; **Regan O'Neill, Joshua Taylor,** and **Elijah Wilbanks,** Clemson University, Clemson, SC

Clemson's Engineers Without Borders (EWB) chapter conducted a hydrogeological assessment in Kagarama, Rwanda, to evaluate water accessibility and quality for a rural community primarily reliant on a natural spring. The spring serves roughly 1500 people, yet even the closest household spends over 30 minutes retrieving water, highlighting significant accessibility challenges. Due to the region's remote location and limited data availability, an in-person evaluation was essential.

Key hydrologic measurements included a spring flow rate of 4.36 L/s, water transport methods, and consumption patterns of the community. Community members primarily use Jerry cans to collect and carry an average of 20 liters per person per day. Water quality testing confirmed the presence of E. coli, fecal coliforms, and total coliforms, posing significant health risks and underscoring the need for improved treatment solutions.

Additionally, an assessment at G.S. Musave, a local school with approximately 3600 students, highlighted infrastructure challenges. The school relies on a 5000-liter storage tank that is filled only during intermittent water supply periods, requiring the school to rely on costly water transportation methods to supplement the supply.

This study provides critical hydrological data to inform the design of sustainable water infrastructure solutions, emphasizing the intersection of groundwater management, public health, and community resilience in resource-limited settings.

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Geophysical Evaluation of the Line Street Cemetery, Melbourne, Florida to Locate Unmarked Graves for Cultural Heritage Preservation

Brantley, Duke, office@reedtechinc.com, Reed Tech Geophysical, Columbia, SC; and **Kimberly Nagle**, S&ME, Columbia, SC

The Line Street Cemetery in Melbourne Florida was a lost and overgrown cemetery until residents uncovered and revealed two grave markers during a clearing operation in 1980. After the discovery, a Boy Scout group continued the clearing efforts revealing more grave markers, the earliest legible maker dating back to the late 19th century. The well-intentioned Boy Scouts spent three weeks cleaning up the cemetery, cementing newly discovered headstones and footstones in the ground and, at some point, a perimeter chain link fence and sign were erected. The initial archival research and site investigations by S&ME found a history of the first black pioneers of the City of Melbourne. The cemetery includes the grave of William Wright Brothers, one of the recognized original settlers of Melbourne and examples of carved cross stones and elements that are consistent with African American burial traditions. Both the William Wright Brothers grave and the carved elements of other markers deem the site eligible for inclusion in the National Register of Historical Places.

Additional findings from S&ME's archival research and site investigation included discrepancies in the recorded narrative size versus mapped size of the cemetery, headstones and footstones oriented at angles, not east/west, and a history of the markers being moved from their original locations. A systematic probing was also unable to confirm the 12 "marked" grave locations. For these reasons, S&ME recommended a geophysical survey be conducted to 1) aid in the location/orientation of the "marked" graves inside the fenced perimeter, 2) investigate the entire parcel for unmarked graves in and beyond the fenced perimeter, and 3) delineate the boundary of the cemetery to include the unmarked graves. Sandy Ramseth of the City of Melbourne Community Development Department applied and was granted The Abandoned African American Cemeteries Grant, used to fund the geophysical evaluation.

Geophysics offers a non-destructive/non-invasive rapid way to investigate large areas for unmarked graves. For this study, a two-pronged approach was taken using multi-frequency electromagnetic induction profiling and ground penetrating radar geophysical methods. These complementary methods take a macro to micro (respectively)

approach and help reduce oversight/non-detection and help increase result confidence. Using these methods, the Line Street Cemetery lot, an approximately 0.8-acre area, was evaluated, and all detected graves were field marked and mapped. As a result of the geophysical evaluation, a total of 13 graves were found inside the existing fence area and an additional 31 graves were located outside of the fence. The data suggests that the cemetery is spatially much larger than previously

believed and that the cemetery extends to the north and east beyond the current fenced boundary. The geophysical data from this project will 1) aid in the effort for the resources to be included in the National Register of Historic Places to better preserve the memory and legacy of the early Black pioneers, and 2) establish a new cemetery boundary for this preservation effort.

This presentation aims to discuss the benefits and limitations of using multi-frequency electromagnetic induction profiling and ground penetrating radar methods for locating unmarked graves.

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Innovative and Cost-Effective Boron Absorbent Media

Butler, Julia, julia.butler@siremlab.com, **Rosemary Le,** and **Jacques Smith,** SiREM, Knoxville, TN

Boron naturally occurs as borates in oceans, sedimentary rock, and some soils and are released into the environment through weathering and anthropogenic processes. Anthropogenic sources include agricultural runoff, industrial processes, landfills and coal combustion residual (CCR) impoundments. Although it is well recognized as a micronutrient, boron is classified as a moderate to highly toxic element in aquatic environments and due to its high mobility in water, it easily enters surface- and groundwater systems. As such, boron is used as an indicator of CCR impacts to groundwater due to its elevated concentration within CCR materials and is currently included as a detection monitoring constituent under the Federal CCR Rule (40 CFR 257 Subpart D) and may be added to the list of assessment monitoring constituents. If boron is part of assessment monitoring programs, exceedances would need to be addressed to satisfy applicable remedy selection criteria. Additionally, some states regulate boron in groundwater and/or drinking water, with variable compliance criteria. Current options for in situ treatment of boron via remedial technologies such as permeable reactive barriers (PRBs) are limited by low efficiency of boron removal or high costs.

This presentation will highlight initial testing of an absorbent media using a two-phased column treatment system. The initial test evaluated groundwater collected from a site which is impacted by boron and other CCR constituents to simulate field treatment conditions as closely as possible. In addition, data from a bench treatability study using the absorbent media as a permeable reactive barrier to remove boron and other metals from non-CCR groundwater will be presented.

Results from the column study found that boron concentrations were reduced from 30 mg/L to less than 2 mg/L for approximately 230 pore volumes. This resulted in a boron loading rate similar to those observed for commercially available ion exchange resins. Testing was also completed to evaluate boron behavior under post-closure conditions, with artificial groundwater representing background conditions with no boron passed through the column. Desorption equilibria in the media allowed leaching that approximated the breakthrough concentration, suggesting concentration reductions will be maintained long-term.

Evaluating the media as a PRB to treat site groundwater resulted in successful treatment of not only boron, but also cobalt, selenium and manganese. The results suggest that

the patented boron removal technology is a promising cost-effective alternative to currently available commercial technologies, and SiREM continues to evaluate the applicability of this removal technology for both in-situ and ex-situ applications.

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Life Cycle Assessment of the Carbon SIRGE Approach

Carbajales-Dale, Mik, madale@clemson.edu, and **Lawrence Murdoch,** Clemson University, Clemson, SC

Carbon SIRGE is a simultaneous climate mitigation and adaptation strategy that sequesters carbon dioxide in biomass within the subsurface while providing flood control by raising ground topology.

This talk presents a life cycle assessment (LCA) to evaluate the potential environmental impacts of CarbonSIRGE and compare them with direct air capture and sequestration of carbon dioxide.

Examining Foraminiferal Microfossils to Provide Evidence of Prehistoric Hurricanes at Topsail Hill National Park in Florida

Diaz, Denise, denised@clemson.edu, and **Joshua Bregy,** Clemson University, Clemson, SC; and **Emily A. Elliot** and **Lexie Thornton,** University of Alabama, Tuscaloosa, AL

Foraminifera, single-cell organisms, are critical indicators of past marine flooding events, particularly those caused by hurricanes. During storm surges, foraminifera are transported inland and preserved in overwash deposits within sediment layers, creating a valuable record of prehistoric storm activity. As a proxy for paleohurricanes, reconstructions using foraminifera can contribute to predictive models of hurricane activity and enhancing preparedness in coastal regions.

This research used foraminifera in sediment cores from Campbell Lake in Topsail Hill Park in Florida, to identify past hurricane events. A 4.5-m sediment core was collected in the lake using a vibracore. The sediment core was sampled at 10-centimeter intervals, after which, the samples were processed by measuring the wet and dry weights, dried at 100 °C, and washed before undergoing sample picking. Foraminifera were then isolated from the bulk sample for analysis. The presence of foraminifera at specific depths was used to identify overwash deposits associated with storm surges. Preliminary results revealed no foraminifera within the analyzed sediment core samples, suggesting two possible explanations: either the sampling resolution of 10 centimeters was insufficient to detect thin overwash deposits, or the presence of two 6-meter dunes along the storm surge path to Campbell Lake prevented marine sediments from entering the lake due to insufficient surge height. These findings highlight the need for higher-resolution sampling to reconstruct hurricane events better.

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Petrographic and Geochronological Investigation of the Contact Between the Poor Mountain and Chauga River Formations in the Upstate, South Carolina

Duncan, Jackson, jkdunca@g.clemson.edu, **Scott Brame,** and **Alex Pullen,** Clemson University, Clemson, SC

The published geologic map of the Sunset quadrangle in Pickens County, SC indicates a sharp contact between the Chauga River Formation (CRF) and Poor Mountain Formation (PMF). In the field, picking the exact contact is complicated because the formations exhibit similar lithologies where they meet. As a result, we formulated a hypothesis that the contact is gradational. This hypothesis is based on an interpretation of the parent rocks and the geologic setting of their formation. The parent rock of the CRF is sedimentary, the source is terrestrial, and the depositional environment is nearshore marine. The parent rock of the PMF is more complicated as there is evidence for both oceanic basalt flows and associated volcanoclastic deposition. Both rocks have been highly metamorphosed, so any primary bedding features have been imprinted over.

To test our hypothesis and resolve the discrepancy, we sampled rocks along two separate road traverses where exposures are plentiful. The rocks were assessed using several methods. A hand sample analysis was used to characterize the lithologies. Thin sections were made, and petrographic analysis was conducted. Using the assumption that the PMF rocks would be substantially younger than the terrestrial sediments of the CRF, a geochronology study using extracted zircons was conducted to determine if the age distributions would show intermixing. The results suggest intermixing along the contact and thus evidence for a gradational model.

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Batch Sorption Analysis of Iodine in Selected Biochars and FerroBlack™

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An environmentally inert material is needed to mitigate radioactive iodine leachate from the Savannah River Site (SRS) F-area basins. Biochar, amended granular activated carbon (GAC), and layered double hydroxides (LDH) are promising for this task because they are widely recognized as low-cost materials with strong sorption capabilities. In this study, iodine sorption capabilities were determined for five selected biochars, and a commercially amended GAC with FerroBlack™ and synthetic LDH to evaluate their potential to remove radioactive iodine from the F-area leachate. These materials were evaluated in batch experiments to calculate percent sorption of the three chemical species of iodine present in the F-area leachate: iodide (I-), iodate (IO3-), and a synthesized organo-iodine (OI). Preliminary results indicate that the bone and rice husk biochars have the most significant sorption of both I- and OI out of the selected biochars. The bone char sorbed 56% of the I-, and 75% of the OI, while the rice husk sorbed 63% of I- and 43% of OI. Scanning electron microscopy coupled with energy dispersive spectroscopy was used to compare the morphologies of the sorbents as well as their chemical composition to provide insight into the mechanisms governing iodine sorption. Comparison of the percent sorption of the biochars, and FerroBlack™ and LDH amended GAC with all three chemical species of iodine in the F-area leachate will inform further

investigations with the goal of selecting a material to use at the SRS F-area basins.

Decentralized Runoff Management

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The decentralization of water management offers transformative resilience benefits, including enhanced evaporative cooling, transpiration, and ecological restoration. By strategically incorporating ponds that connect to and from streams, we can leverage these water bodies as natural biological filters. This approach significantly improves infiltration, minimizes erosion, and addresses the excessive phosphorus loading—commonly the rate-limiting nutrient for algal blooms in freshwater systems. In contrast to nitrogen-driven limitations in marine environments, phosphorus management through this method directly benefits river and stream ecosystems.

Decentralized water systems also extend the hydrological benefits to aquifer recharge. By increasing the wet surface area along watersheds, runoff velocity decreases, allowing for enhanced infiltration. This process bolsters groundwater reserves, fosters soil percolation, and ensures aquifers, particularly semi-open ones, are recharged sustainably. Beyond ecological benefits, these systems provide long-term solutions for addressing water scarcity, erosion, and stream health, enabling regions to adapt to the challenges of climate variability.

This abstract proposes a nationwide initiative to implement decentralized runoff management practices, emphasizing the strategic placement of ponds over critical aquifers. Such systems are crucial for securing groundwater resources for future generations while enhancing ecosystem functionality, biodiversity, and water quality. May bring Regenerative Agriculture practices into this idea so that we can minimize wasteful water usage in Ag.

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High Temperature Subsurface Thermal Energy Storage

Falta, Ron, faltar@clemson.edu, **Larry Mudoch,** Clemson University, Clemson, SC; **Chuck Hammock, Andrews Hammock** and **Powell, Macon**, GA; and **Josh Grant, Mark Heyer,** and **Jack Horvath,** Clemson University, Clemson, SC

We are field testing a high temperature subsurface thermal energy storage system at a site on the Clemson campus. The purpose of this project is to show that significant amounts of thermal energy can be stored in the ground at high temperatures (> 100 C) and later recovered for production of electricity or for process heat. The heat is delivered to and recovered from the ground using closed-loop vertical borehole heat exchangers (BHEs) that are similar to those used in geothermal heat pump applications but modified for use in a high temperature environment. These heat exchangers use a food-grade heat transfer fluid instead of water as the working fluid to allow high working temperatures (up to 250 C) without generating high pressures.

Last summer, we drilled a hexagonal array of 7 boreholes to depths of about 33 ft. and installed welded steel U-bends in each borehole. The BHEs were completed using a high temperature cement, with a graphite additive to increase the thermal conductivity. The upper 5-6 feet of each borehole was insulated with foam glass around the U-bends and expanded pearlite to fill the hole. The top foot of each BHE was filled with high temperature

cement.

We also installed 3 thermocouple wells on the interior of the pattern, and two vapor extraction wells to remove steam that will be generated during initial heating. The subsurface U-bends are connected to surface piping that is insulated and routed to a 460 volt, 25 kW electric oil heater that is used to supply the heat to the heat transfer fluid. Heating operations are underway and will continue through at least this summer.

Reclaimed Limestone Quarries: Potential Groundwater Resource for the Future

Foldesi, Christopher, cfoldesi@nutterinc.com, and **David Huff,** Nutter & Associates, Athens, GA

Obtaining reliable water resources in the southeastern United States is becoming more difficult as competition for groundwater and surface water sources increases. Abandoned quarries fed by groundwater offer potential raw water without the complications associated with the development of traditional surface water sources like rivers and reservoirs. The amount groundwater recharged can be significant in quarries completed into productive water-bearing units like limestone. This study evaluates potential groundwater yields, water quality, and water storage of three flooded limestone quarries in Bartow County, Georgia. The quarries were pumped for 30-day periods at rates of 1,500 to 3,000 gallons per minute, while precipitation, evaporation, groundwater levels, pond drawdown, and pond outflows were monitored onsite. A three-dimensional bathymetric model of each quarry pond was generated in GIS from sounding measurements prior to pumping and used to calculate pond volumes and surface areas at each drawdown level. The monitoring and bathymetric data were incorporated into a mass balance model to estimate groundwater yields, which ranged from 0.5 to 1.5 million gallons per day. Higher yields generally occurred in larger basins, after heavy rainfall, and with increased pond drawdown. Water quality sampling conducted before and after the pumping tests indicated the quarry water is generally high quality and will meet drinking water standards with minimal treatment. Numerous other quarries in South Carolina offer potential for raw water sources, but site-specific geologic and hydrologic limitations should be accounted for. Quarries with limited groundwater recharge may still be favorable for storage of other raw water sources.

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Geotechnical Analysis for Construction of a Subway in High Water Content Soils

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The Subway Construction Master Plan for Mexico City was developed in 1960's. About 226 km (140 miles) and 195 stations have been constructed since 1969 which include a combination of routings both above ground and below ground. Main routes cross through downtown areas that include aged buildings and utilities. Difficult soil conditions are present in these areas which are characterized by low strength and high compressibility lacustrine clayey soils, exhibiting natural water content ranging from 400% to 700%. Subsidence effects are also present due to intensive groundwater drawdown caused by Mexico City's water supply well network.

Geotechnical analysis for the planned excavation of the below-ground subway routes considered lateral earth pressure, water pressure, and working loads to identify a stable construction method. A "cut and cover" construction method was developed for several routes. The method

consisted of soil excavation, braced excavations with reinforced concrete diaphragm walls, and pouring horizontal concrete slabs to create a top and bottom structural support. The resulting concrete box was covered and subsequently utilized for construction of the subway infrastructure.

The cut and cover underground box construction also required dewatering systems in the retained soil zone using well points and dewatering wells to make the excavation areas stable. Deformation monitoring of the existing aged buildings and utilities located on the sides of the excavations demonstrated that the excavation and construction activity did not compromise the stability of the nearby structures.

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Utilizing High Resolution Design Optimization (HRDO) for an Injection Remedy at Brookley AFB, Mobile, AL

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The US Air Force (USAF) reportedly used AOC-009 at Brookley Air Force Base (AFB) for burning waste oil, fuel, and solvents during fire training exercises. Contaminants of concern include trichloroethylene (TCE); 1,2-DCA; (cis)-1,2-DCE; and vinyl chloride. In January 2013, an in-situ chemical reduction (ISCR) injection pilot study consisting of in-situ injection of EHC, which is a mixture of micro-scale zero valent iron (ZVI) and food grade organic carbon nutrients. In 2017, a feasibility study was completed and recommended saturated zone residual source area ISCR via soil mixing, elevated concentration plume area ISCR injections, and plume area monitored natural attenuation. This case study addresses the ISCR and enhanced in situ bioremediation (EISB) injections where Delmonico PKS JV LLC teamed with Cascade Environmental and were awarded the project.

A key aspect of the team's proposal was to optimize their approach through high-resolution design optimization (HRDO) to further define contaminant mass distribution versus standard lithology targeting. Membrane Interface / Hydraulic Profiling Tool (MiHPT) borings and confirmation soil and groundwater samples were used to define contaminant mass and lithology and develop three unique injection approaches. A total of 11 MiHPT investigation borings were advanced during the predesign phase of the field work.

The HRDO resulted in a significant but optimized departure from the as-bid scope of work, with both liquid and solid ISCR amendments injected as follows:

1. Area 1: Source area with EHC/DPT injections Mg(OH)2 and DHC
2. Area 2: Outside source area with EHC/DPT Mg(OH)2 and DHC
3. Area 3: EISB with ELS - DHC and Buffer NaHCO3
4. Area 4: ISCR-BIO-GEO with Geoform soluble + DHC

The pre and post HRDO injection plan and the rationale on the overall injection approach, chemistry selection, and equipment utilized by Cascade will be presented. Additionally post remediation data will be presented from the first and second quarters of 2023, and later sampling

events as available. Lessons learned during the HRDO, design, and injection will also be presented.

Comparative Analysis of Water Quality Degradation in Streams Originating in Blue Ridge and Piedmont Watersheds in Upstate South Carolina and North Carolina

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The Blue Ridge and Piedmont provinces in the southern Appalachian Mountains have historically been rural regions with low population densities. However, rapid human development in parts of these regions has led to declines in surface water quality. This study compares water quality characteristics between adjacent Piedmont and Blue Ridge watersheds in upstate South Carolina and North Carolina to identify the primary factors driving water quality degradation. The hypothesis is that streams originating in the Blue Ridge, which primarily drain protected National Forest lands, are less impacted by development activities than those originating in the Piedmont, which drain predominantly private lands with higher urban and agricultural land use.

Water quality data were collected from 2023 to 2025 across multiple watersheds, including Twelve Mile Creek, Eighteen Mile Creek, and Three and Twenty Creek in the Piedmont, and the Chauga River and Chattooga River in the Blue Ridge. In-situ measurements of temperature, conductivity, total dissolved solids (TDS), pH, dissolved oxygen, and turbidity were collected using a YSI multiparameter sonde. Laboratory analyses were conducted to quantify nitrate, nitrite, ammonia, phosphate, and E. coli concentrations. Watershed delineation and land cover assessments using GIS were correlated with stream reaches exhibiting elevated contamination levels.

Results indicate that Piedmont streams, particularly Eighteen Mile Creek and Three and Twenty Creek, exhibited significantly higher levels of nutrients (nitrate, ammonia, and phosphate) and bacterial contaminants (E. coli and coliform) compared to Blue Ridge streams. These elevated contaminant levels were strongly associated with higher percentages of urban and agricultural land use in the Piedmont watersheds. Particularly, Clemson University's agricultural activities near Eighteen Mile Creek and Three and Twenty Creek were linked to increased nutrient and bacterial contamination. In contrast, Blue Ridge streams, which drain predominantly forested and protected lands, showed minimal contamination, leading to the decision to focus sampling efforts on the Piedmont after the initial round of data collection.

Seasonal trends indicated higher concentrations of E. coli and phosphate during the summer months, likely due to increased agricultural runoff and recreational activities. These findings support the hypothesis that land use and development activities, particularly on private lands, are major drivers of water quality degradation. The study underscores the importance of targeted land management practices and conservation efforts to mitigate the impacts of human development on surface water quality in the Piedmont.

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Leveraging Digital Processes to Streamline Complex Assessment Projects

Grant, Jeremy, jeremy.grant@aecom.com, AECOM, Columbia, SC, **Robin Mikeal,** AECOM, Charlotte, NC, and **Diana Joyner**, Westinghouse, Hopkins, SC

An effective and adaptable conceptual site model (CSM) drives rapid understanding of a site's dynamic story. Digital data collection, management, analysis and visualization are the four pillars that support the CSM. Westinghouse recognized the importance of implementing a defined procedure that would help in the development and continued refinement of their CSM for the Columbia Fuel Fabrication Facility (CFFF). The team routinely collaborated with regulatory leaders representing community interests and stakeholders along with technical experts from AECOM to compile historical data, evaluate data gaps, develop site investigation plans, and analyze spatial and temporal data distributions.

Many industrial sites struggle with understanding the history and extent of environmental contamination on their property. Further, once environmental impacts have been discovered, a company must consider the potential impacts on neighboring properties and therefore thoroughly investigate the potential for migration. Westinghouse found themselves in this position when they discovered environmental impacts at their Columbia, South Carolina facility. Several multi-media investigations had been performed over multiple decades at the site causing data silos. Lack of effective transfer of historical knowledge and central data storage limited the team and regulatory agency's ability to develop action plans with confidence.

Complex geology, hydrogeology, multiple source areas, and two types of surface water bodies (which effect groundwater flow very differently) resulted in unexpected migration directions. Changing aquifer geochemistry resulted in rapid reductive dechlorination of chlorinated volatile organic compounds (CVOCs).

Westinghouse developed a site-specific procedure according to state and federal guidelines for CSMs. The team implemented a four-phase approach for a digital and dynamic CSM. Westinghouse initiated digital workflows to compile historical data, streamline mobile data collection, centralize data management, and perform routine and variable analysis scenarios. In each of these steps, compatible tools allowed for a seamless flow of new information into the digital CSM. New data was collected using Bluetooth®-enabled digital tools which promoted greater efficiency, quality, and streamlined transfer to the central database. Cloud-based telemetry allowed for near real-time viewing of surface water levels and use of pressure transducers within select monitoring wells allowed for analysis of the groundwater – surface water interaction. Plume statistics were used to demonstrate that the area, mass, and average concentration of the CVOC impacts were increasing, stable or decreasing.

Within each phase, the team collaborated in person and later in virtual meetings (due to COVID) with regulatory oversight agencies to identify and address data gaps that guided additional site investigation. This strategy elevated regulatory collaboration, stakeholder engagement and enabled better decision making using interactive CSMs. Overall, the approach allowed Westinghouse to efficiently address the concerns of their many stakeholders and neighbors relative to the impacts identified on site.

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Utilizing Distributed Temperature Sensing for Underground Thermal Energy Storage Monitoring

Grant, Josh, jvgrant@g.clemson.edu, **Ronald Falta, Lawrence Murdoch,** and **Mark Heyer**, Clemson University, Clemson, South Carolina

Subsurface thermal energy storage is a growing area of research driven by a need for sustainable solutions for energy storage and extraction. The installation of subsurface borehole heat exchangers is one method for adding and removing heat in the subsurface. Distributed temperature sensing (DTS) can measure the temperature distribution along an optical fiber. DTS has the potential to measure temperature distribution in the vicinity of borehole heat exchangers, and these data can then be used to calculate the total amount of energy stored in the system. This would be a useful tool for evaluating subsurface energy storage, but this application has seen limited evaluation. We are conducting a field test where borehole heat exchangers arranged in a hexagonal array are used to store and recover heat at temperatures high enough to generate electricity. The objective of this investigation is to evaluate the use of DTS to characterize thermal energy storage at high temperatures.

The field test uses two separate continuous optical fibers to monitor a borehole array consisting of seven u-bend borehole heat exchangers. These two continuous fibers extend over 300 linear feet through the borehole array. The borings were completed using copper tubing which extends from the surface down to the bottom of the u-bend and then bends 180 degrees back up to the surface. The optical fiber was then deployed pneumatically using an air compressor and motorized spool to push the fiber through the tubing. The fibers were then spliced between borings to create a continuous path. This allows the borings to be completed without the risk of breaking the fiber. This would also allow for the optical fiber to be replaced if it is damaged during operation. One of the optical fibers extends down and back up four of the heat exchangers and the other fiber extends down and up along three temperature monitoring borings deployed within the array of heat exchangers.

The system uses Fiber Core GIMM(50/125)P graded index multimode optical fiber. This fiber is ideal for DTS measurements, and it is coated with polyimide, which gives the fiber a temperature rating of 300 degrees Celsius. Splicing optical fiber with a polyimide coating is particularly challenging and typically requires sophisticated equipment to remove the coating. We developed a simple but effective method to remove the coating in the field using a specialized solvent and a small heater, which played a key role in the deployment of the fiber.

Temperature is measured continuously along each fiber with the measurement averaged over approximately 1 m of fiber. The initial temperature record for the two fibers consists of three or four symmetric arcs where the temperature increases and then decreases separated by low temperature band readings. The low temperature bands are where the optical fiber extends above the ground surface, and the symmetric arcs are where it goes down and back up the borings. To ensure accuracy and correct for instrument drift, reference coils were created in insulated vessels that can be heated and are continuously monitored by the interrogator. Additional calibration will be done using an array of thermocouples which are deployed next to the DTS fiber. This investigation will give insight into the effectiveness of using DTS for energy storage characterization.

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Subsurface Thermal Energy Storage and Removal of Steam During Initial Heating

Heyer, Mark, mheyer@g.clemson.edu, **Ronald Falta, Larwrence Murdoch, Josh Grant**, and **Jack Horvath,** Clemson University, Clemson South Carolina; and **Chuck Hammock,** Andrews Hammock and Powell, Macon, GA

With the rise of awareness of climate change, the demand for high-efficiency energy storage has become increasingly important. While solar and wind power are ideal energy sources, energy retention remains challenging. Borehole Heat Exchangers (BHEs) are proposed as a storage system offers a solution to the energy retention problem by allowing heat to be stored in the subsurface and extracted during times of low production. Once attached to an energy source, a closed loop filled with a heated heat transfer fluid acts as a medium to transfer heat into or out of the ground. U-bend pipes extend approximately 31 feet below the surface surrounded by a high temperature calcium-aluminate cement mixed with graphite (6:1 by weight). The cement graphite mixture has an experimentally measured thermal conductivity of 2.6 W/m ^{o}C, which enhances thermal conduction with the surrounding subsurface geological system. The system is located above the water table, and the desired temperatures are above the boiling point of water. To achieve higher temperatures, the local pore water must be removed by boiling and evaporation.

During heating, water in the surrounding area evaporates and boils, creating steam. This steam may condense in cooler areas if it is not removed, and the condensate could be pulled back into the heated pattern by capillary pressure, leading to an undesirable "heat-pipe" effect. Drying this zone is pivotal in creating a storage zone with temperatures above the boiling point of water.

With the goal of heating the surrounding formation to at least 120 ^{o}C a key challenge arises as steam is generated. Soil vapor extraction wells are being used to remove steam from the formation, condense it in a chamber. The geometry of the field site was analyzed, and an array of thermocouples were strategically placed to monitor temperatures. Ongoing work will analyze the effectiveness of two vapor extraction wells while a portion of the system will remain untouched to serve as a control area. The aim of this work is to improve our understanding of the heat pipe effect and how to prevent it during high-temperature thermal energy storage.

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Groundwater Potential Zone Controlling Source and Flow Using Multi-Criteria Decision-Making Analysis (MCDMA) Based on Analytical Hierarchical Process (AHP) of Yankari Game Reserve and Its Environs, Northeast Nigeria

NO SHOW

Groundwater plays a crucial role in sustaining ecosystems and meeting the water demands of both human and wildlife populations. This study applies Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) techniques to delineate groundwater potential zones within the unique ecological context of Yankari Game Reserve in Northeast Nigeria. The aim is to comprehensively understand groundwater resources' spatial distribution and variability, aiding in sustainable water resource management. Eleven (11) thematic layer GIS component spatial datasets maps, which include rainfall, lineament, geology, drainage density, soil types, landuse

landcover, slope, curvature, topographic roughness index (TRI), topographic position index (TWI) and topographic wetness index (TPI), were integrated to create a comprehensive database for analysis.

AHP, a multi-criteria decision-making technique, is then applied to assign weights to these factors based on their relative importance in influencing groundwater occurrence. The weighted layers were combined using GIS tools to generate a groundwater potential map, categorizing the study area into high to low-potential zones. After cross-validation with data on the region's groundwater prospects, the output accuracy was 70% and above.

Three classes were identified from the resulting groundwater potential zone map: high, moderate, and low. The results of the analysis found that a moderate groundwater potential zone dominates the study area's 88.11% (2,887.21 km2), high groundwater potential zones dominate 11.85% (388.32 km2), while Low groundwater potential zones dominate 0.04% (1.20 km2) of the study area. Only a small portion of the basin's total area is classified as having very high or very low potential zones.

The study contributes to the scientific understanding of groundwater potential in Yankari Game Reserve and addresses the critical need for water resource management in ecologically sensitive areas. The delineation of groundwater potential zones facilitates informed decision-making for sustainable water supply planning, habitat preservation, and biodiversity conservation. The methodology presented can also serve as a model for similar studies in other regions, fostering a holistic approach to groundwater resource assessment and management. Ultimately, integrating GIS and AHP techniques proves to be a valuable toolset in supporting evidence-based decision-making for the sustainable utilization of groundwater resources in environmentally significant areas like Yankari Game Reserve.

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Multiphysics Simulation of Plume Transport with Viscous Fingering in Geomechanically Sensitive Aquifers

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The coupling between flow and geomechanics is two-way: fluid-to-solid coupling exists via the effective stress and pore pressure and the solid-to-fluid coupling exists via porosity, conductivity, and storativity, which can change during consolidation and stress-induced fracture activation. In case of solutes with viscosity and/or density different from the ambient groundwater, fingering and convective mixing develop at the interface between the two fluids, which strengthens the flow-geomechanics coupling. Fingering leads to stretching of the plume interface and enhanced mixing, which affect plume size and shape and the breakthrough concentrations at wells. Examples of solutes with viscosity/density contrast are methylene chloride, chloroform, MTBE leaking from underground gasoline tanks, TCE, alcohols, ethylene dibromide, jet fuel, diesel, and m-Cresol found in pesticides and antiseptics. Fingering also develops when a remedial fluid is injected, e.g., remediation by steam, surfactants, oxidizing agents, or polymer can produce a plume with a viscosity/density that is different from the viscosity/density of the fluid bank ahead or behind it. In this talk, I will discuss multiphysics modeling tools for simulating fingering-dominated transport in geomechanically sensitive aquifers.

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Evaluation of Strategies to Remediate Mixed Wastes at an Industrial Site in Brazil

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The study was conducted for a large industrial facility Brazil with a complex mixture of constituents of concern (COCs) in soil and groundwater. The objective of the study was to evaluate remediation strategies that include aerobic and anaerobic biodegradation, along with chemical reduction and oxidation. The COCs include chlorobenzene (CB), 1,2-dichlorobenzene (1,2-DCB), 4-nitrotoluene (4-NT), 2,6-dinitrotoluene (2,6-DNT), 4-isopropylaniline (4-IPA), and 1,2-dichloroethane (1,2-DCA) that are present in the part per million range and other chemicals of concern such as 2,4-dinitrotoluene (2,4-DNT), 2-and 3-nitrotoluene (NT), and 1,4-dioxane. Microcosm studies indicated that the site has microbes capable of aerobically biodegrading the chlorobenzenes and mono-nitrotoluenes. The dinitro-toluenes at this site are recalcitrant to aerobic biodegradation but are subject to chemical and microbial reduction to amino-toluenes, which were amenable to chemical oxidation and/or aerobic biodegradation. This suggests a sequential treatment strategy may be the most effective remediation approach, consisting of aerobic biodegradation, followed by anaerobic reduction (abiotic or biotic) and then aerobic biodegradation and/or chemical oxidation. This approach was the most effective in a continuous flow column experiment using site soil.

Approach/Activities. Microcosm studies were developed with soil and groundwater from the site to aerobically degrade CB (5.0 mg/L) and 1,2-DCB (1.0 mg/L) and anaerobically degrade 2,6-DNT (6.0 mg/L) and 4-NT (3.0 mg/L), using enrichment cultures previously developed. Lactate served as electron donor to evaluate the influence of nutrients and pH adjustment. Chemical treatments such as oxidation and sequential reduction and oxidation were also evaluated using sodium persulfate and zero valent iron respectively. Biodegradation rates of CB, 1,2-DCB, 2,6-DNT, and 4-NT enrichment cultures were determined in batch studies that included bi-mixtures of compounds compared to the presence of all compounds. Column experiments that used soil from the site and synthetic groundwater prepared with the COCs at their maximum concentrations were used to evaluate the most effective treatment sequence. Acrylic columns were packed with soil and different layers of oxidant or reductant pre-mixed with soil. Groundwater was pumped continuously. Bioaugmentation involved the injection of aerobic and anaerobic enrichment cultures previously developed. Four treatment strategies were tested (one per column) along with a control column. Oxygen and nutrients were provided, and vegetable oil (ABC) was used as the electron donor.

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Results/Lessons Learned. Microbes with the ability to aerobically biodegrade CB, 1,2-DCB, 2-NT, 3-NT, and 4-NT are present in the shallow portion of the contaminated aquifer at the industrial site. pH adjustment and addition of nutrients was not required to sustain biodegradation activity. The dinitrotoluene isomers, 1,2-DCA, and 1,4-dioxane were recalcitrant under aerobic conditions. However, 2,6-DNT, 2,4-DNT, and 4-NT were readily reduced to amino-toluenes under anaerobic conditions with lactate serving as the electron donor. In batch tests and column experiments, the amino-toluenes were amenable to chemical oxidation and/or aerobic biodegradation. This suggests a sequential treatment strategy may be the most effective remediation approach, consisting of aerobic biodegradation, followed by anaerobic reduction

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(abiotic or biotic) and then aerobic biodegradation coup.

Comparison of Fracture Aperture Monitoring Using Arduino Based Data Loggers Versus Modified Hobo Temperature Loggers

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Measurements of changes in fracture aperture width are critical to assessing the potential for future slope failure events in mountainous regions in the upstate of South Carolina. Off-the-shelf instruments capable of providing continuous fracture monitoring over extended periods require an electrical power source and can be expensive and difficult to deploy in remote areas on steep slopes with limited accessibility. An alternative design is to use open-source hardware that can be customized for specific applications. An example is an Arduino board that can be readily configured at a low cost.

An off-the-shelf linear potentiometer was combined with an Arduino board customized for data logging and powered by a rechargeable 12V 5200mAh lithium battery. The result can continuously log changes in fracture width and ambient temperature at 15-minute intervals for over a year without having to recharge the battery or download the data. The performance of this Arduino based instrument was compared in the field to a Hobo temperature logger hacked to translate movement from an identical linear potentiometer as used in the Arduino system. The Hobo design had been assessed in previous studies to be both reliable and accurate. Analysis of the results indicate that open-source hardware is a viable and robust alternative to off-the-shelf instruments where budget, portability, and the potential for customization are important.

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Developing Equilibrium Removal Isotherms of Base Carbons for Colloidal Carbon PFAS Adsorption

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Per- and polyfluoroalkyl substances (PFAS) are a group of chemicals that have become widespread in groundwater through their use in aqueous film forming firefighting foams and the manufacturing, use and disposal of products including clothing, furniture, pizza boxes, food wrappers, cooking utensils, and much more.

Colloidal Carbon is an activated carbon aqueous dispersion of very fine particles (< 3 ?m) typically contains 15 weight % carbon solids in a stable dispersion that is diluted for injection. The base carbon may be bituminous, lignite or coconut. Base carbon materials lend themselves to unique activated carbon functionalities, but activated carbon features responsible for controlling adsorption mechanisms can be engineered onto a range of base carbon materials. Colloidal Carbon pore volumes and surface area are necessary but are not the only controlling properties required for adsorption of PFAS. The surface characteristics of the activated carbon also play a critical role in controlling capture of PFAS especially for less hydrophobic/more difficult to remove constituents. Molecular diameters of targeted compounds give a first indication of the necessary carbon pore sizes for transport and sequestration while hydrophobicity and charge impact receptivity to capture.

Bituminous activated carbons performed well in capturing" Long Chain" PFOA and PFOS. Single Solute Equilibrium Removal Isotherms show predicted adsorbed concentrations of 0.06

mg/gram for coconut, 0.14 mg/gram for lignite and 9 mg/gram for bituminous at the 70 ng/L (ppt) Historical Health Advisory Limit. Lignite activated carbon performed well in capturing "Short Chain" PFBS. Single Solute Equilibrium Removal Isotherms show adsorbed concentrations of 0.07 mg/gram for coconut and bituminous and 3 mg/gram for lignite at the 2000 ng/L (ppt) Health Index Reference Concentration. This presentation will present the methods, tabulated results and single solute equilibrium removal isotherms showing the performance of activated base carbon materials in adsorption of PFAS.

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Effective, Sustainable In-Situ Remediation Approach at Brownfield Site Using a Combination of Zero-Valent Iron and Emulsified Vegetable Oil

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This brownfield site in North Central Ohio consists of a 7-acre plume located within the unconsolidated zone and includes residual source material under the retail shopping center, surface water and shallow groundwater contamination, and indoor air contamination. The site is primarily an open field surrounded by busy streets in the township, with mixed commercial and residential occupancy. The dry cleaner reportedly discharged an estimated 70 to 150 gallons of tetrachloroethylene (PCE) when a valve on a dry-cleaning machine malfunctioned. Investigations showed that volatile organic compounds (PCE, TCE, and VC) were contaminating the groundwater.

The objective of this phase of the remediation project was to promote in situ reductive dechlorination to remove the cVOCs by injecting Ferox-Plus carbon/ZVI formulation into the shallow groundwater. For comparison, one fourth of the treatment area was treated with a similar EHC® ISCR reagent (PeroxyChem Inc.). Also, in ~10% of the injection points, bioaugmentation was performed 2 weeks after injection of the Ferox¬Plus® to determine the effectiveness of the addition of dehalococcoides sp. microorganism to effect complete dechlorination of site contaminants to ethene.

A total of 145,000 lbs of Ferox-Plus was injected, with an average of 10 injection pts and 4,600 lbs of Ferox-Plus injected per day. Over 370 injection points were installed from ~4 to 14 feet bgs. A radius of influence (ROI) of greater than 15 feet was achieved through angled injection nozzles. Over 100 conformational borings were completed to determine the ROI. For comparison, 74,333 lbs of an EHC Slurry was emplaced into ~200 injections points. The Ferox-plus was found to be easier to inject and distributed well in the subsurface.

Over 98% removal of PCE and 93% of TCE was found in all wells within the treatment zone. Ferox-Plus carbon/ZVI amendment provided a very effective and cost-efficient solution to enhancing cVOC removal at this site. Its site-ready format eliminated any mixing or clumping problems. It distributed easily in the subsurface with greater ROI, ensuring its effectiveness on site.

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Bountiful Superfund Case Study – Eight Years of Successful Chemical Reduction in Low Permeability Soils Aided by Permeability Enhancement

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The Bountiful/Woods Cross Operable Unit 1 Superfund Site is a large and challenging chlorinated solvent site that had residual DNAPL source area and a mile long plume near Salt Lake

City. The Site entered the remedial action phase in 2008. Since then, hundreds of wells have been installed and multiple bioremediation amendment injections have been performed onsite for source area reduction and downgradient from the site to mitigate the dilute plume. While bioremediation was effective in the higher permeability sandy soils, rebound occurred in several areas in the silty low permeability zones highlighting potential limitations in the remedial design or in the conceptual site model (CSM) established by the original Remediation Investigation (RI).

Additional characterization in high resolution was performed to better quantify the extent of residual NAPL and/or low permeability zones that resulted in rebound and limited performance of initial remediation approaches. The improved high-resolution data supported a revised CSM that led to considerable refinement of the limiting conditions recognized at the site and ultimately in optimization of the remediation approach that better confronted challenges of high residual mass and associated diffusive mass flux limitations.

The optimized approach centered on implementing permeability enhancement in conjunction with chemical reduction with a biostimulation contingency. Hydraulic injection propagation mechanics are key to this injection method and can facilitate overcoming challenges associated with low permeability lithologies. The use of proppants improved reagent delivery and increased hydraulic conductivity required for achieving controlled groundwater flux. Models, methods and procedures are presented to explain how mass flux rates of VOCs in low permeability media is increased and how engineered chemistries or remediation technologies are designed to control it.

Fifteen years of data in total include eight years of bioremediation performance data and seven years of performance data for the subsequent permeability enhancement with chemical reduction. The performance data supports that increased and controlled groundwater transport through the target treatment zone is one of the primary benefits from permeability enhancement with a secondary benefit of reducing back-diffusion time frames resulting in limited rebound or no rebound, and rapid compliance with groundwater treatment goals.

In combination with engineered chemistries and reagents to reduce, destroy or sequester the contaminants of concern over extended periods of time, increasing hydraulic conductivity within the treatment zone is able to achieve superior performance and rapid compliance at sites with a single injection event. This is a paradigm shift for the environmental remediation industry that has assumed the default of multiple injection events for most groundwater remediation strategies.

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Remediation of Emerging Heavy Metal Contaminants from Coal Ash, Including Li, Mo, B, and As

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Remediation of lithium, molybdenum, boron and arsenic metals among the many others present at Coal Combustion Residuals (CCR) sites can be accomplished by chemical, physical or biological mechanisms resulting in immobilization (e.g., ion exchange, complexation, precipitation or stabilization), sequestration (i.e., sorption), solidification (e.g. cementation) and/or reduction in bioavailability relying principally on formation of metal hydroxides, sulfides, carbonates, organometal species, or by adsorption and or coprecipitation mechanisms. However not all are permanent and can be reversible under changing hydrogeologic redox conditions resulting in very difficult remediation design challenges.

The above metals and metalloids function

cationically, oxi-anionically and/or amphoterically depending on the biogeochemical conditions present in the soil, groundwater and/or ash environment in which the remediation activities (i.e., reactions) are to take place. Site conditions in both unsaturated and saturated zones present different redox conditions by which one or more metals are more likely to be soluble. In almost every case, pH adjustment alone is not a solution and has been shown to lack robustness and resiliency for long term efficacy. Additional complexity is derived from variable redox conditions across a treatment area resulting from seasonal changes, localized CCR landfill contributions to groundwater, and upgradient groundwater source(s) or adjacent river or surface water body exchanges.

The results of more than 40 heavy metals remediation projects including soil, groundwater, CCR sites and industrial waste media, demonstrate up to 100% reduction of maximum leachable concentrations of heavy metals in accordance with TCLP and SPLP testing methods with average reduction of 91% across all mixed metals sites. The average site wide reagent dosage rates also varied from approximately 0.5% to 10% percent by soil weight with an average site wide average dose of approximately 4%. Where-as industrial waste applications reveal a 6% average dose with a range of 5-18%. All projects included bench trial analysis to verify COCs and scavengers and to establish a dose – response curve for the site-specific conditions. Column studies proved to be most helpful in demonstrating long term resiliency and reagent performance.

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Foraminifera Fidelity to Environmental Settings: A Meta-Analysis of Foraminiferal Assemblages from the Southeastern United States

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Foraminifera are a diverse group of single-celled protozoans which have been used to answer questions in micropaleontology, climate sciences and oceanography. They are useful for these studies due to their abundance and preference for specific environmental settings. While information concerning foraminifera species fidelity is mentioned in individual studies, an analysis that incorporates numerous assemblages is beneficial for understanding the extent of species prevalence. A meta-analysis of twelve published assemblages was conducted to determine species fidelity to environmental settings. Focusing on studies from the Southeastern region of the United States, a matrix of 429 core and surficial samples was included in the analysis. Species comprising less than two percent of the total assemblage were removed and a total of 113 species were present in the final cluster analysis. A dendrogram from a hierarchical cluster analysis using Ward's linkage has yielded eight sample clusters. The samples within each cluster were diverse, with samples from multiple studies included within each cluster. This suggests that the analysis can successfully identify biofacies and depositional environments across assemblages. Biofacies fidelity scores were assigned for each species within each cluster to understand the faithfulness of each individual species to its preferred environment. Results of the analysis suggest a high percentage of variability in the occurrence of foraminifera species across studies. These results are especially important in depositional environment reconstructions as foraminifera species can be a central tool for interpreting past environments.

Evaluating a Former Quarry for a Piedmont Raw Water Storage Site: Geological, Geochemical, and Hydrogeologic Insights

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This study explores the potential for a crystalline rock quarry located in the Piedmont physiographic region, as a raw water storage facility. Comprehensive field investigations were conducted in 2018, encompassing outcrop mapping, test well drilling and aquifer testing, mineralogical assessments, and the analysis of surface water, groundwater, and quarry solids.

Outcrop mapping determined the local rock fabric and expected fracture sets within the quarry. This was followed by test well installation and subsequent hydraulic connectivity evaluations. The evaluation revealed that the quarry's host rock, primarily a gneiss, exhibits low hydraulic conductivity (~6.49×10^{-8} cm/sec) and a poorly connected fracture network above the proposed bottom of the facility. These characteristics support the suitability of the quarry for water storage, minimizing risks of groundwater contamination or significant water loss through infiltration.

Geochemical analyses identified exceedances of U.S. Environmental Protection Agency (USEPA) secondary drinking water standards for iron, manganese, sulfate, aluminum, and total dissolved solids (TDS) in surface and groundwater. However, these exceedances reflect naturally occurring conditions derived from the host rock mineralogy, which includes biotite mica, amphibole, pyrite, and magnetite. No exceedances of USEPA primary drinking water standards were detected. Analytical results for quarry solids, including aggregate and overburden, confirmed no exceedances of state screening values.

Mineralogical and petrographic analyses revealed no unique geochemical hazards associated with the site. The mineral composition of the quarry rock aligns with regional geology, characterized by amphibolite, gneisses, and migmatites with minor sulfide and oxide content. This further mitigates concerns about leaching or chemical mobilization during raw water storage.

Concentration trends in surface waters followed predictable spatial patterns, decreasing from quarry floor waters ("Pit") to process ponds ("Processed") and finally to natural waters ("Pond"). The observed chemical gradients suggest that quarry operations and natural drainage dynamics concentrate dissolved constituents in quarry ponds while natural stream flows dilute these constituents downstream.

This research concludes that the quarry is a viable candidate for raw water storage. The low hydraulic conductivity, stable geochemical conditions, and natural attenuation processes highlight its capacity to meet long-term water supply needs vital for mitigating the effects of future climactic variations, while minimizing environmental risks.

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Lights, Catalyst, PFAS: How Long Can the Magic Last?

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By using UV light as energy, photocatalysis presents a chemical-free and energy-efficient method to degrade poly- and perfluoroalkyl substances (PFAS) in contaminated water. Hexagonal boron nitride (hBN), a photocatalyst that degrades both perfluorocarboxylic acids such as PFOA and perfluorosulfonic acids such as PFOS, is a promising method for aqueous PFAS remediation. Pilot-scale treatment of PFAS-impacted groundwaters promisingly showed no degradation of hBN after six hours of UV irradiation while less than 1% of hBN is degraded

in pure water. Herein, we explore the conditions (e.g., irradiation time, water matrix) that cause hBN degradation and the resultant impact on performance.

Investigating Biodegradation of 1,4-Dioxane and Co-Contaminants by Pseudonocardia BERK-1

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1,4-Dioxane is a recalcitrant groundwater contaminant often requiring advanced treatment due to its persistence and widespread occurrence. Recent research has focused on the microbial biodegradation of 1,4-dioxane, with microorganisms able to metabolize 1,4-dioxane as their primary substrate. The study presented herein utilizes a recently isolated strain, Pseudonocardia dioxivorans BERK-1, as the bioremediation agent. This study aims to understand how the initial ratio of biomass concentration to 1,4-dioxane concentration influences biodegradation kinetics at environmentally relevant concentrations (~100 µg/L). Additionally, the study explores the impact of co-contaminants, specifically 1,1-dichloroethene (1,1-DCE), on the biodegradation of 1,4-dioxane to determine potential limitations in mixed-contaminant plumes.

To achieve the aims of this study, laboratory-scale experiments were conducted using 1,4-dioxane-grown Pseudonocardia dioxivorans strain BERK-1 at five biomass-to-substrate ratios: 0.005, 0.05, 0.25, 1.25, and 2.5 mg 1,4-dioxane as COD per mg biomass as COD. These ratios encompass extant kinetics (≤0.025) and "defined" ratios (≥0.025) per Grady et al. (1996). 1,4-Dioxane degradation was monitored to assess the impact of these ratios on the kinetics. Subsequent experiments were also run to examine the effects of low concentrations (approximately ~13 µg/L) of co-contaminant 1,1-DCE on biodegradation at ratios of 0.005 and 0.05. Kinetic modeling was performed to fit observed data using parameters from Ramos-Garcia et al. (2022).

Results of these experiments demonstrate that 1,4-Dioxane was degraded below 1 µg/L within 5 days at a ratio of 0.005 mg per mg biomass COD, while the 0.05 ratio required ~49 days. Degradation was slower at a ratio of 0.25, and minimal degradation was observed at 1.25 and 2.5. Controls without biomass showed no decrease in 1,4-dioxane, confirming the critical role of biomass concentration in achieving significant biodegradation to a level below 1 µg/L. Preliminary modeling suggests that kinetic parameters from higher 1,4-dioxane concentrations are applicable to lower concentrations under extant conditions. In the presence of 1,1-DCE (~13 µg/L),

1,4-dioxane degradation was initially inhibited over the first ~10 days of incubation, but both contaminants were consumed in the 0.005 ratio treatment following 49 days of incubation. The use of 1,4-dioxane as a primary substrate for aerobic cometabolism of 1,1-DCE is a novel finding. Previous studies indicate that a primary substrate such as propane or isobutane is needed to aerobically cometabolize chlorinated ethenes, as a prerequisite for biodegradation of 1,4-dioxane. These results demonstrate the importance of optimizing biomass-to-substrate ratios and understanding co-contaminant interactions for effective bioremediation strategies.

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A Strainmeter Array Used to Evaluate Well Tests at a Deep Aquifer

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The strain caused by pressure change during a well test propagates upward into the confining unit where it can be measured using strainmeters or other sensors. Analyzing strain changes measured at shallow depths during well test has the potential to identify characteristics of underlying aquifers in much the same way that pressure changes measured at monitoring wells are used in classical well test analyses. This concept was successfully demonstrated using data measured during an injection well test at a single shallow tensor strainmeter (AVN2) completed at 40 m depth above a 530-m-deep aquifer in the North Avant Field in northeastern Oklahoma. Three more tensor strainmeters were deployed at the North Avant Field to extend the initial findings by evaluating spatial variability in the strain field and its effect on interpreting the strain signal. Two of the new strainmeters were deployed at shallow depth (40m). One of them AVN22 is 240m north, and the other (AVN87) is 230 m ENE from the injection well. One strainmeter (AVN31) was at 500m depth in the vicinity of the reservoir. This is the deepest strainmeter ever deployed, to our knowledge, and it is 530m NE of the injection well.

Six well tests were conducted during the summer of 2022 and data were measured at the strainmeter array and pressures were measured at monitoring wells completed in the reservoir. The well tests involved injecting at a constant rate from 77 to 337 hrs, allowing the aquifer to recover for a week or two and then conducting another test. Data from the six injection tests were combined to estimate the average response and uncertainty of the estimate of the average. This was done by assuming that the pressure and strain response could be characterized by a simple function. Many of the time series were nearly linear during injection and their slope reversed during recovery, so the initial characterization assumed the data were linear and could be characterized by a constant strain rate, or pressurization rate during injection and another rate during recovery.

The ensemble data indicate the average normal strain rates range from 0.9 to 2.5 ne/hr (1 ne/hr ~ 3x10-13 1/s). The signs of the horizontal strains are opposite those of the vertical strains in most cases. The horizontal strains at shallow strainmeters, AVN2 and AVN22, are tensile, while the vertical strains are compressive. Both horizontal strains at the deep strainmeter AVN31 are compressive and the vertical strain is tensile. The magnitude of the mean horizontal strain rate is slightly larger than the vertical strain rate in all three cases. An exception occurred shallow strainmeter AVN87 where one of the horizontal strains is tensile but the EW strain is compressive. The injection well is slightly south of west from AVN87, so the anomalous compressive strain is approximately in a radial direction relative to the pumping well. The variability of the normal strain rate data is in the range $0.1 < \text{Coefficient of Variation} < 0.4$ during injection, and it is more variable during recovery $0.3 < \text{CoV} < 0.7$.

These results demonstrate that the strain tensor signal is repeatable enough to have confidence that the data are a valid response from the aquifer. We have evaluated this response by developing a poroelastic model of flow in the aquifer and the resulting deformation. The model results demonstrate that the relative magnitudes of the strains at the different strainmeters can be explained by the spatial distribution of the strain tensor field during injection. The model results also indicate that details of the strain measurements are sensitive to the location of boundaries within the aquifer. This sensitivity is required to develop a quantitative interpretation of the array of strain tensor data using inversion methods.

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Sustainable Approach for Boron Stabilization in Coal Combustion Wastewaters

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This research focuses on the removal and stabilization of boron from various coal combustion waste products, including coal ash leachate (CAL), coal combustion residuals (CCR), and flue gas desulfurization (FGD) wastewater. The objective is to mitigate the environmental and health risks associated with boron toxicity and prevent its leaching into groundwater. To achieve this, we have developed a cost-effective and efficient treatment approach tailored for these waste streams.

The treatment strategy utilizes controlled precipitation and coprecipitation techniques by optimizing the concentrations of aluminum, calcium, sulfate, and hydroxide ions. Sustainable materials, such as steel slag and recycled aluminum cans, serve as calcium and aluminum sources, respectively. Experimental results indicate that calcium and aluminum play a crucial role in boron removal, facilitating the formation of stable boron-containing minerals. By adjusting the process within a pH range of 10 to 12, X-ray diffraction (XRD) analysis confirms the formation of stable boron compounds, including ettringite, inyoite, ameghinite ($Na_2B_5O_6(OH)_4{\cdot}3H_2O$), borcarite ($Ca_4MgB_4O_6(OH)_6{\cdot}H_2O$), garrelsite ($CaB_2O_4(OH)_2{\cdot}3H_2O$), jarandolite ($CaB_3O_4(OH)_3{\cdot}H_2O$), and olshanskyite ($Ca_3B_4(OH)_{18}$). Further characterization of the residual solids using Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and X-ray photoelectron spectroscopy (XPS) is ongoing to clarify the chemical interactions and removal mechanisms.

In addition to precipitation-based removal, bone biochar has emerged as a promising sorption medium for boron. Column experiments conducted thus far involve pre-treating wastewater with $Ca(OH)_2$ before passing it through a layered biochar and aluminum powder column, demonstrating significant sorptive capacity.

This method has proven highly effective, achieving up to 95% boron reduction in CAL and FGD wastewater. The findings provide critical insights into boron stabilization, contributing to the protection of soil and water resources. The innovative and cost-effective treatment process being developed presents a practical solution for the coal power industry, sea water desalination efforts for agricultural water use, thereby addressing boron contamination in a way that enhances environmental sustainability and public health safety.

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Influence of Social Networks on Retention and Recruitment of Geoscience Majors

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Introductory level geoscience courses provide an excellent opportunity to recruit and retain geoscience majors. One aspect of interest in these courses are the social interactions among students and their influence on retention and recruitment. This project used social network analysis (SNA) to construct the social networks within two introductory level geoscience courses in which students frequently completed group work to understand the potential influence of interest in geoscience majors and/or careers on certain social interactions within the course. A survey was deployed in two classes (N = 24, 136) that asked for students to recall various types of interactions

amongst their peers. Six networks were defined for each course including: who students knew prior to the course, who they completed group work with, who they studied for tests with, who attended non-course related geoscience activities, who attended any other social activities, and which peers they were likely to stay in contact with. Sociograms were created for each network and statistics of the network were calculated. Ultimately, we did not find that geoscience majors were highly connected within class networks, which would limit their potential influence on growing other students' interest in geoscience. We suggest that increasing opportunities for all students to engage with a wider variety of other students in their geoscience course may lead to them making more connections with geoscience majors or students who are interested in becoming a geoscience major or minor, potentially growing interest in the field.

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High-Volume Sub-Slab Sampling is More Than Just a Vapor Intrusion Tool, it is an Effective Tool for Developing CSMs

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The High-Volume Sub-Slab Sampling (HVS) method is a recent addition to the vapor intrusion (VI) assessment toolbox and is best at completing rapid investigations in large buildings. Additionally, it has proven to be a cost-effective tool for quickly building Conceptual Site Models (CSMs) for challenging and complex contaminated sites that partially or completely underlie buildings. Groundwater contaminated sites with buildings have the potential for vapor intrusion. The exposure pathway generally consists of the partitioning of dissolved volatile contaminants from groundwater into soil gas, diffusion and advection of soil gas through the vadose zone, and intrusion of soil gas into indoor air via foundation/slab cracks and utility conduits. HVS has advantages over both discrete sub-slab soil gas sampling and drilling soil borings to sample soil and groundwater to characterize the nature and extent of contamination in the shallow subsurface.

Traditional VI investigation involves collecting small sub-slab soil gas samples, less than 10 liters, which may require increasingly large sample sets for large buildings. HVS offers several advantages over traditional VI investigation methods, such as assessing larger subsurface areas, providing real-time data, and being more efficient and economical due to reduced sampling density. Additionally, HVS enhances CSM development by collecting multiple lines of evidence with each test.

HVS methodology involves collecting large volumes of soil gas beneath a structure's slab often reaching a radius of 20 to 40 feet. The large, sampled area reduces the risk of failing to identify a significant source of contamination in vadose zone soils and in groundwater present at the water table. Field and laboratory data from HVS testing help determine the contaminant source geometry ("source area" and plume direction), and provide critical design parameters for VI mitigation, which can reduce or eliminate an entire field mobilization to collect predesign data.

Already used in dozens of regulatory jurisdictions, HVS can reduce sampling scope, reduce cost and invasiveness, and demonstrate an absence of significant subsurface contamination.

This presentation will describe the HVS methodology, its implementation in various site conditions, and its role in improving the accuracy and reliability of CSMs at complex and challenging groundwater contaminated sites.

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Grassroots Rapid Response to Hurricane Helene

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Evidence suggests that weather events are becoming more extreme - in frequency, intensity, and damage caused. Places that were once considered climate havens, such as Western North Carolina, have been forced to reconsider this notion. Response times from governmental agencies for major events like Hurricane Helene vary depending upon their classifications. Emergency response falls into three traditional categories:

1) First responders (e.g.: police, EMS, fire),

2) Second responders (e.g.: those that support the first responders and help in recovery), and

3) Emergency managers (e.g.: FEMA).

Moreover, the frequency and intensity of disasters has led to the need for an underrecognized fourth category that includes grassroots efforts consisting of untrained individuals and specialists alike working to bring systems back online after events. First and second responders, alongside fourth responders, have the benefit of being flexible and can implement aid quickly while third responders arrive on location 48-72 hours after a state of emergency has been declared - and in some cases, this timeline may be 5-7+ days. Therefore, response in the 0-7 day period after a natural disaster occurs is pivotal - and, depending on the severity of the disaster, may rely on specialist volunteers to ensure basic societal needs are met.

The grassroots group, Carolina Water Volunteers, formed in response to Hurricane Helene and consists of water quality specialists from North and South Carolina who deployed to Western North Carolina over 4 weeks to ensure drinking water was available to residents in the hardest hit areas. I will report on their response to Hurricane Helene and discuss the processes and procedures behind that response, the partnerships that were formed during the response, and the importance of volunteerism and community connections for water quality scientists.

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Overview of Borehole Geophysics Methods for Groundwater Investigations

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Geophysical borehole logging is a powerful technique for characterizing the subsurface environment in new or existing wells. It involves measuring various physical properties of rocks and soils using downhole instruments and sensors. These tools can be applied in every type of geological terrain, but are particularly useful in complex environments, and can provide information on fracture orientation and characteristics, lithology, porosity, permeability, and other important properties of the subsurface. This information is crucial for a variety of applications such as groundwater exploration, environmental remediation, and geotechnical investigations.

Borehole geophysical applications have a proven track record of providing accurate, high-resolution data, at a relatively low cost.

When used properly, borehole geophysics can improve project efficiency, reduce cost over-runs, and create a more robust understanding of the subsurface, allowing geologist and engineers to make the most out of every boring.

This presentation will cover standard logging methods, such as electrical logs and borehole

televiewers, as well as more novel tools like sonic logging and nuclear magnetic resonance (NMR). Also covered will be the most common applications of these tools in groundwater investigations and the importance of considering the synergy between different methods when designing a logging program.

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Identification and Enhancement of Naturally Occurring In-Situ Aerobic Metabolic Biodegradation of 1,4-Dioxane

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Shallow groundwater at a former warehouse was impacted by 1,4-dioxane and volatile organic compounds (VOCs) from wastewater discharges to a septic tank and associated leach field during pack parts cleaning operations. Historical concentrations of 1,4-dioxane at the Site were reported up to 60,000 micrograms per liter (µg/L). A phytoremediation pilot study and source mass removal activities had reduced the maximum 1,4-dioxane concentration to 11,000 µg/L in 2021; however, a pilot study expansion is warranted to increase the rate of contaminant concentration decline and the degree of contaminant mass flux reduction at the property line. 1,4-Dioxane, a probable human carcinogen, is an emerging contaminant in groundwater at many military and industrial contaminated sites, and currently has limited in-situ remedial options. Numerous laboratory and pilot-scale studies provide evidence that 1,4-dioxane can undergo aerobic metabolic biodegradation; therefore, in situ bioremediation options were evaluated.

To support the development of future additional remedial options for the Site, natural attenuation processes were first examined. The metabolic 1,4-D degrader Pseudonocardia dioxanivorans BERK-1 was isolated from the site aquifer. In addition, observation of degradation process in laboratory systems and isotope enrichment downgradient of the source areas in compound specific isotope analyses (CSIA) indicate the occurrence of natural degradation of 1,4-dioxane at the site. A data gap investigation was performed to evaluate vertical and spatial connections of 1,4-dioxane concentrations and aquifer characteristics.

The results of the data gap investigation provide evidence that naturally occurring aerobic microbiological destruction of 1,4-dioxane is occurring in the shallow, oxic portion of the aquifer but not in the deeper, anoxic zone. The confirmed relationship between aerobic geochemical conditions and lower 1,4-dioxane concentrations indicated that introduction of atmospheric air to the subsurface will increase DO, stimulate biodegradation, and accelerate the destruction of 1,4-dioxane. Pilot study expansions in the second half of 2023 have included installation of a novel engineered aeration trench at the source area and a downgradient TreeWell® phytoremediation system. Preliminary testing of the aeration trench system was performed in 2024, with full-scale start-up to follow. Cellular-connected environmental monitoring systems providing oxidation-reduction potential and water level data will be utilized for real-time system monitoring.

High-Permeability Zone Volume Fraction and First-Order Rate Constant Effects on 1,4-Dioxane Degradation in Simulated Aquifer-Aquitard Systems

Romero, Juan, juanjor@clemson.edu, and **David Freedman**, Clemson University, Clemson, SC; **Paul B. Hatzinger,** Aptim Federal Services, Lawrenceville, NJ; and **Charles Schaefer,** CDM Smith, Edison, NJ

Groundwater contamination with 1,4-dioxane presents significant remediation challenges due to its high mobility, persistence, and the limitations of conventional treatment methods in terms of cost and efficiency. The mechanisms involved in an aquifer-aquitard system are complex, including back diffusion from low permeability zones, and chemical degradation through hydroxyl radical reactions and microbial biodegradation. This study examines the relative contributions of these mechanisms to simulated remediation times and identifies threshold values for a first-order reaction rate constant that significantly reduces remediation times.

Simulations were conducted to model 1,4-dioxane degradation in a groundwater system comprised of sand as the transmissive medium and clay as the low-permeability medium. A 20-year loading period was assumed, with a monitoring well positioned 50 meters downstream of the source. The simulations were performed using REMChlor-MD, with model parameters sourced from its data base, including transmissive medium tortuosity (0.56); low-permeability medium porosity (0.47); hydraulic conductivity (2.17x10-8 cm/s); and tortuosity (0.32). Additional parameters, such as 1,4-dioxane molecular diffusion coefficient (1.06x10-9 m2/s) and retardation factor (1.01); transmissive medium porosity (0.37); and hydraulic conductivity (0.0036 cm/s) were sourced from the literature (Adamson et al., 2016). The base case excluded degradation and back-diffusion effects. Sensitivity analyses explored variations in low-permeability zone volume fractions and first-order reaction rate constants. The primary performance metric was the time required to reduce the concentration of 1,4-dioxane at the monitoring well from 1,000 to 1 µg/L.

In the base case simulation, a decrease in 1,4-dioxane to 1 µg/L required 48 years after the end of the loading period, aligning with estimates made by Adamson et al. (2016) for similar aquifer-aquitard systems. Sensitivity analyses revealed that increasing the volume fraction of low-permeability zones to 20%, 40%, 60% and 80% extended remediation times to 55, 66, 85 and 129 years, respectively, highlighting the impact of back-diffusion on contaminant persistence. Conversely, increasing the first-order reaction rate constant reduced remediation times significantly, with reductions to 46, 36, 12, and 2 years for constants of 0.001, 0.01, 0.1, and 1 yr^{-1} (corresponding to half-lives of 693, 69.3, 6.9, and 0.69 years, respectively). The rate constants cover the full range that has been reported from laboratory and field studies for biotic and abiotic degradation of 1,4-dioxane. These results highlight the importance of correctly estimating the contribution of 1,4-dioxane degradation and permeability dynamics to predicting the potential for monitored natural attenuation or the need for active remediation. The simulations will also inform experimental efforts to measure key parameters and thereby deepen our understanding of the mechanisms driving 1,4-dioxane degradation.

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Stormwater Runoff as a Pathway for Per- and Polyfluoroalkyl Substance (PFAS) Transport

Salawu, Omobayo, osalawu@clemson.edu, and **Alireza Faraji**, Clemson University, Clemson SC

Per- and polyfluoroalkyl substances (PFAS) are persistent and mobile contaminants that pose significant risks to water quality, ecosystems, and public health. This review examines the role of stormwater runoff as a critical pathway for PFAS transport, particularly during catastrophic storm events. These severe events mobilize PFAS species from sources such as industrial zones, landfills, and firefighting training grounds into surrounding water bodies and groundwater. Drawing on field studies, modeling approaches, and regulatory frameworks, we synthesize current knowledge on the occurrence, fate, and transport mechanisms of PFAS in stormwater. Evidence indicates that PFAS concentrations in urban waterways are significantly elevated during wet weather events, with long-chain PFAS accumulating in sediments and short-chain PFAS remaining highly mobile in the aqueous phase. Key sources of PFAS in stormwater include atmospheric deposition, industrial emissions, traffic-related materials, and aqueous film-forming foams (AFFFs). This review highlights the influence of intense precipitation, soil properties, and hydrological connectivity on PFAS leaching and erosion, as well as seasonal trends that exacerbate their transport during heavy rainfall and snowmelt. While stormwater biofilters and green infrastructure show promise in retaining some PFAS, their limitations in preventing short-chain PFAS leaching and precursor transformation are noted. This review underscores the need for advanced stormwater treatment technologies, improved monitoring frameworks, and integrated management strategies to mitigate PFAS contamination. Future research should focus on developing cost-effective filtration materials, enhancing regulatory approaches, and addressing knowledge gaps in PFAS mobilization and transport dynamics to better protect water resources.

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Utilizing Blind Horizonal Wells for a Variety of Remediation Applications

Shinall, Brian, Bshinall@ellingsoncompanies.com, Ellingson-DTD, Acworth, GA

Horizontal Directional Drilling, or HDD, has become a preferred technology for installing wells to remedy contaminated soils and groundwater. HDD has been used to install all current remediation technologies, from Soil Vapor Extraction to In Situ Thermal Remediation systems. The advantages of HDD are recognized, enhanced access to areas with surface obstructions that prevent vertical drilling and reduced number of wellheads, pumps, and other remedial equipment being just two of the many benefits.

One area where HDD has historically been difficult to employ is in the completion of horizontal wells in soft or caving soils. Although wells in these materials can be completed using double-ended bores, on many sites there is no room to drill back to the surface for a double-ended bore. In other cases, well depths would require excessively long wells to accommodate both entry and exit curves. A reliable method to install long horizontal wells in marginally stable soils was needed to advance the technology.

Over a period of several years and multiple iterations, the Knock-Off HDD technology was developed to meet the requirements of assured installation of wells in soft, caving, or collapsing soils. The method combines a remotely detachable drill bit with an offset navigation sonde housing and oversized drill rods, to provide a stabilized means to install wells to any reasonable length.

In use, the bore is advanced to the desired end point. The drill string is then opened at the rig and the well screen and casing are advanced through the drill rods to the well terminus. At the bit, a special end cap engages with a latching mechanism on the drill bit to both detach the bit and anchor the well string to it. The drill rods are then withdrawn, leaving the well in place.

This technology has enabled the installation of blind horizontal wells to record lengths, in extremely tough conditions. Wells up to 2,600 long have been installed for drainage in coal combustion product ponds and embankments, and remediation wells over 1,500 feet long have been installed using the technology. The method assures well installation in collapsing boreholes, and by installing through the drill rods, there is no chance of the well diverging from the drilled bore, a risk in soft soil conditions.

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Influence of Organic Matter on the Effectiveness of Iron Flocculation

Smith, Evelyn, Evelyn3@g.clemson.edu, and **Brian Powell,** Clemson University, Clemson, SC

Iron flocculation is a useful remediation tool for removing trace metals from a body of water. However, organic matter complexes can impede the proper sequestration of contaminants. Batch experiments were conducted to determine the change in the percent removal of trace metals from solution via iron flocculation once in the presence of organic ligands. Trace metals studied include Mn, Se, 238U, Co, Cr, and Cd. Each trace metal was put into solution with soluble iron and an organic compound (i.e., citrate, sulfate, oxalate), and trace metal concentration was measured from the solution after precipitates had formed. The lab-generated samples were compared to field samples to verify if the observations in the lab setting occur naturally as well. Data from both the lab and field samples showed a reduced percent removal when organic material was present, particularly among Se samples. The combined data indicate that organic ligands may play a role in keeping metal ions suspended in solution, preventing them from becoming incorporated into a precipitate.

Optimizing PFAS Remediation Strategies from Lab to Field

Smith, Jacques, jsmith@siremlab.com, **Rosemary Le**, and **Michale Healey,** SiREM, Knoxville, TN

Per and poly fluorinated compounds (PFAS) present a major remediation challenge in soils, sediment, groundwater, surface water, wastewater and landfill leachate due to their chemical properties, potential to bioaccumulate, and pervasiveness. Addressing these challenges requires implementing innovative solutions to develop effective and sustainable remediation strategies for PFAS contamination.

Navigating the growing range of PFAS remediation technologies requires site and contaminant specific data when implementing approaches such as in situ stabilization (ISS), soil washing, sorption technologies, precipitation/coagulation, cross flow filtration, and aqueous foam fractionation, to name a few.

Site managers use laboratory treatability testing to identify and evaluate effective and lowest cost PFAS solutions for site-specific scenarios. Studies can involve comparing different technologies or

validating and optimizing a chosen approach. Passive sampling is another tool which is used in the field, to quantify the bioavailable fraction of PFAS and assess the effectiveness of PFAS remediation technologies.

This presentation will provide an overview of PFAS remediation technologies and present case studies of PFAS treatability studies, including an ISS study, column testing of sorptive media for PFAS removal from groundwater, and the deployment of passive samplers in lake sediment at a site near an International Airport.

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Conceptual Site Model Development, Source Removal, and Soil Amendment Get a UST Site Closer to Closure

Thompson, Rob, rob.thompson@anteagroup.us, Antea Group, Charlotte, NC

A release was discovered at a former underground storage tank (UST) site in Charlotte, North Carolina when gasoline vapors were detected at sanitary sewer connections in nearby residences in May 1990. Between May and August 1990, one 8,000-gallon gasoline UST and one 10,000-gallon diesel UST were removed from the site. In 1999, a Corrective Action Plan (CAP) was prepared with air sparge and soil vapor extraction (AS/SVE) as the remedy until 2004. Mobile multi-phase extraction (MMPE) and Aggressive Fluid/Vapor Recovery (AFVR) were used between 2013 and 2016 with minimal success. Benzene has been the primary regulatory driver with concentrations as high as 30,000 micrograms per liter (µg/L) in groundwater and a Gross Contaminant Level (GCL) cleanup target of 5,000 µg/L. A 3-Dimentional (3D) Conceptual Site Model (CSM) was prepared, remedial alternatives evaluated, and a path to closure was developed.

Soil assessment was directed by the North Carolina Department of Environmental Quality (NCDEQ) from 2014 through 2015 with soil boring locations and sample depths specified by the NCDEQ. After the soil assessment was completed, a 3D CSM was developed which showed the extent of soil and groundwater contamination and the range of historic groundwater depth (10-22 ft.) with respect to the locations of the former USTs. The CSM illustrated what could be considered a 'classic' or 'textbook' UST site where the USTs had leaked prior to removal, the soil was not properly investigated, the extent of groundwater contamination was not fully understood, and the incorrect remedy was selected.

In April 2017, a Proposed CAP was submitted to the NCDEQ for removal of 'worst case' soils where benzene concentrations in soil exceeded 20 milligrams per kilogram (mg/kg) and remediate groundwater to levels below GCLs. After the CAP was submitted, the 3D CSM was presented to the client and the NCDEQ which supported the best course of action to achieve site closure within a realistic length of time, and the CAP was approved. The recommended technology included a combination of source removal by excavation and in-situ chemical oxidation (ISCO) by placing soil amendment in the excavations prior to backfilling to support groundwater remediation.

An updated CSM made the remedial design as effective as possible with the data available. The original excavation was planned as one large area as the client planned to vacate the property to a new location prior to excavation. When plans to vacate the property changed, a Structural Engineering evaluation identified the need to change from one large area to three smaller areas utilizing a slide rail shoring system. The three areas had dimensions that ranged from 16 ft. by 16 ft. to 16 ft. by 20 ft. to depths of 22 ft., just into the saturated zone. A total of 1,262 tons of soil were excavated from the three areas. A total of 2,204 lbs. of sodium persulfate soil amendment was mixed into the bottom two ft. of the saturated zone within each excavation. Four ft. of gravel backfill was placed on the amended soil with a geofabric placed

on top of that before bringing the excavations up to grade for resurfacing.

The soil assessment specified by the NCDEQ did not identify all areas of soil with the highest contaminant mass. An extended area of high contaminant mass was identified during excavation where lower levels of contaminant mass were previously identified. Had a more thorough soil assessment been specified prior to excavation, the extended area with the high contaminant mass at deeper depths would have been identified, and the CSM would have been more complete. During excavation, the depth was adjusted to 22 ft. below grade to remove the additional contaminant mass.

Quarterly groundwater performance monitoring completed after the remediation indicates benzene concentrations have decreased to levels below GCLs in four of the six monitoring wells after three sampling events. Benzene remains above GCLs with increasing concentrations in two of the six monitoring wells. To address the two wells with benzene above GCLs, ISCO was continued by placing canisters of potassium persulfate into the wells. Performance monitoring will continue to evaluate the effectiveness of the canisters. Site closure will be achieved when the benzene is reduced to levels below GCLs.

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Geotechnical Case Study of a Wick Drain System Beneath a Constructed Soil Embankment

Vastag, Johnny, johnny.vastag@blecorp.com, **Lawrence Simonson**, and **Tanner Whitesell,** BLE, Greenville, South Carolina

Per and poly fluorinated compounds (PFAS) present a major remediation challenge in soils, sediment, groundwater, surface water, wastewater and landfill leachate due to their chemical properties, potential to bioaccumulate, and pervasiveness. Addressing these challenges requires implementing innovative solutions to develop effective and sustainable remediation strategies for PFAS contamination.

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Passive and Solar-Powered Bioventing Implementation to Augment Natural Source Zone Depletion (NSZD) of Petroleum Light Non-Aqueous Phase Liquids (LNAPL) in the Subsurface

Wheeler, Kevin, kwheeler@sovcon.com, Sovereign Consulting, Robbinsville, New Jersey

Non-migrating and residual (immobile) petroleum light non-aqueous phase liquid (LNAPL) often represents a challenge to site remediation. Low measured thicknesses of LNAPL in wells and low-LNAPL transmissivity (i.e., mobility) prevents this LNAPL from being practicably recoverable, yet it may still represent a source of groundwater impact due to its soluble composition. Based on risk associated with the residual LNAPL composition or lack of regulatory acceptance, Natural Source Zone Depletion (NSZD) may not represent a viable remedy by itself.

Bioventing is a proven remedial approach and has routinely been used to successfully remediate petroleum LNAPL sources. Research has shown that biodegradation is the primary remedial mechanism in soil vapor extraction and air sparging (SVE and AS/SVE) application, particularly as the remedy progresses and the associated volatile composition of the impact decreases. Because SVE and AS/SVE require off-gas treatment and are not as efficient in delivering oxygen to support biodegradation, these remedies are more energy intensive than bioventing approaches. Bioventing uses lower flow rates delivered at lower pressures, with less expensive equipment and energy needs, to introduce air into the vadose zone to stimulate in-situ aerobic biodegradation without the need for emissions controls or ex-situ vapor treatment.

Due to the low airflow requirements and typical low pressures required to create an aerobic vadose zone, bioventing can be accomplished through passive means (using air admittance valves on wells) or through solar-powered blowers (a green and sustainable approach). These features result in relatively low capital costs for equipment, minimal operating costs without electrical requirements, and low effort performance and progress monitoring through soil gas screening.

This presentation discusses performance monitoring of bioventing implementation to document leading and lagging indicators of remedial progress (i.e., groundwater concentrations, geochemistry, temperature changes, and soil gas composition and concentrations) to support calculation of associated biodegradation rates. The presentation further includes examples from successful passive and solar-powered bioventing applications of how to assess this monitoring data, using dashboards to evaluate O2/CO2 ratios, respirometry, as well as soil gas flow modeling and O2 depletion data to document remedial progress and to optimize the bioventing operation to enhance NSZD as an effective remedy for petroleum LNAPL sites.

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Seasonal Variation of Iron Flocculation in Hunnicutt Creek, Clemson, SC

White, Crawford, cwhit26@clemson.edu, and **Brian Powell,** Clemson University, Clemson, SC

Iron redox cycling acts as a natural filtration system for contaminants in water. This process occurs in the gaining stream system of Hunnicutt Creek, Clemson, SC. Ferrous iron remains soluble in groundwater and oxidizes as it is brought into the stream to form clumps of iron known as iron flocs. The concentration of iron and trace metals (including Co, Zn, U) in the stream were measured over a 12-month period. Additional physical and chemical properties of the pore and stream water were taken, including Eh, pH, dissolved oxygen, and natural organic matter (NOM) content. The levels of iron and trace metals in the pore and stream water were then correlated with temperature. Iron and trace metal levels in the pore water were found to peak in cooler months, showing that floc development in the warmer months aided the removal of trace metals from the groundwater.

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NOTES

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Scott Brame installing wells at the Clemson high-temperature geothermal energy storage heater array. He is attaching a five-foot section of a 12" diameter auger flight to the top of 25 feet of 6" augers in the ground. The oversized auger was used to enlarge the diameter of the top five feet of each well to enhance the insulating capability of the wellfield.