AIPG Michigan Section

12th Environmental Risk Management Workshop

The Basics to the Latest in Contaminant Fate & Transport

Welcome!

Welcome to the 12th Annual Michigan Section Environmental Risk Management Workshop, "The Basics to the Latest in Contaminant Fate and Transport"! We are thrilled to have you join us for this exciting event.

This year, we have curated a stellar lineup of speakers who will share their experiences with us on a wide range of topics, from essential tools to cutting-edge advancements in site investigation and remediation. Their expertise and insights promise to provide valuable knowledge that will shape our understanding of this critical field.

At its core, this workshop is built upon the values of connection, knowledge sharing, and partnership building. We firmly believe that by coming together as a community, we can make significant strides in environmental risk management. This event serves as a platform for professionals like you to network, exchange ideas, and collaborate on solutions that will shape the future of Michigan and beyond.

At this juncture in our industry's history, we find ourselves at the forefront of a significant transition to digital tools. While embracing these advancements, let us not forget the essence of what we do. Science should always be at the forefront of the decisions we make. As we explore the latest trends and technologies, let us ensure that our scientific knowledge guides us in making informed choices that will have a positive impact on our environment and society.

Throughout this workshop, we encourage you to engage actively, ask questions, and contribute to the discussions. Take advantage of this opportunity to connect with fellow professionals, exchange ideas, and build lasting collaborations. Together, we can create a positive impact and drive meaningful change.

Finally, we extend our warmest welcome to all attendees and we would like to express our deepest appreciation to each and every one of you for joining us in beautiful northern Michigan. Your presence is a testament to your dedication and passion for our industry. Let us seize this opportunity to learn, connect, and collectively contribute to the future of environmental risk management.

Sara Pearson

AIPG Michigan Section Workshop Chair

AST Environmental, Inc.

Applicable Technologies for Chemicals of Concern

Chlorinated Solvents / DNAPL	Petroleum Hydrocarbons / LNAPL	Metals	PFAS
BOS 100® (L, M)	BOS 200® (L, M, H)	FerroBlack®	Fluoro-Sorb® (L)
CAT 100 (M, H)	BOS 200+® (M, H)	ISCR (L, M)	
In Situ Chemical Oxidation (ISCO) (M, H)	ISCO (M, H)		
In Situ Chemical Reduction (ISCR) (L, M)	ISBR (L, M)		
In Situ Bioremediation (ISBR) (L, M)			

L = Low contaminant concentrations   M = Moderate contaminant concentrations   H = High contaminant concentrations

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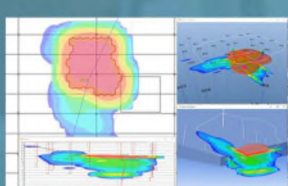

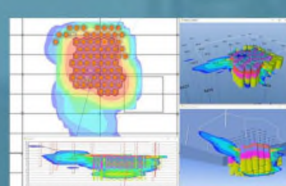

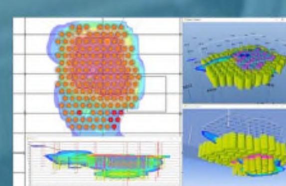

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TECHNICAL SESSION SCHEDULE

TUESDAY - JUNE 13, 2023

Time			
7:30 AM – 9:20 AM	**WORKSHOP REGISTRATION & ROOM CHECK-IN**		
9:30 AM	**Opening Remarks & Keynote Speaker Introduction**		
9:40 AM – 10:30 AM	Keynote - John F. Bratton, PhD, PG (LimnoTech)		
10:40 AM – 11:10 AM	**Using Statistical Modeling and Python to Efficiently Create 3D Deliverables and Design Remedial Options** Jim Depa (Jacob and Hefner Associates, Inc.)		
11:20 AM – 11:50 AM	**Factors Affecting the Fate and Transport of PFAS – Lessons Learned Investigating and Remediating PFAS in Michigan** Len Mankowski (WSP)		
12:00 PM – 12:50 PM	**LUNCH** **Sponsored by - BARR ENGINEERING**		
	BREAKOUT SESSIONS		
	SESSION A **Emerging Contaminants**	**SESSION B** **Site Investigation**	**SESSION C** **Remediation**
1:00 PM – 1:30 PM	**Statewide PFAS Monitoring of Ambient Groundwater and Widespread Impacts from an Industrial PFAS Facility** Michael Ranck (Fishbeck); Andy Neal (NC DEQ)	**Identification of Geologic Controls on Multiple Migration Pathways for Fuel Hydrocarbon Contaminants in a Residential Setting** Richard Raetz, PE and Rex Johnson, PhD (Global Remediation Technologies)	**Effective Use of Colloidal Activated Carbon In Situ to Reach Site Closure** Ryan Moore (Regenesis)
1:40 PM			
1:45 PM – 2:15 PM	**Utilizing a Multi-phase Finite-difference Multi-species Computer Model that Accommodates Dynamic Sorption and Competitive Interactions to Interpret and Predict PFAS Fate and Transport at Michigan Sites** Owen Miller (Regenesis)	**Soil Heterogeneity and the basics of Incremental Sampling** Chris Christensen, CPG (EGLE)	**ZVI Application to Till Via Environmental Fracturing** Derrick Lingle, CPG, Kayla Rooney (Fishbeck)
2:25 PM – 3:05 PM	**Networking Break - Sponsored by - AECOM**		
3:00 PM – 3:30 PM	**In-Situ Occurrence of Feammox Conditions and Anammox Bacteria within a PFAS Plume at the Groundwater-to-Surface Water Interface** Barry Harding, CPG, James Buzzell (AECOM)	**Furthering Hydrologic Characterization by Visual Mapping of Injection Data** Andrew Kavanagh LPG, Seth Benson (Regenesis)	**Do You Know Your Site? Qualitative Characterization, Modeling, and Remediation to Predict Site Closure** Roger Paulson, PG (Southern Environmental Management & Specialties), Bill Brab, CPG (AST Environmental)
3:40 PM			
3:45 PM – 4:15 PM	**Plasma-Based PFAS Destruction Study of Groundwater Infiltrating into a Chrome Plating Facility Basement** Selman Mujovic (Purafide), Nick Swiger, CPG, PE (EGLE), Barry Harding, CPG (AECOM)	**ISM and In-Vitro Bioaccessibility Sampling for Exposure Risk Evaluation at a Former Orchard** Steve Zayko, PE, CPG, Jeff Crum (Hamp, Mathews & Associates), Chris Christensen, CPG, Eric Wildfang, PhD (EGLE RRD)	**Development of an Innovative and Cost-Effective Boron Adsorbent Media** Rob Ferree, CPG (Geosyntec)
4:25 PM	**Closing Remarks**		
4:30 PM – 5:20 PM	***EVENING BREAK - Check-in at local hotel, Shuttle Service Available***		
5:30 PM – 6:20 PM	**DINNER (bar open)** **Sponsored by - ERG and TETRATECH**		
6:30 PM – 7:50 PM	**TECHNICAL DEMONSTRATIONS/INFORMAL Q&A** **Vapor Pin Sampling Device Demonstration - *Vapor Pin - Kyle Chilcote, Austin Johnson*** **Volatilization to the Indoor Air Pathway Roundtable - *Matt Williams (EGLE-RRD)*** **HRSC Demo - *Eagle Synergistic - Janet Castle, Vince Kowalick*** **Geotech Environmental Equipment Demo - *Geotech - Justin Mack***		
8:00 PM – 11:00 PM	**SOCIAL EVENT** **LIVE MUSIC, OPEN BAR, BONFIRES, Shuttle Transportation to Hotels** **Sponsored by - CN, Parsons, EDR Lightbox** *Live music ends @11PM* **Last Call for Shuttle Service to Hotels**		
12:00 AM			

TECHNICAL SESSION SCHEDULE

WEDNESDAY - JUNE 14, 2023

Time			
7:15 AM	**Breakfast - Sponsored by - AECOM**		
7:20 AM 7:50 AM	**SESSION A** **Emerging Contaminants**	**SESSION B** **Site Investigation**	**SESSION C** **Remediation**
8:00 AM 8:50 AM	**Morning Coffee & Networking**		
9:00 AM 9:10 AM 9:20 AM 9:30 AM	**The Role of Microbes on the Fate of PFAS in the Environment** Len Mankowski (WSP), Timothy Repas (Fixed Earth), Janice Adams (EGLE RRD)	**Optimizing Investigations of Complex Co-Mingled Contaminates with Utilizing Subsurface Imaging Technologies to Efficiently Understand the Lithology, Hydrology, Contaminate Mass, Distribution, and Migratory Pathways** Janet Castle, PG, Vince Kowalick (Eagle Synergistic)	**Navigating Processes that Drive Natural Attenuation Demonstrations for Inorganic Contaminants** Brian Ares (Geosyntec)
9:40 AM			
9:45 AM 9:55 AM 10:05 AM 10:15 AM	**Bench- and Pilot-Scale Evaluation of Ozone Fractionation Treatment Technology for PFAS Impacted Landfill Leachate** Christopher Peters, PG, CPG (Arcadis)	**Unified performance assessment metric for NAPL management - status quo or transition?** Ranga Muthu, PhD (Parsons Corporation)	**Chlorinated Solvents in Soil and Groundwater Reduced >95% by in-situ Remediation Techniques to Eliminate Vapor Intrusion Risk Pathways** Doug Spencer, Jeff Crum (Hamp, Mathews & Associates), Ryan Moore (Regenesis)
10:25 AM	**MORNING BREAK Sponsored by - TETRATECH**		
10:35 AM 10:45 AM 10:55 AM 11:05 AM	**Microplastics: A Review of What They Are, Why We should Be Concerned, and Where They Will End Up** Michael Ellis, PE (Barr Engineering)	**Flexible Investigation Tool for Emerging and Traditional Contaminants– GHD InSite** John Owens, Jonathan Eller (GHD)	**Treating PCE Groundwater Flux & Secondary Sources to Address the VIAP** Nick Rogers, Len Mankowski (WSP), Ashley Lesser (EGLE RRD)
11:15 AM			
11:20 AM 11:30 AM 11:40 AM 11:50 AM	**Transport and Effects of Microplastics** Mala Hettiarachchi, PhD, PE (Environmental Resources Group)	**A Tale of Two Models: Combining Analytical and Numerical Modeling to Estimate Contaminant Arrival Time** Katy Lindstrom, PE (Barr Engineering)	**Aerobic Dehalogenation of Organic Pollutants Using Site-Derived Microbes, BAM, and Electrooxidation** Larry Kinsman (Orin Technologies), Timothy Repas (Fixed Earth)
12:00 PM	**LUNCH Sponsored by - DUNE TECHNOLOGIES**		
	SESSION A: Site Closure		
1:00 PM 1:10 PM 1:20 PM 1:30 PM	**Mine Closure Cost Estimations: A heart attack waiting to happen for those who don't plan ahead** Dawn Garcia, CPG (Stantec)	**EGLE's New Table of Contents for Mitigation Systems** Matt Williams (EGLE RRD)	**Incorporating Green and Sustainable Remediation Metrics into a Remediation Feasibility Study** Howard Nichols, PE, Graham Crockford, CPG (TRC)
1:40 PM			
1:45 PM 1:55 PM 2:05 PM 2:15 PM	**Strategy for Closure at 79 Petroleum Sites** Michael Coram, CPG (Geosyntec), Elaine Pelc (EGLE RRD)	**Measurement Uncertainty in Laboratory Test Results: *Understanding What Your Results Really Mean...*** Taras Obal, Ph.D. (Metiri)	**Biotic and Abiotic Reduction to Achieve Green/Sustainable Groundwater Cleanup Objectives at Metals Contaminated Sites** Vincent Buening, CPG, Scott Pawlukiewicz, PE (TRC)
2:25 PM 2:35 PM 2:45 PM	**AFTERNOON BREAK - ICE CREAM SOCIAL** **Sponsored by - EAGLE SYNERGISTICS**		
2:55 PM 3:05 PM 3:15 PM 3:25 PM 3:35 PM 3:45 PM	**Michigan Case Study: Wolverine PFAS Investigations** Karen Vorce (EGLE RRD) **EPA PFAS Criteria Revisions** Abigail Hendershott (EGLE MPART)		
3:55 PM 4:05 PM 4:15 PM	**Closing Remarks - Day 2** **Raffle Drawing**		


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PLENARY SESSIONS

Understanding Fate and Effects of Contaminants in the Real World: The Concept-Data Two-Step

Presenter: John F. Bratton, PhD, PG (LimnoTech)

Figuring out where environmental contaminants come from, where they go, and what they do along the way has never been easy. There is a temptation to go out and collect a bunch of data first, and then figure out what it means later—especially with the advent of new and better tools and technologies. This presentation will give an overview of the interplay between conceptual models and data collection, as illustrated by several mini case studies. Situating field investigations within the proper thought processes is the key to answering the most important questions in the least amount of time when approaching the challenges presented by the complexities of chemicals in air, land, and sea. Warning: this presentation will contain cartoons.

Presenter: John F. Bratton, PHD, PG, is LimnoTech's Senior Science Officer and has broad expertise in earth and environmental sciences, including successful leadership of projects involving large ecosystem restoration with a nutrient reduction focus, adaptive management, remedial investigations for contaminated groundwater and sediment sites, numerical modeling and observing systems, environmental policy, and litigation support. He has worked as a consultant, researcher, educator, and science manager for over 35 years, especially in the Great Lakes, Northeast, and Pacific regions. John previously served as Acting Director of NOAA's Great Lakes Environmental Research Laboratory and research vessel fleet and as a geochemistry research group leader with the Coastal and Marine Geology Program of the U.S. Geological Survey in Woods Hole, Massachusetts. He also holds an adjunct faculty appointment at Wayne State University in Detroit and is a licensed professional geologist in four states.

Using Statistical Modeling and Python to Efficiently Create 3D Deliverables and Design Remedial Options

Presenter: Jim Depa (Jacob and Hefner Associates, Inc.)

While statistical modeling and 3D visualization technology have become more widely accepted tools on large environmental remediation projects, they remain under-utilized at smaller sites. However, recent advancements have made the technology more accessible and affordable to projects of any size. These advancements include:

1) Increased Computing Power – Statistical modeling (kriging in particular) is a computational heavy process. Modeling large datasets (which, even just a few years ago, could take hours) now takes under 10 minutes using a moderately powerful laptop.

2) Innovations in Software – Client access to finished deliverables has always been a challenge. Previously, to view data in 3D, clients were required to install software, which was either impossible (due to lack of administrative rights) or burdensome because of the technical knowledge needed to install and operate the software. Recent innovations have allowed clients to be able to access 3D visualizations using an intuitive, interactive web-based viewer.

3) Python Scripting Integration – Some data processing and visualization tasks can be partially or fully automated using Python to produce 3D models efficiently. Additionally, other types of data deliverables, including maps and cross-sections, can be created much faster than traditional methods.

The result is an economically produced, fully interactive, 3D digital conceptual site model. Not only can the models help clients, contractors, and stakeholders understand complexities in the subsurface, but the statistically modeled data can provide more accurate estimates of the in-situ contaminant mass, volumes of impacted soil, simulate the size of a potential excavation, or design a subsurface injection plan. This results in an effective remedial strategy, improved remedial design, and (perhaps most importantly) reduced costs.

Two case studies will highlight the uses and results of the technology - a mid-sized soil remediation project involving a historic release of TCE, and a smaller investigation from a gasoline release at a typical service station using high resolution tools.

Presenter: Jim Depa is a geologist and senior project manager at Jacob and Hefner Associates, Inc. He is a 2005 graduate from the University of Illinois with degrees in Geology and Geographic Information Sciences (GIS). He has more than 17 years of experience in the environmental consulting field and specializes in creating 3D statistical models to assess complex sites. He has created data deliverables on over 250 environmental investigation projects in 40 states, from routine 3D visuals to multi-million-dollar design remedies.

Specifically, Mr. Depa has helped design over a half dozen thermal remediation systems, calculated the in-situ contaminant mass in soil from one of the largest gasoline spills in United States history, and provided exhibits for three environmental lawsuits.

Factors Affecting the Fate and Transport of PFAS – Lessons Learned Investigating and Remediating PFAS in Michigan

Presenter: Len Mankowski (WSP)

Per and polyfluorinated alkyl substances (PFAS) are a class of emerging contaminants that consist of thousands of individual chemicals. PFAS are recalcitrant compounds due to the strength of the carbon-fluorine (C-F) bond; they are difficult to destroy and are long lasting in the environment. A small subset of these chemicals, principally perfluoroalkyl acids, (PFAAs), such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are being investigated across the U.S. as new screening levels/criteria are developed at the state level to protect drinking and surface water. PFAS compounds contain an elongated hydrophobic “tail” that sorbs to carbon surfaces. PFAS also contain a charged, hydrophilic functional group or “head”. Some PFAS act as “precursor” compounds that can transform to regulated PFAAs. The variety, structure, and chemical behavior of PFAS, as well as their interactions with common co-contaminants (e.g., petroleum or chlorinated hydrocarbons) and the precursor load, complicates our ability to model the fate and transport (F&T) of PFAS in the environment.

This presentation will focus on current developments in our understanding of the F&T of PFAS in the environment and present data collected from sites in Michigan over the last five-years that provide insight into site investigations to better constrain contaminant mass assessment and PFAS retention in the conceptual site model (CSM). While individual PFAS octanol-water partitioning coefficients, coupled with the fraction of organic carbon present in an aquifer, are fundamental components of F&T modeling, additional site-specific factors must be considered to assess the F&T of PFAS at individual sites. This talk will present our collected site data to highlight key factors that influence PFAS F&T, such as:

- How variations in pH affect PFAS sorption
- How the cation exchange capacity and/or the presence of clay may influence PFAS F&T
- How aerobic versus anaerobic conditions may affect bio-transformation of precursor PFAS to PFAAs.
- How PFAS have an affinity for both air (tail) and water (functional head), which results in their partitioning at air-water interfaces. In the subsurface, this behavior creates the potential for a significant accumulation of PFAS mass in the vadose zone and the capillary fringe between seasonally high and low ground-water levels; akin to “smear zones” developed by residual light non-aqueous phase liquids (LNAPL).

Improved understanding of the F&T of PFAS in the environment is needed to the develop appropriate site characterization strategies, a strong CSM and to identify cost effective, long-term remedial approaches suitable for your site(s). Improved understanding of F&T can be used to develop appropriate, site-specific soil to groundwater dilution attenuation factors (e.g., 20x groundwater protection factor) to assess leaching that sustains groundwater plumes. Tools to assess precursor load, such as the total oxidizable precursor (TOP) or total organofluorine (TOF) analyses will also be discussed.

Presenter Biography: Len Mankowski is a VP - Geology at WSP with over 18 years of site characterization and remediation experience at contaminated Sites across Michigan and the Midwest. His primary areas of expertise include: innovative remedial investigation techniques; hydrogeologic and conceptual site model development; emerging contaminants; and conceptual remedial design/technology assessments. Len earned a Bachelor of Science degree (applied geophysics, 1999) and a Master of Science in (geology, 2023) from Michigan Technological University and was an instructor at Michigan Technological University prior to entering consulting. Mr. Mankowski has published and/or presented several papers on applied, innovative characterization and remediation approaches.

Len is married with two children and lives near Suttons Bay, Michigan. He is a volunteer board member and coordinator for the Leelanau County youth soccer program and an assistant soccer coach for the Suttons Bay Public School’s boys’ varsity soccer team. Len also leads hands-on geology fieldtrips for elementary students in the area and previously served as a board member and chair for the non-profit SEEDs, located in Traverse City, Michigan. Len enjoys backpacking, camping, canoeing, and working with kids.

TUESDAY

SESSION A

EMERGING CONTAMINANTS

Statewide PFAS Monitoring of Ambient Groundwater and Widespread Impacts from an Industrial PFAS Facility

Presenter: Michael J. Ranck (Fishbeck) and Andy Neal (North Carolina DEQ)

The State of North Carolina relies on groundwater for approximately 50% of its drinking water use. Because of the importance of this resource, the State has installed, maintains, and monitors a statewide groundwater monitoring well network consisting of more than 700 wells. The information collected from this monitoring well network is used to evaluate climatic and human-induced influences on the State's groundwater supply, as well as for groundwater quality monitoring to evaluate background levels of various constituents (such as metals and nitrates) and also for potential contaminants such as pesticides, volatile organic compounds, and emerging contaminants including per- and poly-fluoroalkyl substances (PFAS).

Groundwater monitoring results across the statewide ambient groundwater monitoring well network indicate that detections of PFAS are widespread, but generally are in low concentrations (<70 nanograms/liter). At monitoring well stations where groundwater samples were collected at different depths in varying aquifers, the more significant detections were typically observed in the surficial aquifer, as would be expected from surficial and/or atmospheric sources. Legacy PFAS including perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) have been detected in most monitoring wells where any PFAS detections occurred, however, additional PFAS are often also detected at these locations.

The influence of one industrial site offers a cautionary tale on how widespread PFAS can mobilize in the environment and increase environmental risk to the public. PFAS have been manufactured at the site for over 40 years and tracking the fate and transport is complicated by releases to the environment via multiple mechanisms including stack emissions, leaks and spills that were conveyed via stormwater outfalls; and direct releases to groundwater which discharges to seeps, creeks, and the nearby Cape Fear River. While robust mitigation and risk reduction measures have already been implemented, the extensive regional impact of these releases can be seen in the PFAS signature in the statewide ambient groundwater monitoring well network as well as in private water supply wells.

Presenter Biography: Mike Ranck is a Senior Hydrogeologist with Fishbeck. He has a Master's degree in Hydrology from New Mexico Tech and a Bachelor of Science degree in Environmental Geosciences from Michigan State University. Mike has over 20 years of experience in both consulting and the public sector as a hydrogeologist, project manager, and groundwater resource manager, and has conducted groundwater assessment and remediation activities for public and private clients across the country.

Andy Neal is a Hydrogeologist with North Carolina Department of Environmental Quality. He has a Master's degree in Soils & Hydrology from Virginia Tech and a Master's degree in Hydrogeology from Kansas State University. Andy has over 12 years of experience in both consulting and the public sector as a hydrogeologist and has conducted groundwater assessment and monitoring activities for a wide range of projects and clients throughout the US.

Utilizing a Multi-phase Finite-difference Multi-species Computer Model that Accommodates Dynamic Sorption and Competitive Interactions to Interpret and Predict PFAS Fate and Transport at Michigan Sites

Presenter: Owen Miller (Regenesis)

Background/Objectives. Injectable colloidal activated carbon (CAC) barriers are an emerging remediation strategy for PFAS plume retardation and risk reduction. In essence, the approach represents the localized engineering of the soil adsorption coefficient (Kd). This naturally lends itself to modelling as Kd is a fundamental of all fate and transport models. This, in principle, introduces sets of tools to support prediction, design and interpretation of CAC PFAS remediations. But CAC adsorption isotherms are non-linear and sorption of mixed solutes is powerfully competitive. The Kd of any given species in a CAC barrier changes dynamically both spatially and temporally as the solute mix changes owing to 'chromatographic separation' of solute species resulting from differential retardation. The change can be significant. Its dynamic nature precludes application of a single isotherm for a given species throughout the modelled system. The changing Kd must be addressed through calculation or error accommodation.

Approach/Activities. A new modelling software, PlumeForce™, is used as a tool to support PFAS groundwater remediation design and data interpretations. The mass-conservative dialog between multiple compartments is modelled for multiple species in parallel, including biotic and abiotic transformations of amenable species. Competitive adsorption on CAC is accommodated, with individual Kds recalculated for each finite difference. The software also allows hidden competition to be factored in based on informed engineering estimates of likely composition – for example, the impact of the hidden / non-quantified PFAS. Performance data of a PFAS retardation barrier pilot study on two sites in Michigan is analyzed. High-resolution model predictions are compared to field observations. Goodness of fit of modelled vs observed data for multiple PFAS species is quantified by coefficient of determination (r-squared). Example overlay graphs are presented for time-series and individual sampling event data sets.

Results/Lessons Learned. Agreement between modelled and observed data is high. (Average r2 =0.90; range 0.51 – 1.00). This is despite the natural variability characteristic of a real-world data set that would reduce the r2 coefficient even if the trendline were perfect. The quantitative synthesis of advection, retardation and equilibratory dialog between aqueous, CAC-sorbed, foc-sorbed and low-transmissivity zone compartments is adequate to describe the data set. The modelling reveals three distinct phases that become more pronounced as distance from the barrier increases – a lag, principal fast decline and a residual slower decline. The basis of these is presented with implications to the monitoring and positioning of barriers. Calibration to pilot performance data allows fate and transport within the CSM to be validated and quantitatively refined ahead of full-scale implementation. The calibrated model becomes a valuable tool that may be used in support of the design process, technical communication and scenario exploration, and, post-application, as a yardstick against which performance may be tracked.

Presenter Biography: Owen Miller is a Senior Design Specialist for the East/Central Region at Regenesis. Owen Miller brings valuable project experience and technical design expertise to the team. He joined REGENESIS in 2014 as a Project Supervisor with REGENESIS Remedial Services (RRS), where he obtained hands-on experience performing remedial injections. This, coupled with his Bachelor of Science degree in Geology from the University of Wisconsin-Milwaukee, provides an invaluable platform for his role as a remediation design specialist. To be a successful remediation design specialist for REGENESIS one needs a solid scientific background as well as a practical understanding of what can and cannot be done in the field. Owen has experience in both areas, which translates to successful projects for REGENESIS clients.

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In-Situ Occurrence of Feammox Conditions and Anammox Bacteria within a PFAS Plume at the Groundwater-to-Surface Water Interface

Presenters & Co-Authors: Barry J. Harding, CPG and James Buzzell (AECOM)

Anaerobic ammonia oxidation coupled to Fe (III) reduction, known as Feammox, is a recently documented nitrogen-cycling process of particular interest to remediation practitioners due to the presence of lithoautotrophic bacteria within the genus Acidimicrobiaceae (Strain A6, or A6 for short) reportedly capable of breaking the carbon-fluorine (C-F) bond in Per- and Polyfluoroalkyl Substances (PFAS). The cleaving of the C-F bond is substantiated by identification of multiple dehalogenase genes in A6. The majority of research performed to date on Feammox and A6 has been in-vitro using controlled laboratory settings, although field-documentation of Feammox conditions are reported. Here, we document both in-situ Feammox modalities and a complex microbial Anammox consortium within an iron enriched groundwater seep adjacent to a river in western Michigan. Objectives were to 1) identify Feammox indicators, 2) document and map the microbiological signature of the seep soils, and 3) document the relationship between the Feammox condition and PFAS chemistry, if any, if possible.

Field reconnaissance during the summer of 2022 identified a prospective study location comprising approximately 150 square feet and adjacent to a western Michigan tributary. Soil and pore-water sampling was performed at three separate locations within the main study area. Soil analytes included: Field redox using resazurin/methylene blue assay, 16s rRNA V3-V4 microbiomics, Shotgun Metagenomic Sequencing, PFAS-28 list, ammonia, nitrate, nitrite, total iron, ferrous iron, and pH. Pore-water analytes included: pH, dissolved oxygen, oxidation reduction potential, PFAS-28 list, and ammonia, nitrate, nitrite, total iron, ferrous iron, and pH. Pore-water extraction was implemented using low-flow techniques via stainless-steel push-point samplers. Next Generation Sequencing and microbiomic reporting was performed by Zymo Research, Irvine, California. Iron mineralogy was confirmed using X-ray Diffraction (XRD).

Documentation of Feammox conditions were largely based on indicators and chemical ratios identified by Jaffé, Huang, Ruiz-Urigüen and others.

Next generation sequencing indicates that bacteria residing in seep locations are primary nitrogen cyclers (Nitrospira, Hyphomicrobium, Gaiella, and Methylomirabilis), iron-reducers (Leptothrix and Acidiferrobacter) and ammonia oxidizers (Nitrospira and Denitratisoma) suggestive of Feammox conditions. Two of the genera identified, Hyphomicrobium and Anaeromyxobacter are known to be encoded with dehalogenase genes. Seep geochemistry, including the ratio of iron-to-ammonia, are Feammox-like with higher iron content than typically found in reported Feammox cells. PFAS is conspicuously absent in one pore-water piezometer exhibiting Feammox-like conditions.

Presenters: Barry Harding, CPG is educated as a geologist, biologist, and botanist. He has worked as an environmental consultant since the late 1980s. His areas of expertise include nature based remedial solutions, including phytoremediation, bioremediation, and use of molecular biological tools for assessing remediation potential. His interests are too varied to mention in a short introduction.

James Buzzell is a senior geologist with AECOM. His career is diverse, originating in off-shore oil exploration and now focusing on emerging contaminant fate and transport and remediation. In his spare time Jim enjoys carving intricate objects out of basswood.

Plasma-Based PFAS Destruction Study of Groundwater Infiltrating into a Chrome Plating Facility Basement

Presenters & Co-Authors: Selman Mujovic, PhD (Purafide), Nick Swiger, PE, CPG (EGLE RRD), and Barry Harding, CPG (AECOM)

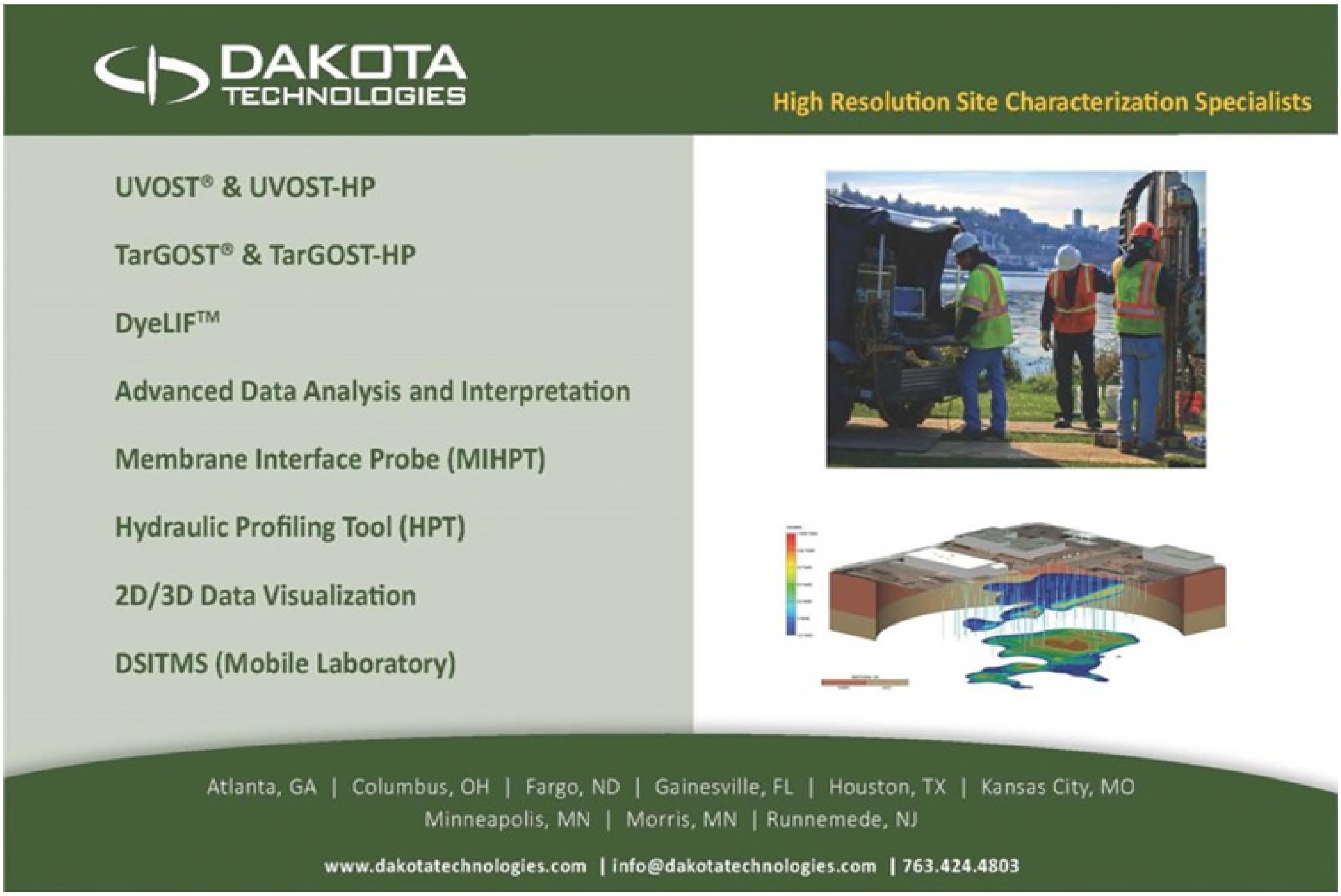
The Michigan Department of Environment, Great Lakes, and Energy is actively assessing alternative technologies for remediation of industry-impacted groundwater. The primary contaminants of concern at a legacy chrome plating facility are 1,4-dioxane and per- and polyfluoroalkyl substances (PFAS). PFAS with the highest concentrations include perfluorooctane sulfonate (PFOS) and perfluoroethylcyclohexane sulfonate (PFecHS) at 5.5 ppb and 8.9 ppb, respectively. Current state of practice for PFAS-laden groundwater is filtration. These techniques produce hazardous waste, such as concentrate and spent adsorbent media, that must be properly disposed, which is costly. Unlike separation-based technologies, plasmas can break down the most refractory contaminants in situ despite scavenger interference from the background matrix.

Purafide evaluated plasma-based destruction of these emerging contaminants in bulk groundwater derived from facility basement water. The Plasma Water Reactor (PWR) underwent parametric bench-scale studies where power was varied to regulate reactions. For example, for a fixed treatment time, preliminary experiments yielded greater than 90%, 88%, and 74% removal of 1,4-dioxane, PFOS, and PFecHS, respectively, with energy consumption on the order of 10-100 kWh/m3 for 90% removal. These unoptimized values are promising because plasma power and configuration customization can significantly improve energy efficiency and scale as reaction pathways are better understood. Decay kinetics unexpectedly exhibited non-first-order reaction rate behavior for many species. Real-time measurements of species and water quality parameters may be used as surrogates to reflect whether sufficient treatment is achieved. This coupled to dynamic plasma power could enable real-time groundwater remediation. Overall, this initial investigation is the first step towards strengthening the security, stability, and sustainability of water.

Presenters: Dr. Selman Mujovic is CEO of Purafide, LLC, a company focusing on cost-effective applications of plasma treatment approaches. His research interests include advanced oxidation processes (AOPs) and plasma treatment of emerging and traditional contaminants and geometric approaches to electrical discharge scaling for water treatment.

Nick Swiger, PE, CPG is a professional engineer and certified professional geologist. He is educated as a geologist and engineer with a focus on remedial design and innovative treatment approaches. His work interests are varied including emerging contaminants as well as non-aqueous phase liquids, petroleum hydrocarbons, and inorganic contaminants.

Barry Harding, CPG is educated as a geologist, biologist, and botanist. He has worked as an environmental consultant since the late 1980s. His areas of expertise include nature based remedial solutions, including phytoremediation, bioremediation, and use of molecular biological tools for assessing remediation potential. His interests are too varied to mention in a short introduction.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TUESDAY

SESSION B

INVESTIGATORY TECHNIQUES

Identification of Geologic Controls on Multiple Migration Pathways for Fuel Hydrocarbon Contaminants in a Residential Setting

Presenters & Co-Authors: Richard Raetz, PE, Rex. Johnson, PhD., Erin Schneider (Global Remediation Technologies, Inc.) and Kevin Selke, EGLE RRD

Previous pilot testing at an orphaned UST site in Torch Lake, Michigan, revealed poorly understood geologic conditions that inadvertently led to a completed vapor migration pathway for VOCs from the source area to several area residences. Follow-up investigations performed to evaluate the cause of the completed pathway and further assess drinking water risks has identified a complex geologic setting, as well as multiple migration pathways for the remaining impacts.

Extensive follow-up rotosonic soil borings with continuous soil sampling identified geologic materials that include near-surface mostly fine-grained lacustrine sands related to former higher water levels for the historic great lakes, underlain by a semi-continuous ice-deposited diamicton layer with an irregular easterly sloping top surface and a composition varying from stiff clay (west) to intermixed clay and clayey sand (east), and further underlying water-lain sands with intermittent clay layers down to a maximum investigation depth of 150 feet below grade. Included in the upper lacustrine sequence is a thin but important clay/clayey sand/silt layer that is continuous on the east side of the site but terminates against the inclined diamicton upper surface to the west.

Groundwater was observed in three distinct intervals: 1) a Shallow Zone (southward flow); 2) an Intermediate Zone (semi-radial flow/predominantly east-ward); and, 3) a Deep Zone (semi-radial flow/predominantly westward). Vertical downward hydraulic gradients were also found between each of the respective zones. Radial flow in the intermediate and deep groundwater zones is attributed to vertical downward groundwater leakage from the respective overlying zones. It is noted that the deep groundwater zone is inferred to be connected to area surface water bodies located east (Torch Lake) and west (Lake Michigan) of the site.

Historically observed in all three groundwater zones, current fuel hydrocarbon impacts above criteria are primarily found in the Intermediate and the Deep zones. The main migration pathway for impacts originating at the source appears to be downward, from the Shallow to the Intermediate Zone, and from the Intermediate to the Deep Zone, as consistent with the vertical hydraulic gradient data. The Intermediate to Deep Zone migration, in particular, appears to be mostly localized and coincides with areas where the intervening diamicton is sandier, thinner, or both. New preferential migration pathways within sand-rich portions of the upper diamicton east of the source area, have also been identified in a few cases and appear to contribute to previously unrecognized local horizontal migration of impacts, including toward area residences.

Based on the expanded assessment work, the previous complete vapor migration pathway for VOCs is considered to have been transient and largely the result of elevated pressures induced by localized air injection within the Intermediate Zone during pilot testing, accompanied by lateral migration of the vapors beyond the western terminus of the clay/clayey sand/silt upper confining layer to the Intermediate Zone and to nearby residences. Further active clean-up measures at the site have been ruled out based on uncertain technical practicability and effectiveness, cost, limited access to area residential properties, and current absence of significant impacts to residential wells. Instead, based on the improved understanding of the impact migration pathways, locations for sentinel wells protective of the existing residential wells are being selected, with the intent of performing on-going groundwater monitoring and replacing individual residential wells in the future, as necessary, based on the monitoring results.

Presenters: Richard Raetz, PE has 36 years of service as an environmental professional performing remedial investigations, feasibilities studies, project management, engineering designs, remediation system construction oversight and operations management, nearly exclusively for State of Michigan DOT and EGLE RRD Site Project Managers (SPM). As GRT's State Program Leader since 1994, Mr. Raetz develops Project Specific Work Plans and Cost Proposals following DOT and EGLE RRD SPM Scopes of Work. Mr. Raetz co-directs a team of environmental professionals, providing guidance for key aspects of the work and serves as a senior design engineer and senior project manager. His experience includes bidding specification document development, groundwater-, soil-, and soil gas- assessments, remedial investigation strategies, remedial alternatives feasibility studies, bench scale prototyping, pilot study development and full- scale remedial system design and implementation. Mr. Raetz is responsible for managing environmental project budgets ranging from $250,000 to more than $6,000,000 for various State of Michigan DOT and EGLE RRD Site Project Managers (PM).

Dr. Johnson has over 30 years of experience in groundwater geology, hydrogeology, chemistry, and contaminant migration assessment (in both aquifer systems and river systems via sediment transport). He conducts remedial investigations at sites containing industrial solvents, petroleum, metals, and PFAS contaminants in unconsolidated deposits and bedrock geologic settings. Recently Dr. Johnson spent nearly three years providing technical guidance to EPA's ER team, as a sub-consultant, directing investigations and supporting transport modeling of river sediments impacted with heavy oils originating from tar sands. Mr. Johnson's expertise includes the use of a wide variety of environmental drilling and sampling techniques, geophysical methods (magnetic, E-M, resistivity, seismic), conventional aquifer testing methods (slug, pump, packer tests) and groundwater modeling. He provides technical reviews of work plans and technical memorandum documents and provides direction on project scopes and RI methodologies.

Soil Heterogeneity and the basics of Incremental Sampling

Presenter: Chris Christensen, CPG (EGLE RRD)

The why and how to set up an Incremental Sampling plan using the Data Quality Objective Process. So, what is IT exactly: It is a robust planning and sampling methodology that is intended to provide representative, reproducible, and defendable soil concentrations.

It is based on collecting 30 to 100 soil increments throughout a decision unit – the decision unit is a volume of soil of which your project is making decisions. Decision units can be based on past depositional history like an orchard or future use as two-acre residential lots.

Those increments are combined to represent a single concentration for the decision unit.

Increased confidence is generated two ways: (1) the technique itself provides increased coverage over areas of interest, and (2) an emphasis on replicate samples provides confidence to the public and other stakeholders that the data is repeatable and defendable.

ISM ensures that cleanup resources are best spent where needed: to focus on areas that are contaminated and provides supporting information on areas that don't.

Case Study: Shallow soil sampling as a result of aerial lead deposition.

Sixty (60) years of lead aerial deposition from a historical brass foundry onto fifty –nine (59) downwind residential lots created a tricky evaluation for the liable party, consultant and EGLE. Initial screening of the soil with over 375 X-ray Fluorescence (XRF) samples indicated high degree of lead heterogeneity at the sub-one-foot level. EGLE teamed with the liable party and consultant to use the Data Quality Objective (DQO) protocol along with Incremental Sampling (IS) methodology to provide a reliable, representative, and reproducible evaluation of the residential direct contact risk that resulted in a residential No Further Action (NFA) for all the properties.

Presenter Biography: Chris Christensen, CPG is an Environmental Hydrogeologist with the Michigan Department of Environment, Great Lakes and Energy (EGLE), Remediation and Redevelopment Division (RRD), Technical Support Unit out of the Grand Rapids District since 1992. Chris works on both Leaking Underground Storage Tank sites as well as chlorinated solvent and surficial soil contamination sites. He is on RRD Technical Teams related to Incremental Sampling, Non-Aqueous Phase Liquids, Risk-based Corrective Action, and Groundwater Modeling. He has advocated for Incremental Sampling use in Michigan since 2011 and contributed as a member of the ITRC ISM-2 team. Chris has a BS in Geology from Michigan State University and a MS in Hydrogeology from Western Michigan University.

Furthering Hydrologic Characterization by Visual Mapping of Injection Data

Presenters & Co-Authors: Andrew Kavanagh LPG, and Seth Benson (Regenesis)

Background/Objectives. Amongst remediation practitioners it is a known truth: there is not sufficient understanding of the hydrology before implementing a remediation project. However, there is a largely unexplored yet abundant data mine collected during in situ remediation projects that can greatly enhance the understanding of hydraulic conditions. When used properly in conjunction with an adaptive remediation approach, a successful remedy and a more rapid site closure can be assured.

Approach/Activities. One of the most common methods employed for the injection of remediation fluids is pumping through drilling rods advanced by a direct push rig. When done correctly, flow rates, pressure responses and applied volumes are recorded for a given vertical interval as fluids are injected. Through the relationship between an applied pumping (i.e., flow) rate and the formation pressure response, a relative permeability can be derived for a given volume or, unit of treatment. These permeability units can then be plotted, and visual enhancement applied to create a cross-sectional picture of the subsurface hydrological architecture. When viewed in real-time during injection, these pictures are a useful aid in properly directing remedial fluids to the target contaminant flux zones. Once completed, they can often greatly enhance the hydraulic understanding at a project site the due to the density of data that is often collected during injection.

Results/Lessons Learned. Case studies will be presented to demonstrate how this approach was used to overcome challenging heterogeneous environments during installation of permeable reactive barriers and source zone grids. This approach led to a more optimal directing of remedial fluids, a better understanding of the more discrete nature of the permeable channels and a successful remedy implementation. Multiple remedial technologies were used at the sites within the case studies. The sites are located in the Midwest, including Michigan, where the target contaminants were CVOC's and PFAS compounds.

Presenters: Andrew Kavanagh serves as a project manager for the central region at Regenesis. He has over nine years of experience related to soil and groundwater remediation and holds a professional geologist license in the state of Indiana. His primary responsibilities include the planning, implementation, and closeout of remediation projects, management of field staff, and the development of technical training content for the division in collaboration with other project managers and departments. Mr. Kavanagh attended Colgate University where he was awarded a division 1AA football scholarship and graduated with a Bachelors degree in geology. In his spare time, he can be found shredding electric guitar with his band at venues throughout the Midwest, spending time with his family, and grilling (charcoal/wood only).

Seth Benson has five years of experience in the environmental field ranging from teaching Microbiology to agriculture to environmental remediation. Mr. Benson joined Regenesis in January of 2021 where he implements Regenesis' full suite of remediation technologies for both small and large scale in-situ remediation projects spanning the continental United States. He graduated from Central Michigan University with a bachelor's in biology and psychology and a minor in chemistry. On top of his primary duties as a Project Supervisor, Mr. Benson has taken several courses which specialize in Geographical Information Systems (GIS). He uses this sought-after skillset to generate surface and subsurface visuals that document data that is collected during an on-site injection application. In his spare time, he plays hockey goalie still believing in that NHL dream. He also enjoys camping with his wife and dabbling in language learning.

ISM and In-Vitro Bioaccessibility Sampling for Exposure Risk Evaluation at a Former Orchard

Presenters & Co-Authors: Stephen Zayko, PE, CPG and Jeff Crum (Hamp Matthew & Associates), Chris Christensen, CPG and Eric Wildfang, PhD (EGLE RRD)

Soil direct contact exposure risk to arsenic in soil was assessed using Incremental Sampling Methodology (ISM) coupled with In-Vitro Bioaccessibility (IVBA) at an apartment complex built on a former orchard. Previously collected discrete and composite soil sample results indicated that an ISM sampling strategy, when coupled with IVBA analysis of soils, may provide a more representative evaluation of site-specific soil direct contact risk. IVBA analytical results were used to calculate relative bioavailability (RBA) for use in calculating a site-specific arsenic direct contact criterion. The comparison of the site-specific arsenic direct contact criterion and ISM representative soil concentrations were used to evaluate soil direct contact risk.

The property is approximately 12 acres that was operated as a former orchard from the 1930s until the 1980s. The property was developed as an apartment complex in the 1990s. A Phase II Environmental Site Assessment (ESA) completed at the property located in Southwest Michigan identified soil arsenic exceedances of the Part 201 arsenic generic soil direct contact criterion of 7,600 ug/kg. The discrete Phase II ESA arsenic concentrations were widely variable (3,800 ug/kg to 60,000 ug/kg) with all but two of the 24 shallow soils samples (0 to 18-inches below ground surface), exceeding the Michigan Department of Environment, Great Lakes, and Energy (EGLE) residential Part 201 generic cleanup criterion for arsenic direct contact.

HMA and EGLE collaboratively developed a sampling plan that utilized ISM to subdivide the property into nine decision units (DUs), each with a shallow (0-6 inches) and deep (6-12) sampled interval. The ISM sampling application yielded representative DU soil arsenic concentrations. HMA and EGLE then utilized the IVBA sample analyses to calculate RBA and worked together to calculate Part 201 site-specific residential soil direct contact criterion (SS-DCC) for each DU. Subsequent comparison of the representative DU soil arsenic concentrations and SS-DDC were then made for innovative evaluation of arsenic soil direct contact risk.

Presenters: Stephen Zayko, PE, CPG is a Senior Engineer that has nearly 30 years of experience completing projects in over 30 states, nine EPA regions, and six countries. He specializes in Vapor Intrusion, Remediation System Design, Statistical Analysis, Computer Modeling, and Risk Assessment. A member of the Michigan Department of Environment, Great Lakes, and Energy (EGLE) Response Activity Review Panel. In 2014, Mr. Zayko participated in the Michigan Criteria Stakeholder's Advisory Group to assist with planned updates to generic cleanup criteria. His current work activities involve volatilization to indoor air pathway assessment and mitigation at sites containing chlorinated volatile organic compounds (CVOCs) and/or petroleum volatile organic compounds (PVOCs). Throughout his career, Mr. Zayko has consistently used the United States Environmental Protection Agency (USEPA) Data Quality Objectives (DQO) process for collecting and evaluating data to develop Conceptual Site Models (CSMs) used to direct and support project decisions.

Jeffrey Crum has invested 32 years of his career as a toxicologist split evenly as a regulator and consultant. Mr. Crum is among the states most recognized vapor intrusion (VI) specialists, having developed the Michigan Department of Environment, Great Lakes, and Energy (EGLE) VI cleanup criteria in 1997; the only EGLE cleanup criteria subjected to review and approval (2001) by the Michigan Environmental Science Board. Mr. Crum has led or reviewed hundreds of VI assessments and coordinated the design, installation, and monitoring of numerous vapor mitigation systems. As HMAs VI practice leader, Mr. Crum serves as project leader for all VI assessment and mitigation projects. Additionally, Mr. Crum ensures that company sampling plans apply the U.S. Environmental Protection Agency (EPA) Data Quality Objectives (DQO) process and incorporate conceptual site model (CSM) development to support reliable risk assessment decision-making.

Chris Christensen, CPG is an Environmental Hydrogeologist with the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Remediation and Redevelopment Division (RRD), Technical Support Unit out of the Grand Rapids District since 1992. Chris works on both Leaking Underground Storage Tank sites as well as chlorinated solvent and surficial soil contamination sites. He is on RRD Technical Teams related to Incremental Sampling, Non-Aqueous Phase Liquids, Risk-based Corrective Action, and Groundwater Modeling. He has advocated for Incremental Sampling use in Michigan since 2011 and contributed as a member of the ITRC ISM-2 team. Chris has a BS in Geology from Michigan State University and a MS in Hydrogeology from Western Michigan University.

Dr. Eric Wildfang is a toxicologist and supervisor of the Remediation and Redevelopment Division Toxicology Unit, where he has worked for 17 years. In this role he provides toxicology guidance, training, and support for EGLE staff, the regulated community, and the public on the Part 201 cleanup criteria and risk assessment practices. He has represented the department in numerous stakeholder groups, developed guidance materials, reviewed site-specific submittals, and developed and managed generic cleanup criteria databases. Eric has background in cancer research, clinical chemistry, and environmental consulting.

TUESDAY

SESSION C

REMEDIATION

Effective Use of Colloidal Activated Carbon In-Situ to Reach Site Closure

Presenter: Ryan Moore (Regenesis)

A retail gas station operating from 1976 to 1992 experienced corrosion failure of its USTs which resulted in contamination to the property and adjacent site. A range of remediation technologies were implemented for site cleanup between 2004 and 2017, including soil vapor extraction, excavation, oxygen diffusion, powdered activated carbon (PAC) injection, and in situ chemical oxidation (ISCO) coupled with slow-release oxygen. These efforts removed more than 7,000 lbs of contamination, reducing the extent of plume coverage, but a large, 6,000 square foot plume remained on the original property and off-site at concentrations orders-of-magnitude above Tier I cleanup levels.

Concerned about the performance of the original remediation approaches applied, the project shifted direction and implemented a new approach using colloidal activated carbon (CAC) in 2019. CAC has a strong affinity for many toxic soil and groundwater contaminants and its very fine particle size (1 to 2 μm) allows for broad distribution into aquifer flux zones. When combined with a destructive mechanism, it rapidly adsorbs contaminants onto the carbon particles, degrading the contaminants through stimulated anaerobic biodegradation.

At this site, CAC was applied using low-pressure, tightened spacing, increased volumes and product tracer testing to overcome previously experienced injection difficulties. Soil cores and groundwater samples were taken during application to visually confirm the presence or absence of material. Using the field data, the original design was modified in real-time with minor adjustments to application volume, pressure, or spacing. Three months post-application nine of 10 plume wells attained over +99% reductions, or non-detect, with benzene while BTEX or TPH-G had similar reductions. Tier I cleanup concentrations were achieved, and the site was granted site closure 18 months post injection.

Lessons learned from the case study as well as the importance of using higher injection volumes to achieve distribution and implementing low-pressure injection techniques versus commonly specified high-pressure approaches will be highlighted.

Presenter Biography: Ryan Moore has more than 20 years of experience as an environmental project manager and laboratory account executive relating to multimedia contamination sites throughout the U.S. His experience focused on site investigations of soil and groundwater contamination, corrective action evaluations, operation & maintenance of remediation systems, in situ groundwater and soil treatment, and business development. Ryan holds a B.S. of Environmental Studies from Manchester University, North Manchester, IN.


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ZVI Application to Till Via Environmental Fracturing

Presenters & Co-Authors: Derrick A. Lingle, CPG, Kayla M. Rooney (Fishbeck)

Fishbeck has supported a private, liable party through a complex remedial investigation and clean-up at a former solvent waste recovery and distribution facility located in West Michigan. Work at the site is conducted in collaboration with the United States Environmental Protection Agency (EPA). Using an environmental risk management approach, high resolution site characterization (HRSC) has identified a complex glacial depositional sequence with multiple saturated permeable zones confined by layers of interbedded till. Contaminants associated with chlorinated solvents, primarily trichloroethene (TCE), have migrated laterally in several directions due to the various groundwater flow regimes as well as vertically through the unconsolidated strata and into the weathered portion of the underlying Michigan Formation (shale). To further complicate matters, the subject site is situated in a highly developed urban setting where buildings, roadways, and utility infrastructure present substantial logistical obstacles to remedial implementation.

Considering the site access constraints and high source area TCE concentrations (>200,000 µg/L in groundwater), the injection of zero valent iron (ZVI) was selected as the preferred remedial approach to reduce source area contaminant mass. Injection via environmental fracturing was selected over traditional in situ injection approaches to achieve the target injectate volume, given the high contaminant mass, low formation permeability, and concern for back-diffusion. Environmental fracturing of the till was employed to deliver approximately 66,000 pounds of ZVI to pre-determined target horizons within the source area.

As part of a pilot study monitoring program, 25 data loggers were deployed in the various saturated units across the study area to assess the aquifer response to environmental fracturing and the correlation with the potential displacement of contaminants. While data collected from several distal monitoring wells identified a brief, nominal hydraulic response that correlated with the ZVI injection activities, a greater hydraulic response was observed within the injection footprint. An upward vertical hydraulic gradient was generally observed between the various saturated units in the source area before the ZVI injection; however, the mass injected into the aquifer appears to have reversed the local vertical hydraulic gradient.

Pilot study monitoring conducted 12 months post-injection indicates that the application of ZVI has resulted in a decrease in source-area TCE concentrations of approximately 75%, although monitoring is on-going to assess the potential occurrence of back-diffusion. Groundwater monitoring data suggests that while reductive dechlorination is actively occurring, reduction via hydrogenolysis has played a greater role than anticipated compared to the beta-elimination pathway in the presence of the ZVI. While the placement of ZVI appears to be limited to the area immediately surrounding the injection wells, the geochemical halo effect induced by the hydraulic response to the injection activities appears to be further reaching. Lessons learned from this case study can be applied to the design and monitoring of environmental fracturing utilized in similar conditions.

Presenters: Derrick A. Lingle, CPG is a Senior Hydrogeologist at Fishbeck, a full-service architecture, engineering, and environmental consulting firm celebrating over 60 years of business. He has a Master of Science degree in Geology from Western Michigan University and a Bachelor of Science degree in Environmental Geoscience from Michigan State University. His expertise is in contaminant and hydrogeological investigations. Mr. Lingle has extensive field experience with vapor intrusion studies, groundwater and surface water interface evaluations, and contaminant delineation in various media. He has also assisted with the design and installation of several sub-slab vapor mitigation systems. Mr. Lingle has managed and implemented hydrogeologic and remedial investigations at facilities such as coal-fired power plants, oil terminals, solvent recovery sites, and retail petroleum distribution centers under Michigan Part 111, 201, and 213 as well as the EPA RCRA Program. Mr. Lingle joined Envirologic in 2013 prior to Fishbeck's acquisition of Envirologic in January 2023.

Kayla M. Rooney is a Geologist at Fishbeck. She has a Bachelor of Science degree in Geology from Grand Valley State University. Ms. Rooney has field experience with various drilling and well installation methods, remediation technologies, aquifer testing, installation of vapor mitigation systems, as well as sampling in support of vapor intrusion studies and contaminant delineation in various media. She is also a Certified Industrial and Construction Stormwater Operator. Ms. Rooney joined Envirologic in 2020 prior to Fishbeck's acquisition in January 2023.

Do You Know Your Site?
Qualitative Characterization, Modeling, and Remediation to Predict Site Closure

Presenters & Co-Authors: Roger Paulson, PG (Southern Environmental Management & Specialties), and Bill Brab, CPG (AST Environmental)

Background/Objectives. A review of the Statistical Inventory Records in August 1993 indicated a release of fuel had occurred into the environment, five (5) gasoline tanks were documented at the site and were subsequently removed in November 1993 or closed-in-place in June 2004. A series of mobile-enhanced multi-phased extraction events were completed between July 1993 and November 2008. The site is >0.25 miles from a wellhead protection area and is zoned commercial and vacant. A dedicated multi-phase extraction unit was deployed at the site beginning in March 2011 and operated until August 2017. Soil gas survey points installed were below the look-up-values and the volatilization to indoor air is not a complete pathway; however, free product was present in one on-site monitoring well and benzene remained elevated above the site-specific clean-up level (SSCL) in seven (7) monitoring wells on and off-site.

Approach/Activities. A Remedial Design Characterization was conducted in September 2018 to rapidly characterize the extent of total petroleum mass in soil and groundwater at the site, emergency interim corrective action was approved for in-situ remedial injections in November 2018 and was completed in December 2018. Modeling of the total mass present at the site in soil and groundwater indicated the required time to reach clean-up would be 4-6 years following completion of the interim measures. To evaluate the progress of the interim measures, a high-resolution site characterization (HRSC) was conducted in January 2021 using the laser-induced fluorescence (UVOST®) to identify the potential extent of remaining residual LNAPL at the site. The UVOST survey was utilized to optimize the subsequent qualitative High-Resolution Site Characterization (qHRSC) program completed in June 2021, the qHRSC Program consisted of the installation of eighteen (18) soil borings across the site to establish a new baseline for contaminant concentrations at the site and update the existing conceptual site model (CSM). Using the data from the qHRSC, a surgical injection design was developed for the site using Trap & Treat® BOS 200+®. To expedite the time to site closure, the second injection event was approved in November 2021 and was completed in March 2022. Post-injection performance monitoring of COCs and degradation biproducts were completed from baseline (RDC 2018) thru the current date, microbial diagnostics were completed throughout 2022 to further evaluate conditions and progress at the site.

Results/Lessons Learned. The presentation will focus on the demonstration of the efficient use of investigative methods to expedite the time to implement a fiscally responsible remediation program, resulting in reduced time to reach site closure and cost to clean-up expenses. A review of the historical Conceptual Site Model (CSM), involvement of all stakeholders to update the CSM using qHRSC (HRSC + RDC methods), and implementation of in-situ injection methods and technologies which enhance source zone depletion and significantly reduce the time to reach the site-specific clean-up goals to justify site closure and No Further Action will also be discussed. Remedial evolution will highlight the development, selection, and use of a new and cutting-edge application of cometabolic synergy: powdered activated carbon coupled with an enhanced biological component. Lessons learned and relevant data to be presented will include benefits of high-density indiscriminate (regardless of field screening/field observations) soil and groundwater sampling for qualitative analysis in the laboratory, post-injection performance analytical and microbial diagnostic tools will also be provided.

Presenters: Roger Paulson, PG is a hydrogeologist at SEMS, Inc. He is a professional geologist in Tennessee, Arkansas, Georgia, Alabama, Missouri, and Florida. He is also a Tennessee Corrective Action Specialist.

Bill Brab, CPG has Bill has been on the AST team since 2011 as a Senior Remediation Geologist and is based in Midway, Kentucky. He manages most of the projects in Kentucky and Tennessee for the company. Bill received his BS degree in Geology from the University of Kentucky. Bill is a long-standing member of the American Institute of Professional Geologists (AIPG) and currently holds the Treasurer Executive Office position for the Kentucky Section. He is also an active board delegate on the Kentucky Board of Registration for Professional Geologists, which manages and oversees licensure within the commonwealth. He was drawn to AST because of their commitment to closing sites quickly and using sound science to maximize efficiency, rather than operating under a framework that promotes stagnation and keeps properties in purgatory for decades.

Telemetry – Remote Monitoring – Data Services
The Cost Benefit Analysis of Continuous Monitoring

Presenter: David A. Wardwell, (Dune Technologies, LLC)

Telemetry & Remote Monitoring technology is nothing new. It has existed for decades, but the cost and complexity of these systems limited their utilization. Most digital data management systems have been relegated to government organizations who have the budget and personnel to install, program, and manage such networks. In recent years, as will all technology, remote monitoring systems have lowered in cost and have evolved much more user-friendly operating systems.

Presenter Biography: Dave A. Wardwell is President of Dune Technologies, LLC an environmental technology representation firm that encompasses the Great Lakes area. He has more than a 33-year history in the environmental industry, including a B.A. in Geology from Denison University an M.S. in Hydrogeology from Western Michigan University, and an M.B.A from the University of New Mexico. His professional experience includes 4 years of environmental consulting/engineering, 6 years of environmental technology research & development in the in-situ remediation and sensor instrumentation fields.

David was a divisional manager for In-Situ, Inc. for 9 years before he started Dune Technologies, LLC in 2009. Dune Technologies, LLC is an environmental technology representation firm that specializes in advanced environmental instrumentation, and in-situ remediation solutions. Dave uses his technical knowledge and project experience to evaluate client projects for in-situ remedial solutions, and provide project evaluation, remedial feasibility & estimates..

TUESDAY

EVENING FIELD DEMONSTRATIONS

Field Demonstrations/Vapor Intrusion Roundtable Session

1. **VaporPin Sampling Device Demonstration –** The Vapor Pin® Sampling Device technology provides a secure platform for consultants to quickly and accurately collect essential sub-slab data (soil gas screening data, soil gas samples for laboratory analysis, and sub-slab pressure readings) used in source characterization studies, vapor intrusion assessments, vapor (VOC and radon) mitigation system design and evaluation. The Vapor Pin® Insert is being specified in drawings and projects across the US and is used to facilitate the collection of soil gas samples and pressure measurements beneath engineered vapor intrusion barriers (e.g., Geo-Seal®), or vapor mitigation coatings (e.g., Retro-Coat™).

   Stop by and see a demonstration of the installed Vapor Pin® Insert, the Mini Vapor Pin® Sampling Device as well as the newest Product the Vapor Pin® ____________________. What is the newest product in the Vapor Pin® product line, come see for yourself.

   The Vapor Pin®, first introduced to the market in 2011, has become the world-wide standard tool for sub-slab investigations with tens of thousands in use in North America, South America, Australia, Europe, Africa, and Asia.

2. **Volatilization to the Indoor Air Pathway Roundtable - Matt Williams (EGLE RRD) –** This session is a unique interactive presentation where the audience is expected to be part of the discussion about the roadblocks and issues concerning the VIAP. As part of the roundtable and discussion process participants will identify and discuss various topics and then begin a process to identify and explore solution-based ideas. In addition to identifying potential solutions, a goal of the roundtable is providing insights into the issues from different perspectives and possibly solutions people can implement immediately. Several topics will be explored. Topics for discussion during the session for those attending can be submitted via email to williamsm13@michigan.gov.

3. **HRSC Demonstration – High Resolution Site Characterization Demonstration** – Eagle Synergistics – Equipment and technology demonstration given by Eagle Synergistics' Janet Castle and Vince Kowalick.

4. **Geotech Environmental Equipment Demonstration** – Geotech representative will be showcasing the equipment that they rent out for environmental investigations and providing a demonstration of how the equipment functions. Justin Mack will be demonstrating the state-of-the art Ayyeka Industrial IoT Wireless Telemetry Devices.

WEDNESDAY (AM)

SESSION A

EMERGING CONTAMINANTS

The Role of Microbes on the Fate of PFAS in the Environment

Presenters & Co-Authors: Len Mankowski (WSP), Timothy Repas (Fixed Earth), and Janice Adams (EGLE RRD)

Per and polyfluorinated alkyl substances (PFAS) are a class of emerging contaminants that consist of thousands of individual chemicals. PFAS are recalcitrant compounds due to the strength of the carbon-fluorine (C-F) bond; they are difficult to destroy and are long lasting in the environment. While PFAS are thought to be resistant to biologic degradation, there is growing evidence of potential microbial facilitated reactions that transform “precursor” PFAS to “dead-end” perfluoroalkyl acids, (PFAAs), such as perfluorooctane sulfonate and perfluoro-octanoic acid (PFOS/A). Some studies have recently identified potential microbial degradation of PFOS/A. Unlocking a biodegradation mechanism to degrade PFAS, including PFOS/A, is needed to create a cost effective, in situ remedy to address these emerging contaminants.

Microbes were isolated from a suspected aqueous film forming foam (AFFF) site in Alpena, Michigan. This site is a good candidate for microbial assessment because PFOS/A concentrations increase when conditions in site groundwater become more aerobic (i.e., downgradient from the source). Six candidate microbes were isolated from site soil and groundwater that were viable in a PFAS growth medium. In an initial microcosm study, the isolated microbes were found to biodegrade PFOS/A in spiked tap water as well as site groundwater at two- and eight-weeks with the addition of various bioenhancements. In another microcosm study funded by WSP and Fixed Earth in 2022-2023, PFOS/A biodegradability is further verified in PFOS/A spiked tap water using a diffusive oxygen source. This study included triplicate analyses, the use of whole bottle extraction methods and controls to assess the potential effect of sorption into the biomass. Kinetics were assessed at one-, two- and four- weeks. Microbial viability assessment of inorganic fluoride formation was assessed at each test stage.

PFAS are considered “forever chemicals” because of the strength of the C-F bonds. PFOS/A biodegradability is difficult to verify, particularly when precursors are transformed into PFOS/A at rates that may be faster than PFOS/A biodegradation. These studies used site microbial cultures acclimated to the high PFAS levels in groundwater. During the initial benchtop study, the microbe treated spiked tap water reduced the PFOS/A concentrations by 97% and 94%, respectively, at eight-weeks under aerobic conditions. In site groundwater treated with microbes PFOS concentrations in the groundwater systems increased slightly (8%) at two-weeks, likely due to transient biotransformation of precursors, before declining by 70% at eight weeks. A preliminary pilot study bioaugmented with the isolated culture and oxygen source also demonstrated initial PFOS/A degradation potential. However, the kinetics of precursor biotransformation to PFOS/A may cloak ongoing degradation of PFOS/A, particularly under field conditions (i.e., open system with additional PFAS flux). The 2022-23 verification microcosm study will confirm PFOS/A biodegradation and assess cleavage of C-F bonds. Recommendations on in-situ biodegradation of PFOS/A will be provided in this presentation based on the lessons learned.

Presenters: Len Mankowski is a VP - Geology at WSP with over 18 years of site characterization and remediation experience at contaminated Sites across Michigan and the Midwest. His primary areas of expertise include: innovative remedial investigation techniques; hydrogeologic and conceptual site model development; emerging contaminants; and conceptual remedial design/technology assessments. Len earned a Bachelor of Science degree (applied geophysics, 1999) and a Master of Science in (geology, 2023) from Michigan Technological University and was an instructor at Michigan Technological University prior to entering consulting. Mr. Mankowski has published and/or presented several papers on applied, innovative characterization and remediation approaches.

Timothy Repas is a co-founder and current President of Fixed Earth Innovations, a biotechnology company with a focus on the development and testing of microbes to solve challenges in remediation, ecosystem restoration, and agriculture. Mr. Repas has over 11 years or experience in the biotechnology and environmental remediation sectors with experience in project management, environmental site investigation, in situ bioremediation of soil and groundwater, emergency spill response, and site reclamation. Mr. Repas earned a Bachelor of Science degree in biochemistry at Elmira College in 2011 and a Master of Science degree in Biology at the University of Saskatchewan in 2014. Mr. Repas is a Professional Agrologist registered with the British Columbia Institute of Agrologists with areas of practice including contaminated sites remediation, soil conservation and restoration, and biotechnology development.

Janice Adams is a Senior Geologist at the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Remediation and Redevelopment Division with 31 years working in environmental remediation. Prior to working for EGLE she had 5 years of consulting experience working throughout Michigan and Florida.

Janice has conducted and overseen environmental remediation and hydrogeological investigations. Janice oversees state-funded sites of environmental contamination, and state and federal grants throughout Michigan.

Janice has a BS in Geology from Lake Superior State University. Janice is married with two adult sons. She enjoys kayaking, camping, hiking, history, and traveling.

Bench- and Pilot-Scale Evaluation of Ozone Fractionation Treatment Technology for PFAS Impacted Landfill Leachate

Presenters & Co-Authors: Christopher Peters, PG, CPG, Baxter Miatke, PE, and Ted Kremer, PE (Arcadis of Michigan, LLC)

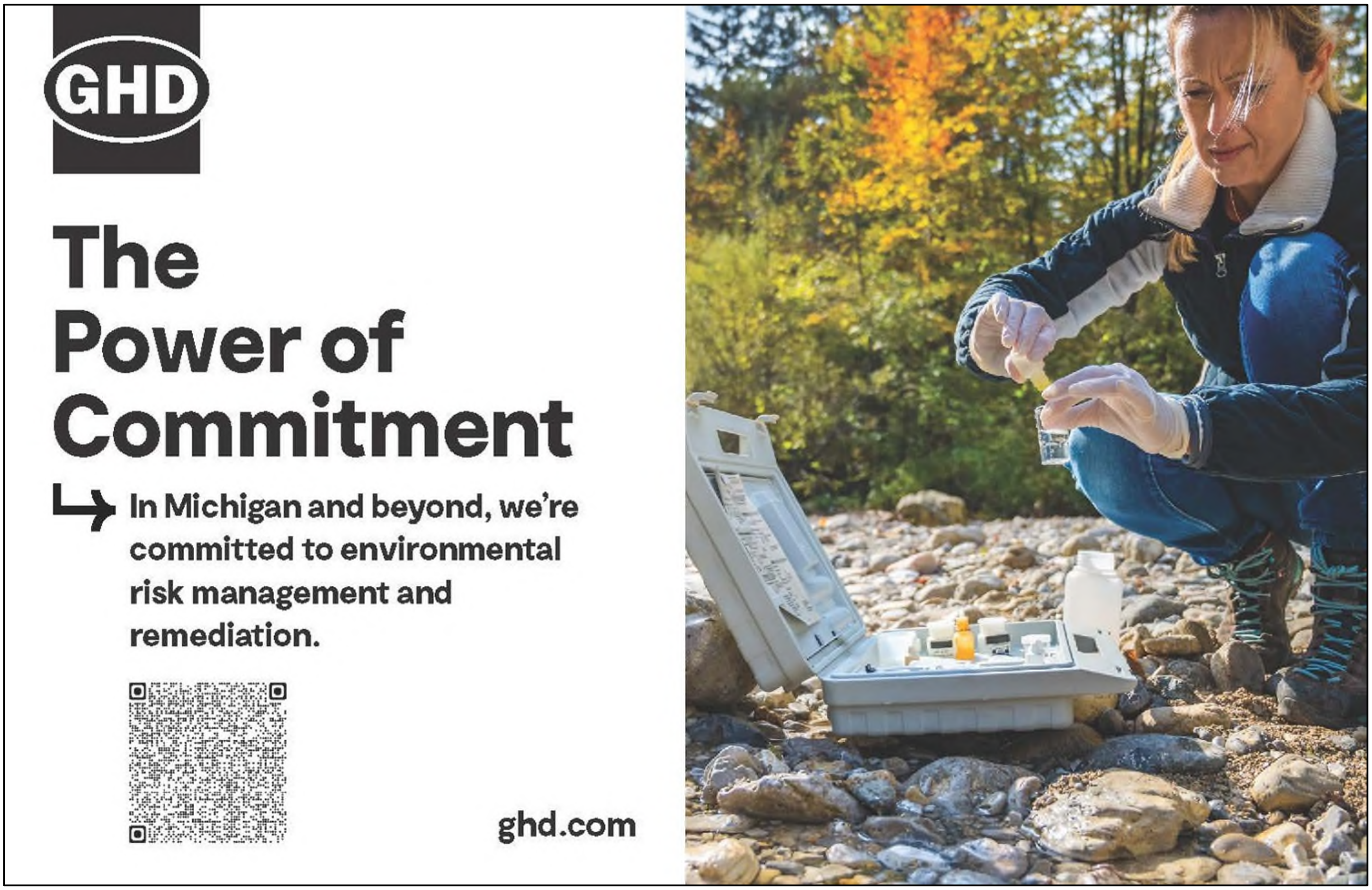
Arcadis was retained by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) to perform a desktop Feasibility Study (FS), bench-scale, and pilot-scale testing to remove per- and polyfluoroalkyl substances (PFAS) from landfill leachate at the former DSC McLouth Steel Gibraltar Plant Superfund Site - Countywide Landfill (CWLF) Operable Unit in Gibraltar, Michigan. The objective of this presentation is to show the development of fractionation technology with a case study progressing from bench scale to pilot scale work and how fractionation can be incorporated into a treatment train approach at full-scale.

Fractionation is a separation technology that uses micron-sized gas (air or ozone) bubbles to remove contaminants, such as PFAS, from water. Ozone Fractionation is a patented process developed by Evocra, Inc. of Australia which has several systems that have been in successful operation for several years. Arcadis partnered with Evocra for development of this treatment equipment in North America. PFAS molecules have hydrophilic and hydrophobic properties attracting them to the gas-liquid interfaces present in fractionation as the injected gas bubbles move through water. Bubbles interact with PFAS and other constituents and are discharged as foam fractionate.

This project included the development of a fractionation bench-scale apparatus to rapidly screen site-specific water and the design, construction, and operation of a portable pilot-scale fractionation plant. Bench-scale testing was performed in December 2020 on a landfill leachate with high PFAS and total organic carbon concentrations to determine technology applicability for full-scale treatment. Bench-scale testing consisted of screening three treatment technologies: ozone fractionation, granulated activated carbon (GAC) filtration, and membrane series filtration. Pilot-scale testing was performed in December 2021 with breakpoint chlorination for pretreatment of ammonia, air, and ozone fractionation with GAC plus ion exchange (IEX) resin filtration.

Analytical samples were collected for PFAS, metals, TOC, TSS, and other general water chemistry parameters. Reduction of PFOS and PFOA concentrations was the primary treatment objective of the study, and both compounds were successfully treated from influent concentrations to non-detect in the treated effluent. PFOS and PFOA concentrations were higher in the foam concentrate after fractionation with ozone gas than with air, suggesting that the gas effect on bubble size can have an impact on fractionation performance and transformation of PFAS precursors. The foam concentrate had high concentrations of PFAS in samples using ozone (upwards of 9,500 ppt) and low volume (<5% of the influent volume) providing successful proof of concept of the fractionation bench testing. The pilot scale was also able to reduce PFAS to non-detectable levels, and the results are being used to compare and confirm waste generation rates and the overall cost effectiveness for full-scale implementation. The design of a full-scale fractionation system to treat the leachate at the CWLF is now underway.

Presenter: Christopher Peters, PG, CPG has 39 years of environmental consulting and management experience, 29 years in Michigan. His areas of expertise include solid waste management, RCRA and state-led (Part 201) remedial investigations, hydrogeologic investigations, surface water management and permitting, expert testimony, and regulatory liaison services. He has managed large portfolios of sites for the private and public sector, including significant experience with PFAS groundwater and soil investigations. He has specific expertise in the pulp and paper and cement industries.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Microplastics: A Review of What They Are, Why We Should Be Concerned, and Where They Will End Up

Presenter: Michael Ellis, PE (Barr Engineering)

Plastics have become an indispensable part of our daily life. Global production of plastics is estimated to be 380 million tons (MT) per year and is projected to reach 12,000 MT by 2050. Only 18% of plastics are recycled, 24% are incinerated, and 58% end up in a landfill or are released to the environment. As they reside in the environment, plastics are subjected to different conditions such as heat, precipitation, and ultraviolet light which causes plastics to undergo degradation through different pathways such as mechanical, photochemical, and microbial. Degradation, also known as weathering, of plastics affects their physical and chemical properties causing them to become more brittle and susceptible to fragmentation and formation of microplastics (MPs) and eventually nanoplastics (NPs). MPs vary in shape (fibers, fragments, films, etc.), material type, source, and size (1 nanometer to 5 millimeters).

The effect of MPs on human health and the environment is not fully understood, but MPs are suspected to have some toxicological effects. Several studies have confirmed the presence of MPs in various environmental media such as surface water, air, biosolids, and soil along with various aquatic organisms. Currently there is not federal legislation that identifies maximum contaminant levels for MPs in the different environmental matrices, although some states have initiated development of regulations, and as more research emerges, it is expected that more regulations will be proposed to mitigate the levels of MPs in the environment.

In order to understand what aspects of human health and the environment will be most impacted by MPs, it is important to develop an understanding of fate and transport for MPs. Knowledge of fate and transport mechanisms will also help identify where MPs may accumulate in the environment and where there may be opportunities to implement mitigation measures to reduce the presence of MPs in the environment.

MPs are an emerging contaminant of concern and the amount of MPs being introduced to the environment is expected to increase in the coming decades which will likely result in this contaminant becoming a more prominent issue. In order for the environmental industry to be prepared for how best to evaluate and mitigate MPs, it is important to develop an understanding of what microplastics are, how they differ from other contaminants, their fate and transport mechanisms, and potential human exposure pathways.

Presenter Biography: Michael Ellis, PE is an environmental engineer with more than 11 years of experience working on complex remediation projects. His work focuses on evaluating, designing, and implementing remedial actions, including conducting feasibility studies, developing remedial action work plans, managing implementation, and assessing comprehensive site remediation strategies. Mike also leads the sediments practice group at Barr and has recently participated on the ITRC microplastics guidance team.

Transport and Effects of Microplastics

Presenter: Mala C. Hettiarachchi, PhD, PE (Environmental Resources Group)

Microplastics (MP) are plastic particles less than five millimeters; there are two categories of MP: primary and secondary. Primary MP are intentionally produced to be microscopic in size. Fragmentation of large plastic debris through physical, chemical, and oxidative processes creates secondary MP, the most abundant type in the environment.

The fate and transport of MP into the aquatic environment depends mainly on their physical properties such as size, density, and shape. These properties affect their spatial movements and settling velocities. The physical properties of MP continuously undergo size changes through processes such as bio growth, salinity, temperature, and photo degradation. Plastic debris enters the aquatic environment via direct dumping or uncontrolled land-based sources. While plastic debris slowly degrades into secondary MP, wastewater and stormwater outlets discharge a large amount of primary MP directly into water bodies. Stormwater carries MP from sources such as tire wear, artificial turf, fertilizers, and land applied biosolids. The wastewater received by wastewater treatment plants (WWTPs) from residential, commercial, and industrial sources contains a large amount of MP. For example, synthetic textiles are one of the largest sources of MP as they shed microfibers during the washing cycle. Also, landfill leachate received by WWTPs contains a large amount of MP because the plastic waste in landfills degrades into MP. Some MP captured into the sludge during the wastewater treatment at WWTPs is generally land applied as biosolids, landfilled, or incinerated. When the sewage sludge is disposed in landfills, MP further reduce in their size. Most MP in land applied biosolids re-enter the aquatic environment via stormwater runoff while some MP leach into the groundwater or remain in the soil. In terrestrial environments, MP can negatively impact soil fertility, and soil organisms such as earthworms. Also, MP can contaminate food crops directly. In the aquatic environment, MP adsorb other toxic chemicals, bacteria, and pathogens from their surroundings. Therefore, in an aqueous environment where MP can move freely, they act as a potential carrier of invasive species, toxins, and pathogens creating various destructive impacts in the food chain.

To protect the environment and human health, entry of MP into the environment must be reduced or eliminated. Source control is one of the best methods available. The existing and growing abundance of MP in the environment requires the use of multiple strategies to combat pollution. These strategies include reducing the usage, public outreach to eliminate littering, reevaluation and use of new wastewater treatment and sludge disposal methods, regulations on single use packaging material and other microplastic sources, and a wide implementation of appropriate stormwater management practices such as filtration, bioretention, and wetlands. Improvements in plastic waste recycling could divert waste from landfills and reduce the plastic debris entering the environment. Wastewater treatment methods such as physical (e.g., filtration), chemical, and biological treatments and advanced oxidation processes could remove MP from wastewater. However, the sewage sludge must be managed appropriately to eliminate the reentry of captured MP into the environment. Bioremediation is an effective way to degrade MP because some algae, bacteria, insects, and fungi have been shown to ingest MP and convert them into environmentally friendly carbon compounds. However, implementation of these strategies is challenging due to the limited intensions to regulate the plastic usage and waste. Current public awareness of the negative health impacts of MP is inadequate. Ultimately, the collaboration of regulators, municipalities, industries, educators, and the public is required to manage this global pollution issue.

Presenter Biography: Mala C. Hettiarachchi PhD, PE is a Senior Engineer at Environmental Resources Group and an Assistant Professor (part-time) at Wayne State University.

WEDNESDAY (PM)

SESSION A

SITE CLOSURE

Mine Closure Cost Estimations: A Heart Attack Waiting to Happen for Those Who Don't Plan Ahead

Presenter: Dawn Garcia, CPG (Stantec)

Even though mine closure plans and cost estimates are a common regulatory and internal company requirement, the cost estimates have been wildly inaccurate when compared to the tracked closure costs when closure activities are implemented. The reasons behind the fluctuations can relate to poor planning, flaws in predictive models or assumptions, closure designs that are in a conceptual phase and not advanced over the mine life, changes in regulations, company costs, unanticipated remediation and ESG (Environmental, Social and Governance) requirements and commitments, among other factors. Early closure planning will allow for optimization and efficiencies during the mine design and operational phases that can reduce closure activities and costs. Even though the closure planning process is dynamic, there are standardized cost estimation practices and techniques that allow for financial estimations that reflect a reasonable accuracy of closure costs, although it is key to acknowledge that the cost estimate is based on the knowledge at the time of the cost estimate. This presentation discusses the objectives of the closure cost estimate, cost estimation practices and closure cost risk assessment exercises.

The primary objective of closure planning is to assess potential physical and geochemical hazards associated with the facilities that will be remaining at the end of the mine life cycle and to design the mine so that the hazards will be eliminated, reduced, or mitigated during and after operations. A key issue is the management of the mining wastes that will be generated during operations, such as tailings, waste rock and spent ore, plus the impacted water and solutions associated with each of these mining wastes. The storage facilities for these wastes remain in perpetuity and the geochemical conditions of the wastes and associated discharges may change radically over time. Geochemical studies rely on a limited number of samples that are deemed to be representative of orebodies that are seldom homogeneous in nature. The static and kinetic testing methods used to predict future water quality are inherently approximations to predict future environmental impacts.

Physical hazards are associated with the geotechnical stability of the remaining facilities, which can include heap leach facilities, tailings storage facilities, waste rock storage facilities, open pits, and underground workings. A detailed final closure design is needed for an accurate cost estimate. Challenges with the preparation of a final closure design is the level of information available to develop the cover designs and configuration of slopes and surface water conveyances. Mine closure typically assume that buildings and infrastructure are removed; the cost of demolition and removal of buildings and infrastructure can be estimated is a well-established estimating procedure based on contractor rates and equipment capabilities. Developing a cost estimate that is realistic will depend on the quality of the data available, assumptions made in the closure plan and the predicted geochemical and geotechnical conditions associated with closure designs.

Engineering, procurement, and construction costs can be estimated using well-established practices, but the unknowns regarding the environmental aspects of mining wastes cause the greatest risks (and heartburn). Confidence in data and predictive models for environmental impacts increases with the detail of the technical studies. Uncertainties can be evaluated using a risk assessment, which identifies the key risks associated with the closure activities, and then applies a probabilistic cost model. A quantitative risk assessment with a probabilistic cost model would consider factors such as anticipated performance criteria of schedule and cost, based on possible future impacts related to environment, health and safety, social and corporate aspects, which have been identified by subject matter experts. The probabilistic model uses Monte Carlo simulations to assess uncertainties for each key risk by using the closure plan as a "base" future performance scenario and then assigning performance parameter uncertainties to each key risk. The severity of each performance parameter is identified. For example, a health and safety impact severity would be based on fatal versus non-fatal casualties. An environmental impact would consider land, water, air, and wildlife impacts and the consequences (destruction versus disturbance, size of area, or exceedance of a regulatory standard). The model analyzes the combined performance parameters. The model outputs are used to evaluate possible variances from the base cost estimate; which risks have the highest impacts based on cost and schedule; and the confidence of the estimated cost associated with each key risk. This information informs the decision-makers where more conservative closure plan activities are warranted to reduce future cost and closure schedule uncertainties.

Presenter Biography: Dawn Garcia, CPG is a hydrogeologist and a licensed professional geologist with over 35 years of experience in environmental permitting and compliance, mine life cycle planning and studies, and hydrologic projects. She has worked in characterization, remediation, and reclamation projects at a wide variety of industrial and mining sites. In addition to her extensive project experience, she has taught a short course on mine closure at the University of Guanajuato (Mexico) and been an invited speaker at mine closure workshops. She has been a presenter at numerous technical conferences. She has served as the Geologist Member of the Arizona Board of Technical Registration by appointment of the Governor. The American Institute of Professional Geologists named her as the 2021 recipient of the Martin Van Couvering Memorial Award for distinguished service to the profession of geology.

She is the 2023 President of the American Institute of Professional Geologists.

Her expertise includes the following areas:

- Environmental compliance for mining and industrial properties
- Hydrogeologic studies for environmental permitting, environmental compliance and water supply
- Characterization of soil, surface water, groundwater, mining waste and air for baseline studies and environmental compliance
- Due diligence for acquisition and merger opportunities
- High-level reviews for optimization of mineral development projects and operating mines
- Preparation of documents per the Canadian NI 43-101 and SK-1300 guidelines and services as a Qualified Person for water supply, environmental and community relations
- Mine closure planning and cost estimates, preparation of closure plans and implementation of closure projects
- Negotiation with regulatory agencies and all levels of government departments (i.e., local, county, state and federal).
- Technical writing and editing
- Experience at diverse project sites such as smelters, active mining operations, aerospace facilities, steel foundries, crude oil production land, manufacturing facilities, and petrochemical facilities

Strategy for Closure at 79 Petroleum Sites

Presenters & Co-Authors: Michael Coram, CPG (Geosyntec), and Elaine Pelc (EGLE RRD)

The Department of Environment, Great Lakes, and Energy (EGLE) has entered a $35 million settlement with the Premcor Refining Group Inc (Premcor) for resolving claims for environmental cleanup of 79 sites in Michigan with identified leaking underground storage tank systems in accordance with Part 213 of the Natural Resources and Environmental Protection Act, Public Act 451 of 1994, as amended (Part 213).

The 79 sites across eight districts all have some remaining levels of contamination. The contamination is generally consistent with petroleum releases and each site requires an updated conceptual site model (CSM) due to time gaps in data acquisition. The updated CSM generally consists of a review of current conditions and updated groundwater, soil, and soil gas analysis.

Upon review of the updated CSM, and relevant pathways are identified, an appropriate corrective action will be implemented to control any unacceptable risks.

When performing state funded corrective actions or response activities, RRD's goals generally are to define the nature and extent of contamination, mitigate unacceptable exposures existing at the time of the corrective action, remove source areas, and document the actions conducted.

Documentation of the environmental condition of the property after RRD's work is complete is a critical component of all publicly funded projects.

An "Approved Project Completion" (APC) documents state funded work at a project where Part 201 or Part 213 closure will not be pursued by the division. The actions conducted with state funds have demonstrated an unacceptable exposure is not occurring, will not occur or have resulted in a reduction of risk to human health and the environment to levels where state funded activities are no longer necessary.

Exposure to contamination is not anticipated based on current and reasonably foreseeable land uses.

Documentation of an APC includes the following:

- A description and history of the site
- The nature and extent of environmental contamination
- A description of response activities or corrective actions
- An analysis of the effectiveness response activities or corrective actions
- Other site-specific information as deemed pertinent.

The APC process allows the corrective actions on state funded sites to abate and control risks to protect the public health and the environment while conserving public resources to address other sites throughout the state.

Presenters: Michael Coram, CPG is a Senior Geologist with Geosyntec Consultants with more than 15 years of experience working on contaminated properties across Michigan. He is currently working on contract remediation projects for Michigan's Department of Environment, Great Lakes and Energy.

Elaine Pelc is currently an Environmental Quality Specialist in Remediation & Redevelopment Division's Field Operations Section. She has been in EGLE's environmental cleanup program for her entire 34-year career with the majority of that time spent as a project manager in the Gaylord District Office.

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WEDNESDAY

SESSION B

INVESTIGATORY TECHNIQUES

Optimizing Investigations of Complex Co-Mingled Contaminates with Utilizing Subsurface Imaging Technologies to Efficiently Understand the Lithology, Hydrology, Contaminate Mass, Distribution, and Migratory Pathways

Presenters & Co-Authors: Janet L. Castle, PG, and Vince Kowalick
(Eagle Synergistic Optimizing Technologies, LLC)

For challenging sites with potential co-mingled plumes, there is a growing acceptance for the application of new technologies, such as High-Resolution Site Characterization (HRSC) subsurface imaging since it has been shown to increase the efficiency and accuracy of CSMs. Whether there is one main compound or several possible contaminants of concern, an upgraded process is now currently being utilized.

On the majority of commercial, DOD, and state sites, there are not only co-mingled plumes containing non-aqueous phase liquid (NAPL) hydrocarbons and chlorinated solvents, but also PFAS concerns. Several HRSC case studies have been highly successful in distinguishing between multiple releases within the same area of interest. Not only free phase, DNAPLs, VOCs, but also polyaromatic hydrocarbons (PAHs) are detected and delineated in an efficient process. With the escalating concerns of PFAS, there is currently an upgraded method of locating the migratory pathways for this highly mobile compound, while profiling the lithology and estimating hydraulic conductivity in real time mode.

Additionally, case studies will highlight another upgraded and efficient method of running lab grade data in the field, along with targeted samples from the HRSC log data, to help speciate in near real time. This added optimizing technology on site for further correlation, a second miniature portable gas chromatograph with columns, is utilized to correlate the HRSC signatures, which provides targeted, quantitative analysis of impacted intervals identified by HRSC subsurface imaging data. Since contaminants are speciated in real time in the field, comingled plumes are delineated efficiently, both vertically and laterally, while noting the intervals of plume migration.

Due to obtaining thousands of subsurface imaging data points for contaminants, lithology, hydrogeology, and migratory pathways, highly accurate 3D visualizations can be completed to further assist with understanding fate and transport. With a more accurate and defined conceptual site model (CSM), tax dollars are shown to be saved during the remediation phase.

Presenters: Janet L. Castle, PG has over 20 years of experience with utilizing geophysics, petrophysics, geology, hydrology, and geochemistry to optimize projects. She is a Professional Geologist and president of Eagle Synergistic Optimizing Technologies. Her primary area of focus includes managing a team of subsurface imaging specialists that complete HRSC investigation projects and 3D visualizations. Other areas of expertise include working with geochemistry to correlate soil and groundwater samples to HRSC subsurface imaging data, including a portable onsite lab grade GC and 3D modeling. As a geologist and petrophysicist, she has developed optimized strategies for various types of sites, including commercial, Superfund, EPA, O&G, and DOD sites. She recently helped upgrade the investigative methods for PFAS sites and is actively engaged in the rapidly evolving world of PFAS science and regulations. Education is in geophysics and petroleum geology at University of Houston and Colorado School of Mines.

Vince Kowalick is an environmental scientist with several years' experience completing HRSC sites. He has numerous years of experience in 3D modeling and leading the 3D visualization team for Eagle Synergistic. Vince currently leads Technical Sales but also specializes in creating 3D visual models of contamination plumes, subsurface lithology, and permeability below ground surface. Through his studies, he focused on Geographic Information Systems, water resources and sustainability.

Unified Performance Assessment Metric for NAPL Management - Status Quo or Transition?

Presenters & Co-Authors: Ranga Muthu, PhD, and Andrew Kirkman (Parsons Corporation)

At numerous sites impacted by Non-Aqueous Phase Liquids (NAPLs) like petroleum hydrocarbons, a structured approach to performance assessment is useful to determine whether an existing remedy will be the most effective long-term strategy to address risk (i.e., plume stability, recovery, control, and capture) or a transition is warranted. With increasing recognition of natural attenuation processes as a critical component of conceptual site model (CSM) and a feasible long-term remedy at such sites, a unified performance assessment model (UPAM) is presented that normalizes risk associated with various phases (e.g., NAPL, dissolved, vapor) to natural losses. The output of UPAM is the potential migration distance (i.e., flux normalized by losses) that allows for an easy and effective risk-to-receptor comparison. The remedy agnostic model provides a decision framework for choosing the right remedy or optimizing an existing one with regards the remedial action objectives (RAOs).

The UPAM, developed as a dashboard tool was applied to a refinery setting to evaluate the performance of existing pump and treat (P&T) systems to address effectiveness in mitigating the NAPL and dissolved phase risks to offsite receptors. Additionally, the role of these P&T systems in the long-term site strategy of monitored natural attenuation was also evaluated. The model assessment indicated the long-term strategy to mitigate the (NAPL and dissolved phase) risks is best served by alternate remedies, but existing P&T systems can be optimized on an interim basis (e.g., change in pumping operations) while data gaps identified by the UPAM assessment are addressed. The simplicity and scalability of the tool allows for risk evaluation at various stages of the CSM.

Presenters: Dr. Ranga Muthu has over 14 years of field and project management experience in life-cycle management of contaminated sites, with technical proficiency in the science of light non-aqueous phase liquids such as petroleum hydrocarbons and various distillates and sites impacted by them. He is proficient in environmental site assessments and management, including field sampling, data management and visualization, conceptual site model development, modeling, risk assessments, and corrective actions. He also focuses on sustainable remediation with focus on green technologies, natural restoration, climate resiliency. Ranga has functioned as a technical contributor and national taskforce member involved in developing standards and practice and guidance documents for ASTM International, Interstate Technology and Regulatory Council (ITRC) and the American Petroleum Institute (API). He has developed customized software tools using Excel VBA and is proficient in data analytics and visualization related to various environmental data. Ranga also writes and interprets technical documents such as site closure reports, environmental guidance documents, environmental assessment reports, agency response letters, and research documents.

Flexible Investigation Tool for Emerging and Traditional Contaminants– GHD InSite

Presenters & Co-Authors: John Owens, Jonathan Eller, Tom Fewless, and Beth Landale (GHD)

Introduction: PFAS, chlorinated compounds, BTEX, and TPH were identified to be co-contaminants of concern in groundwater at two facilities: a former automotive manufacturing site in Ypsilanti, Michigan and a petroleum transfer station in Seattle, Washington. During review of investigation results for the manufacturing site, concentrations in adjacent areas separated by a trench appeared to have two separate PFAS sources. Traditional methods and workflows to visualize and evaluate the data for both sites were time consuming and inefficient when new data was added.

Approach: A custom web platform was built to provide flexible and easily updatable views of the data across the trench and the entire site. The design of the digital platform is intended to enable project teams to review large amounts of data quickly. Several visualization tools were built into the platform, including interactive maps with sample locations and results, a data dashboard, time series graphs, and Mann-Kendall statistical test result diagrams. Each visualization tool is linked to a central database and contains predefined settings, including groups of sample locations on either side of the trench. These settings can be customized by the user to tailor visualizations to specific questions that arise during assessment. In addition, the platform will rapidly recalculate and update all the results of the analysis tools and mapping features as new data is reported from the laboratory. The project team used the platform alongside traditional static figures and tables to assess data across the sites.

Results: Streamlining the visualization process with the help of this digital tool facilitated site analysis and created opportunities for cost savings throughout the lifetime of the project. The dynamic nature of the interface facilitated evaluation and allowed the project team to quickly compare site result patterns and groupings. Results indicated that more site investigation was needed. Several mobilizations have been completed. With each new set of data incorporated into the database, the platform can update the visualization efficiently allowing for quicker and more effective data review and interpretation. The practicality of this platform has made it a key resource for future work on this site.

Presenters: John Owens leverages his background as a geologist to develop innovative data visualization and analysis tools for internal use and GHD’s clients. John specializes in creating 3D data-driven conceptual site models, interactive web figures, project collaboration platforms, and digital automation tools to boost efficiency and help project teams take their data further.

Jonathan Eller leads the development of Advanced Analytics offerings for many of GHD’s public and private clients. These offerings include software tools, development of analytical/statistical methodologies, text analytics, and software codebases, whose collective goal is to support our clients and technical teams in all stages of a project.

A Tale of Two Models: Combining Analytical and Numerical Modeling to Estimate Contaminant Arrival Time

Presenter: Katy Lindstrom, PE (Barr Engineering)

Groundwater flow and contaminant fate and transport models can be useful tools for evaluating potential exposure risks due to groundwater contamination, and there are model options ranging from simple to complex. Early in the modeling process, one or more mathematical models should be selected based on the site setting and modeling objectives. “Analytical” models can be solved with straightforward calculations but often apply assumptions that are overly simplistic for typical hydrogeologic settings. “Numerical” models are better able to represent hydrogeologic complexities like heterogeneity and three-dimensional groundwater flow but typically require more complex computer codes to iteratively approximate solutions to mathematical equations of groundwater flow and contaminant fate and transport.

At an industrial site in the Midwest, modeling was used to estimate the arrival time of methyl tert-butyl ether (MTBE) at a potential receptor, a key question for the site. Years of hydrogeologic and groundwater quality data were used to develop a numerical, three-dimensional groundwater flow and contaminant fate and transport model to estimate the fate and transport of multiple site constituents and assess the uncertainty in model results. While providing a useful tool for detailed evaluation of site conditions, results of the numerical modeling were less suited for clear communication of the key question regarding MTBE arrival at a downgradient receptor. Using site characterization data along the approximate axis of the MTBE plume, the plume’s travel velocity was estimated, and a simple, analytical equation was used to estimate the arrival time of the MTBE at the potential receptor. In 2013, it was estimated that the MTBE concentration at the potential receptor would reach a maximum concentration of approximately 20 micrograms per liter (µg/L) in 2020. Subsequent monitoring indicates a maximum concentration of approximately 6 µg/L was observed between October 2020 and March 2022. The analytical estimate was found to be relatively accurate and was a useful tool for project planning and communication with stakeholders. The numerical model, while useful for other aspects of the project, confirmed what the simpler modeling approach was able to estimate.

Presenter Biography: Katy Lindstrom, PE is an environmental engineer with more than 14 years of experience helping clients assess and remediate contaminated sites, achieve environmental compliance, and address groundwater management issues in Michigan and throughout the U.S. Her work focuses on hydrogeologic characterization, investigation and remediation of contaminated groundwater, soil, and sediment sites, groundwater-surface water interface evaluations, and groundwater flow and contaminant transport modeling. Katy is a member of Barr Engineering’s computational hydrogeology practice group.

EGLE's New Table of Contents for Mitigation Systems

Matthew Williams (EGLE RRD)

The Table of Contents (TOCs) for mitigation system were developed in coordination consultants that regularly perform the work and submit information for RRD to review. These TOCs were developed to promote a consistent and informed approach for the data required to complete the review of a mitigation system and provides recommendations on where to provide the information. A preliminary pilot program using these TOCs has shown that the submittals have been more technically complete and provide the necessary information for RRD to complete a timelier review with fewer comments. Therefore, RRD is expanding the program. Feedback for these documents will be obtained directly from those parties that use and submit these documents and not through an open review process and a formal review period prior to finalizing them in a new volatilization to indoor air guidance document.

The TOCs that will be presented and discussed include:

- For an Active Vapor Mitigation System (AVMS): Design, Installation and Commissioning, and Operation, Maintenance, and Monitoring (OM&M)
- For a Passive Vapor Mitigation System (PVMS): Design, Installation and Commissioning, and Operation, Maintenance, and Monitoring (OM&M)

Presenter: Matthew Williams is the Volatilization to Indoor Air Specialist for the development and implementation of methods used to investigate and assess the volatilization to indoor air pathway, which includes vapor intrusion, for the Michigan Department of Environment, Great Lakes, and Energy Remediation and Redevelopment Division (EGLE-RRD). Matt currently serves as the technical lead for the Vapor Intrusion Technical Assistance and Support Team and has participated in multiple stakeholder groups. He is the lead author on several MDEQ guidance documents and standard operating procedures concerning vapor intrusion. Matt has also conducted numerous trainings and talks on soil gas methods, vapor intrusion, and indoor air across the United States and in China.

Matt was a section leader for the ITRC Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation and Management (2014) and a Co-Leader for both the classroom and the internet-based training teams, as well as co-leader for ITRC's Vapor Intrusion Mitigation Team. Matt earned a Bachelor of Science degree in Geology from Central Michigan University in Mt Pleasant, Michigan in 1993.

Measurement Uncertainty in Laboratory Test Results:

"*Understanding What Your Results Really Mean...*

Presenter: Taras (Terry) Obal, PhD (Metiri Group)

The concept of measurement uncertainty is widely recognized among analytical chemists. Uncertainty of laboratory measurements is arguably the most important single parameter that describes the quality of laboratory test results. This is because the uncertainty in a measured parameter can fundamentally affect decisions related to: site assessment and remedial options; process control; water treatment options and optimization; and/or regulatory compliance. As an example, to utilize a laboratory test result to decide whether it indicates compliance or non-compliance with a certificate of approval or municipal by-law, it is necessary to account for the measurement uncertainty.

All measurements are imperfect and have many potential sources of variation. In addition to laboratory measurement uncertainty, the uncertainty associated with the sampling program also contributes to the total uncertainty associated with a reported value. In fact, sample collection is often the more significant contributor to the uncertainty in a result reported by a laboratory, and hence requires equally careful management and control. An awareness of an entire process (sampling and analysis) is important, irrespective of the division of effort, since analytical and sampling processes both contribute to the uncertainty in a reported result.

This presentation will:

- Introduce the concept of measurement uncertainty in laboratory test results.
- Describe approaches to estimate measurement uncertainty.
- Identify best laboratory and field practices to minimize measurement uncertainty; and
- Offer suggestions on how to use uncertainty information in compliance testing.

Presenter Biography: Taras (Terry) Obal, Ph.D. is the Chief Science Officer at the Metiri Group. His experience includes more than 35 years in analytical chemistry, laboratory management, and environmental chemical consulting.

WEDNESDAY

SESSION C

REMEDIATION

Navigating Processes that Drive Natural Attenuation Demonstrations for Inorganic Contaminants

Presenter: Brian Ares (Geosyntec)

Inorganic contaminants contain fundamentally different chemical traits and characteristics than organic contaminants. As a result, inorganic contaminants such as metals and rock-building ions interact with aquifer materials and other components in groundwater in entirely different ways. Notably, metal contaminants cannot be degraded or destroyed; however, depending on geochemical conditions within a particular contaminated groundwater system, inorganic contaminants may undergo natural attenuation as a result of geochemical transformations and mineral-water interactions occurring along a groundwater flow path.

Monitored natural attenuation (MNA) is the terminology used for basing a remedial strategy on leveraging a system's ability to reduce contaminant mass along a flowpath without additional action. MNA represents a potentially effective and largely passive strategy to address impacted site remediation. Natural attenuation may occasionally have a physical component associated with processes like advection and dispersion, but successful demonstration of an MNA remediation strategy is predominantly rooted in the interpretation of geochemical processes. This demonstration is guided by an existing four-tier analysis structure which in part involves a robust evaluation of system geochemistry (both solid and aqueous phases), speciation or equilibrium modeling using geochemical software packages such as PHREEQC or Geochemist's Workbench, and laboratory column testing of site-specific soil and groundwater to investigate factors like contaminant speciation, association with different aquifer solids, and sorption/desorption to aquifer solids.

The direction of such a geochemical evaluation will be influenced by the constituent of concern. The behavior of each inorganic contaminant is associated with a different suite of considerations, some of which include groundwater oxidation-reduction (redox) conditions, groundwater pH, groundwater major ion chemistry, aquifer mineralogy, and aquifer bulk chemistry. While MNA demonstrations of multiple contaminants may be conducted for a single site, the mechanisms of chemical attenuation will be different for each constituent. An understanding of specific geochemical characteristics is required to determine the feasibility of dynamic mechanisms which drive natural attenuation for each individual inorganic contaminant. A review of these characteristics and subsequent mechanisms has been completed for multiple common inorganic contaminants, utilizing academic studies and multiple bench-scale and field case studies.

Presenter Biography: Brian Ares is a Geologist with Geosyntec Consultants in Detroit, Michigan. His technical background is focused on mineral-water interactions and geochemical modeling of inorganic parameters in groundwater. Brian has diverse experience in vapor intrusion assessment, multimedia site investigations, groundwater geochemistry, and litigation support. He received an M.S. degree in Geology from Michigan State University, where his research focused on low temperature geochemistry and clay mineralogy.

Chlorinated Solvents in Soil and Groundwater Reduced >95% by in-situ Remediation Techniques to Eliminate Vapor Intrusion Risk Pathways

Presenters & Co-Authors: Doug Spencer, Joel Parker (Hamp, Matthews & Associates), Jeff Crum (Hamp, Matthews & Associates), Ryan Moore (Regenesis)

Background/Objectives. A former dry cleaner presented vapor intrusion (VI) risk to nearby residents in Temperance, Michigan. Several anthropogenic and hydrogeologic factors led to a bifurcated groundwater plume of tetrachloroethene (PCE) and related daughter products that intruded the basements of two residences, which complicated both near term vapor mitigation and long-term vapor source reduction. PCE was discovered in saturated soil at several locations at concentrations above the soil saturation limit, presenting a long-term source for VI. The objective of this State-led project was to significantly reduce source mass and related VI risk, ultimately achieving VI screening levels for groundwater in contact with the structure at the compliance point, the basement sump crock(s).

After a significant remedial investigation/feasibility study (RI/FS) and several interim remedial measures, an in-situ remediation pilot study was designed and implemented in two phases. In-situ chemical reduction (ISCR) via sulfidated zero-valent iron and enhanced reductive dechlorination (ERD) via addition of electron donor and halorespiring bacteria were selected as the destructive mechanisms for PCE and related daughter products. At some of the locations these technologies were coupled with colloidal activated carbon to expedite the reduction in volatile organic compounds. These technologies were implemented in source areas and in barrier-type configurations at mid-plume and distal plume locations.

Groundwater monitoring at source – transport route – and receptor flow paths have demonstrated significant reduction in PCE, trichloroethene (TCE), and cis-1,2-dichloroethene (cis-1,2-DCE) without accumulation of vinyl chloride. PCE and TCE mass reduction have been estimated at greater than 95% after only 12-15 months. Daughter product mass reduction of cis-1,2-DCE has also been observed, and, most importantly, all chlorinated ethenes are below stringent VI screening levels at the compliance point (the basement sump crocks).

Approach/Activities/Results. RI/FS and interim remedial actions (e.g., spent solvent tank removal) were completed in April 2020. Additionally, there were two phases of an in-situ pilot study completed in August 2020 and May 2021. During the two field applications, over 20,000 gallons of colloidal activated carbon, colloidal sulfidated zero-valent iron, a staged release electron donor, and a microbial consortium of Dehalococcoides were applied in multiple areas at the project site. The performance monitoring of groundwater and soil vapor have been demonstrated significant (greater than 95%) reduction in the aqueous plume(s) and the related vapor plume within the first few months. These results and the field application/approaches will be presented along with verification of remediation results, performance metrics and their impact on vapor intrusion risks.

Presenters: Doug Spencer (presenting on behalf of Joel Parker) Doug has been a Vapor Mitigation Specialist and Operations Manager on the VIAP Team with Hamp, Mathews, and Associates since 2017. He enjoys the fast-paced nature of the environmental field, working outside, and the hands-on approach to problem solving. Doug is a proud husband and father, and he enjoys traveling with his wife and their three children to the Outer Banks and Northern Michigan. In his free time, you can find Doug fishing, camping, woodworking, or doing home remodeling projects. Doug plays a vital role in navigating environmental challenges, getting involved in protecting the health of our communities through various charitable efforts, and incorporating new technologies at HMA, and we are thankful for the knowledge and fortitude that he brings to the team.

Jeff Crum has invested 32 years of his career as a toxicologist split evenly as a regulator and consultant. Mr. Crum is among the states most recognized vapor intrusion (VI) specialists, having developed the Michigan Department of Environment, Great Lakes, and Energy (EGLE) VI cleanup criteria in 1997; the only EGLE cleanup criteria subjected to review and approval (2001) by the Michigan Environmental Science Board. Mr. Crum has led or reviewed hundreds of VI assessments and coordinated the design, installation, and monitoring of numerous vapor mitigation systems. As HMAs VI practice leader, Mr. Crum serves as project leader for all VI assessment and mitigation projects. Additionally, Mr. Crum ensures that company sampling plans apply the U.S. Environmental Protection Agency (EPA) Data Quality Objectives (DQO) process and incorporate conceptual site model (CSM) development to support reliable risk assessment decision-making.

Ryan Moore has more than 20 years of experience as an environmental project manager and laboratory account executive relating to multimedia contamination sites throughout the U.S. His experience focused on site investigations of soil and groundwater contamination, corrective action evaluations, operation & maintenance of remediation systems, in situ groundwater and soil treatment, and business development. Ryan holds a B.S. of Environmental Studies from Manchester University, North Manchester, IN.

Treating PCE Groundwater Flux & Secondary Sources to Address the VIAP

Presenters & Co-Authors: Nick Rogers (WSP), Ashley Lesser (EGLE RRD) and Len Mankowski (WSP)

Tetrachloroethylene (PCE) was released at a former coin laundry/dry cleaning facility that is located upgradient of multi-residential apartments and the Huron River in Ann Arbor. The site property is currently being redeveloped in coordination with the Washtenaw County Brownfield Authority. Site characterization results suggest that PCE product historically migrated via a tortuous route through the vadose zone and aquifer - influenced by both the distribution of coarse grained, highly permeable lenses of water lain soil and the geometry and distribution of finer-grained silts. High resolution geologic and chemical data were integrated into a conceptual site model (CSM) to constrain the nature and extent of PCE and other site-related chemicals in various media (soil, groundwater, soil vapor, and surface water) to assess potential exposure pathways/risks. This presentation will focus on the fate and transport (F&T) of PCE and its breakdown products with respect to the Volatilization to Indoor Air Pathway (VIAP).

Beginning in 2018, the Site developer implemented corrective actions to address contamination on the property. Permeable gravel rich units onsite create vertical hydraulic conductivity contrasts (even when sandwiched between sands) where gravity driven flow appears to have caused lateral migration of PCE product below the release area. With EGLE's support, the selected remedy was expanded to include in-situ injections of CAT-100 and BOS-100, carbon-based media that include chemical and/or biological enhancements that have reduced PCE in shallow groundwater at the property boundary from 15,200 micrograms per liter (µg/L; March 2019) to 230 µg/L (June 2022; >99% reduction). Despite the reduction in groundwater contaminant flux, elevated concentrations of PCE and related breakdown products persist in offsite shallow groundwater. Slug testing, passive flux meters, and groundwater and saturated soil sample results demonstrate that the dissolved phase groundwater plume migrated downgradient preferentially in permeable lenses. PCE diffused from groundwater into finer-grained lenses where it now represents an offsite "secondary" source that sustains the shallow groundwater plume and the offsite VIAP.

EGLE has implemented a receptor-based approach to mitigate and remediate the VIAP. Sub-slab depressurization systems (SSDSs) were installed in downgradient apartments to prevent migration of PCE vapors into the buildings. In 2021, three offsite permeable reactive barriers (PRBs), consisting of colloidal activated carbon (PlumeStop®) and Sulfidated Zero Valent Iron (S-MicroZVI®) were injected along the axis of the offsite PCE groundwater plume. S-MicroZVI was installed to address the flux of PCE and related breakdown products in groundwater, while PlumeStop was installed to further retard "back" diffusion of PCE from the finer-grained units into shallow groundwater. Groundwater PCE concentrations in the shallow aquifer have decreased by 97% (or more) downgradient of the offsite PRBs and the flux reduction has decreased PCE by 78% in untreated portions of the aquifer. The additional remedial actions were performed to reduce concentrations in the shallow groundwater plume to address the groundwater to VIAP and reduce projected SSDSs run time.

Presenters: Nick Rogers is an Assistant Vice President/Project Manager - Geology at WSP with over 20 years of site characterization and remediation experience at contaminated Sites across Michigan and the Midwest. His primary areas of expertise include: planning and implementation of large scale drilling and river sampling programs, remedial investigation drilling techniques; remediation systems operations and maintenance and remediation of dry cleaner sites. Nick earned a Bachelor of Science degree (Geology, 1999) from Calvin University.

Nick is married with two children and lives in Chelsea, Michigan. He is a volunteer board member and Referee Assignor for the Chelsea Soccer Club youth program. Nick is also active in his son's Boy Scout Troop (Troop 425) in Chelsea as the Committee Chair. Nick enjoys camping, kayaking, paddle boarding, and water skiing.

Ashley Lesser, P.E., joined the Michigan Department of Environment, Great Lakes, and Energy (EGLE) in 2021 after over a decade in environmental consulting, where she performed environmental investigations on a variety of property types and worked on major infrastructure, construction, and remediation projects including Little Caesar's Arena and the Gordie Howe Bridge. Her past firms include NTH Consultants, Testing Engineers & Consultants, and Shaw Environmental (now APTIM). As part of EGLE's Remediation and Redevelopment Division, she manages state-funded cleanups of contaminated sites in Washtenaw County and provides technical review of Brownfield plans and compliance activities to ensure they are protective of human health and the environment. She is the Groundwater-Surface Water Interface (GSI) Technical Assistance and Program Support (TAPS) point of contact for Jackson District.

A civil engineering graduate of Princeton University (B.S.E.) and Wayne State University (M.S.C.E.), she continues to seek solutions to complex pollution problems and values active involvement in the professional community. Last year, she led an author subgroup developing Sediment Cap Chemical Isolation Guidance for the Interstate Technology Regulatory Council (ITRC). She currently serves on national career and leadership development committees for the American Society of Civil Engineers and Society of Women

Engineers and will be installed as a Fellow of the Engineering Society of Detroit later this month. She is also a member of the Michigan Association of Environmental Professionals and the Urban Land Institute.

Len Mankowski is a VP - Geology at WSP with over 18 years of site characterization and remediation experience at contaminated Sites across Michigan and the Midwest. His primary areas of expertise include: innovative remedial investigation techniques; hydrogeologic and conceptual site model development; emerging contaminants; and conceptual remedial design/technology assessments. Len earned a Bachelor of Science degree (applied geophysics, 1999) and a Master of Science in (geology, 2023) from Michigan Technological University and was an instructor at Michigan Technological University prior to entering consulting. Mr. Mankowski has published and/or presented several papers on applied, innovative characterization and remediation approaches.

Len is married with two children and lives near Suttons Bay, Michigan. He is a volunteer board member and coordinator for the Leelanau County youth soccer program and an assistant soccer coach for the Suttons Bay Public School's boys' varsity soccer team. Len also leads hands-on geology fieldtrips for elementary students in the area and previously served as a board member and chair for the non-profit SEEDs, located in Traverse City, Michigan. Len enjoys backpacking, camping, canoeing, and working with kids.

Aerobic Dehalogenation of Organic Pollutants Using Site-Derived Microbes, BAM, and Electrooxidation

Presenters & Co-Authors: Larry Kinsman (Orin Technologies), and Timothy Repas (Fixed Earth)

In this presentation we will discuss two case studies that utilized aerobic systems to dehalogenate and degrade halogenated organic pollutants in soil and groundwater systems. In each of these systems we deployed site-derived microbes, BAM, and electrooxidation to maintain aerobic conditions.

The first case study presented is a site located in Edmonton, Alberta where significant PCE and associated daughter products were found in soil and the shallow aquifer below the foundation of an industrial building. Initial investigations of the site showed PCE concentrations in soil of 3,990 ppm and 160 ppm in groundwater with a plume expanding towards the property boundary. Through remediation of the site using this combination of technologies we have observed a 97.9% reduction in PCE in soil with negligible daughter product formation. In groundwater an 86% reduction in PCE was observed with minimal formation of chlorinated daughter products. By using microbes capable of reductive dechlorination in aerobic environments, this full-scale remediation project was able to avoid the large accumulations of chlorinated daughter products such as trichloroethene, 1,2-dichloroethene, and vinyl chloride that are often associated with the anaerobic degradation of PCE. It is anticipated that the remediation of the highest concentration source zones will also result in the stabilization and eventual reduction of the dissolved plume. The outcome of the site is a significantly reduced risk management plan for any remaining contaminants, significant long-term savings for the property owner, and lower human health risks associated with vapor intrusion.

The second case study presented is a continuation of a pilot study previously presented located in Madison, Wisconsin. The site is an area impacted with poly- and perfluoroalkyl substances (PFAS) at the Dane County Airport that was remediated using a blend of aerobic microbes derived from the site, BAM, and oxygen provided through chemical oxidants and electrooxidation. Prior to remediation of this source area the potential for PFAS impacted groundwater to enter surface water bodies was significant. Previous presentations of this case study were limited to 10-weeks of monitoring data where significant reductions in total PFAS concentrations were observed. In this presentation we discuss a total of 32 weeks of monitoring data that spanned multiple seasons and groundwater conditions. During this extended pilot, the down-gradient monitoring point averaged 97% removal of total PFAS while upgradient monitoring points saw large and unpredictable changes in PFAS concentrations. Total Absorbable Fluorine concentrations followed a similar pattern and putative formation of fluorine-based minerals was observed as further evidence of PFAS destruction rather than transformation alone. Previous studies in lab environments, at other sites, and at this site have all supported the potential for PFAS degradation by aerobic microbes derived on a site-specific basis. These technologies may be applicable for the management of groundwater plumes containing fluorinated organic compounds, reducing risk to groundwater resources, and preventing discharges to surface water bodies.

Presenters: Larry Kinsman has assisted in the development of treatment chemistries used for the destruction of organic and inorganic contamination. As a result of this work, Mr. Kinsman has been awarded multiple patents for the development of chemistries to serve the environmental remediation sector as well as the oil and gas industry.

Timothy Repas is a co-founder and current President of Fixed Earth Innovations, a biotechnology company with a focus on the development and testing of microbes to solve challenges in remediation, ecosystem restoration, and agriculture. Mr. Repas has over 11 years or experience in the biotechnology and environmental remediation sectors with experience in project management, environmental site investigation, in situ bioremediation of soil and groundwater, emergency spill response, and site reclamation. Mr. Repas earned a Bachelor of Science degree in biochemistry at Elmira College in 2011 and a Master of Science degree in Biology at the University of Saskatchewan in 2014. Mr. Repas is a Professional Agrologist registered with the British Columbia Institute of Agrologists with areas of practice including contaminated sites remediation, soil conservation and restoration, and biotechnology development.

Incorporating Green and Sustainable Remediation Metrics into a Remediation Feasibility Study

Presenters & Co-Authors: Howard Nichols, PE and Graham Crockford, CPG (TRC)

As the incorporation of green and sustainable practices becomes more common in remediation, the ability to quantify the environmental footprint of a remedy has become more valuable. Stakeholders are recognizing the benefits of evaluating sustainable decision making in remedy selection and implementation, and State and Federal stakeholders are building in expectations for these evaluations within their remediation programs. TRC has recently added green and sustainable remediation (GSR) metrics as a screening criterion to several feasibility studies.

In a recent feasibility study, the GSR metrics were estimated for a former drycleaning site where remedial actions for soil and groundwater impacts were considered. The incorporation of a GSR assessment to the feasibility study process is relatively simple, and the metrics were used to aid in the comparison and selection of the preferred remedial alternative. The GSR metrics evaluation included quantifying the environmental footprint of the remedial actions, with a focus on the five core elements: Air Emissions, Water Use, Material Use and Waste, Land and Ecosystems Impacts and Energy Consumption. The evaluation was conducted using the US EPA's Spreadsheets for Environmental Footprint Analysis (SEFA) program. The SEFA program allows users the latitude to enter project-specific equipment (such as excavators and drill rigs), project materials (such as clean fill, PVC or steel well casing), anticipated water consumption and electricity use.

The feasibility study alternatives included several excavation scenarios to different soil concentrations, stabilization and solidification, soil blending with zero valent iron, a permeable reactive barrier, on-Site and off-Site groundwater remediation. All alternatives, except the no action alternative, also included the incorporation of engineering and/or institutional controls.

Although GRS metrics were used as a balancing criterion in the alternatives assessment, and not the sole driver for remedial action selection, the large disparity in greenhouse gas emissions between alternatives with different excavations sizes was used to support recommending the excavating to the restricted use soil standards as opposed to the lower unrestricted use standards. Excavation of soils with contaminant impacts over the unrestricted use soil standards would have increased the excavation area and soil disposal volumes, while increasing greenhouse gas emissions nearly sixfold, while the removal of soil to the restricted use standard maintains the protectiveness of the remedy.

The use of these environmental footprint assessment tools and emission equivalents will allow for fair comparisons between alternatives and implementation strategies and provides the user with quantifiable reductions in environmental footprints. Application of these methods are advantageous in many project stages, including feasibility study evaluations, remedial designs, remedial system optimizations and site management stage.

Presenters: Howard Nichols, PE, is an expert in soil and groundwater remediation with a proven record of remediating complex contaminated sites in state and federal regulatory programs. He has designed and implemented many remediation technologies including soil vapor extraction, air sparging, biosparging, in-well air stripping, thermal remediation, aerobic and anaerobic bioremediation, in-situ chemical oxidation and reduction, surfactant flushing, product recovery, stabilization and solidification, and pump and treat. He also has experience in landfill investigations, closure and landfill gas management, collection, and treatment, as well as investigating and mitigating vapor intrusion. His experience includes work on residential, commercial, industrial, rail, and Department of Defense facilities. Implementing innovative technologies to achieve the remediation goals has been a focus of his career, often resulting in cost savings for his clients. Howard has taken his decades of remediation experience and focused that wealth of knowledge towards green and sustainable remediation programs and projects. He co-leads TRCs sustainable remediation program where he not only identifies and implements sustainable remediation projects, but he is also adept at using the tools that are available to quantify the environmental and social benefits of these approaches.

Graham Crockford, VP, CPG, has over 33 years of professional experience in the fields of consulting, environmental engineering, and hydrogeology. He currently serves as TRC's Unit Leader for the Midwest Region, provides though leadership in TRC's Coal Combustion Residual (CCR) practice, leads TRC's Center of Research CORE vapor intrusion (VI) and sustainable remediation workgroups, and is a member of TRC's PFAS CORE team. He also serves as a Principal Consultant/Program Manager for solid waste, utility, and manufacturing/industrial clients, and is a program manager for TRC's CCR program. He also has decades of contaminant investigation, remediation, and liability assessment/estimation experience focused recalcitrant solvent contamination, and metals. Graham also provides litigation support services including expert and fact witness. Graham has taken his decades of remediation experience and focused that wealth of knowledge towards green and sustainable remediation programs and projects. Graham co-leads TRC's sustainable remediation program where he not only identifies and implements sustainable remediation projects, but he is also adept at using the tools are available to quantify the environmental and social benefits of these approaches.

Biotic and Abiotic Reduction to Achieve Green/Sustainable Groundwater Cleanup Objectives at Metals Contaminated Sites

Presenters & Co-Authors: Vincent Buening, CPG and Scott Pawlukiewicz, PE (TRC)

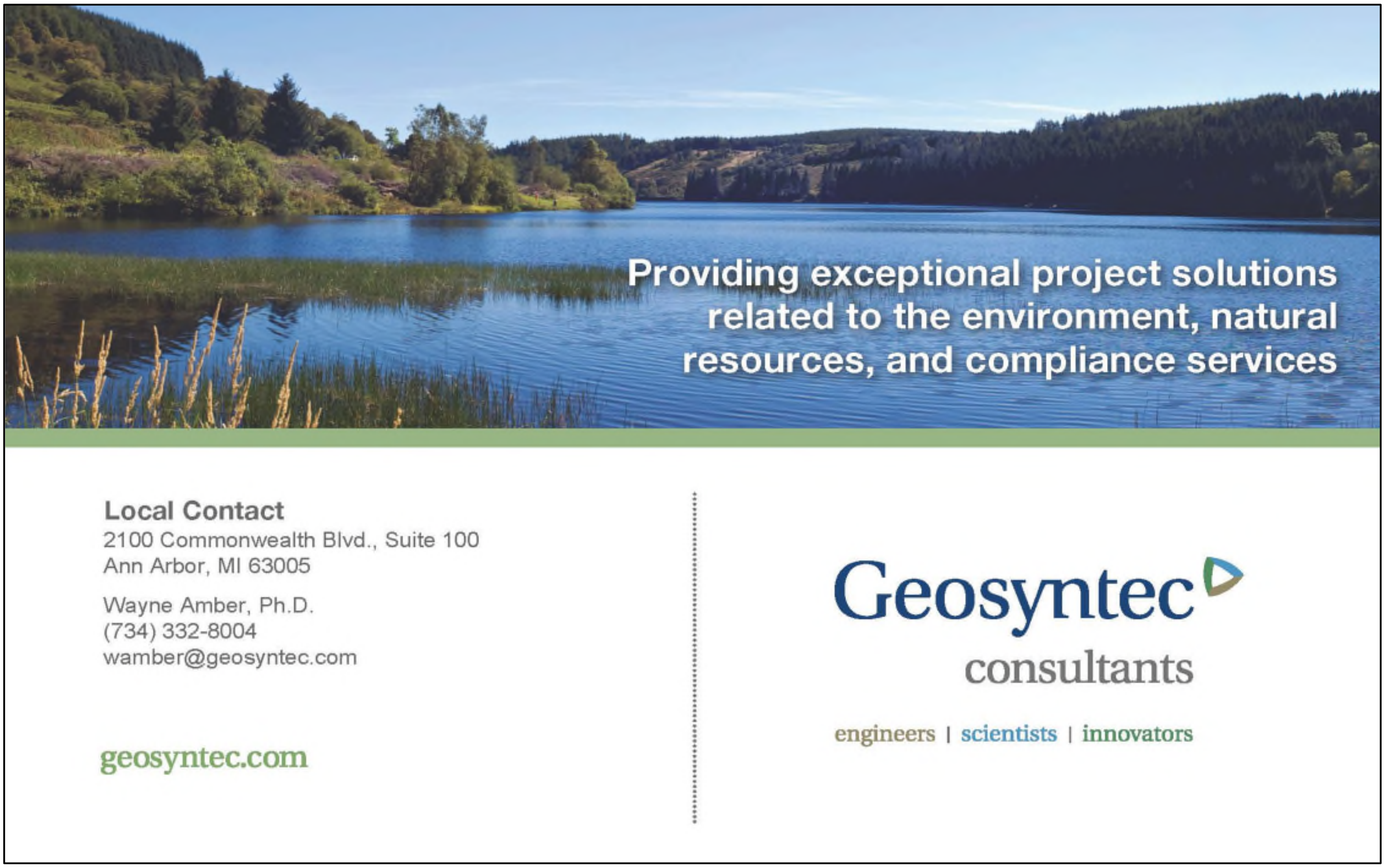
Metals contamination within groundwater is a persistent problem at many facilities across the Midwest, oftentimes at relatively lower levels, but above applicable cleanup standards. Achieving cleanup levels for metals can be complicated as metals are present naturally in the subsurface, in both soil and groundwater, and several anthropogenic activities at complex industrial and manufacturing sites add to the complexities. Most engineered remedies (e.g., excavation and removal, groundwater extraction and treatment) have high carbon footprints, are costly, and are oftentimes not considered green/sustainable approaches to achieve cleanup levels. Attenuation-based remedies, which rely on natural sequestration of contaminants, can be more sustainable, less invasive, and lower cost, however, the timeframes to achieve the cleanup levels may be longer than desired.

Relying solely on in situ conditions to naturally attenuate metals in groundwater to achieve cleanup levels within a reasonable timeframe has proven to be challenging. To that end, stakeholders are seeking ways to use in situ technologies to expedite groundwater compliance through Enhanced Attenuation (EA) strategies. EA uses low-energy, longer-acting technologies to accelerate the natural processes and promote reduction over extended timeframes in cases where Monitored Natural Attenuation (MNA) alone is not sufficiently effective and can serve as a bridge from engineered remediation technologies to MNA.

There are several viable strategies to alter metals concentrations in groundwater, including abiotic (chemical) and biotic (biological) reduction techniques. Under favorable conditions, closure objectives can be achieved using reductant chemistry to promote the decrease of metals concentrations in groundwater through a process of adsorption and co-precipitation. The use and feasibility of chemical and biological reduction to support EA of arsenic and other metals in groundwater is dependent on site-specific conditions. TRC has developed a case study for arsenic that provides insight into the development of a site conceptual model, groundwater geochemical conditions, bench scale testing, and pilot testing used to determine the appropriate reductant technology for a full-scale application to sequester arsenic in the subsurface while rendering other metals chemistry stable. TRC has also classified the types of data necessary to characterize site conditions along with the site characteristics that favor, and the strategies to achieve successful application of in situ treatment alternatives that bolster EA and MNA.

Presenters: Vincent Buening, C.P.G., is a senior project manager and hydrogeologist in TRC’s Ann Arbor, MI office with 30 years of experience and progressive responsibility in the environmental consulting field. He has overseen the delineation of contamination in soil, sediment, groundwater, and surface water; aquifer characterization; 2-D and 3-D groundwater modeling; risk-based corrective action; and the design / installation / operation of groundwater collection and in-situ treatment systems. He has also provided regulatory interface for numerous hydrogeologic investigations, remediation projects, and other related projects that resulted in no further action (release closure) in the Midwest. More recently, he has managed programmatic groundwater compliance and remediation work related to eight coal combustion residual (CCR) units. He is TRC’s senior hydrogeologist on the case study project presented, providing hydrogeological support during the feasibility, bench-scale testing, and pilot-scale implementation.

Scott Pawlukiewicz, P.E., is a project manager and environmental engineer in TRC’s Grand Rapids, MI office with 17 years of experience and progressive responsibility in the environmental consulting field. His project work has focused on remedial and industrial wastewater engineering design, construction, and treatment system operation. Scott also has a wide variety of experience in construction permitting, oversight/field engineering, and construction quality control assurance on remedial construction. More recently, Scott has performed various assessments related to coal combustion residual (CCR) management strategies. He is TRC’s project engineer on case study project presented, providing engineering support during the feasibility, bench-scale testing, and pilot-scale implementation.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WEDNESDAY

PFAS UPDATE

WOLVERINE CASE STUDY

EPA CRITERIA

Michigan Case Study: Wolverine PFAS Investigations

Presenter: Karen Vorce (EGLE RRD)

In 1958 Wolverine World Wide started commercial use of Scotchgard™ with the introduction of the "Hush Puppy" line of shoes. The shoes were waterproofed using Scotchgard™, which generated Tannery wastes containing per- and polyfluoroalkyl substances (PFAS). The Tannery wastes containing PFAS were disposed of in North Kent County at various sites from the late-1950s through the 1980s. Investigation of the disposal areas was initiated in 2017 and led to a 25 square-mile study area with PFAS impacting hundreds of residential drinking water wells.

A number of issues have led to a challenging hydrogeologic investigation including PFAS' role as an emerging contaminant and behavior in the environment, the geologic-geographical setting of the waste disposal sites, and the complex geology found in the study area.

EGLE Remediation and Redevelopment (RRD) staff will discuss the response efforts which have occurred to investigate and mitigate the PFAS groundwater contamination, how a working conceptual site model was put together for the study area, and what response actions are occurring as required by the 2020 Consent Decree with Wolverine World Wide.

Presenter: Karen Vorce has worked for the Michigan Department of Environment, Great Lakes, and Energy in the Remediation and Redevelopment Division, Grand Rapids district office for six years. Karen is currently the Grand Rapids RRD District Supervisor, and previously was the Senior Project Manager overseeing the Wolverine World Wide PFAS investigation in north Kent County. Prior to joining the State, Karen worked in the environmental consulting field for seven years and holds a B.S. in Geology from Wayne State University.

PFAS Updates from the Michigan Perspective

Presenter: Abigail Hendershott (EGLE Michigan PFAS Action Response Team)

Michigan is a leader among the states in responding to the discovery, investigation, remediation, and management of per- and polyfluoroalkyl substances (PFAS) as we continue to learn more about the fate and transport of these emerging contaminants. This update from the Michigan MPART director will feature the state's perspective on the latest information about these forever chemicals as well as US Environmental Protection Agency insights.

Presenter: **Abigail (Abby) Hendershott**, a 30-year veteran of the Michigan Department of Environment, Great Lakes, and Energy (EGLE), is the Executive Director of the Michigan PFAS Action Response Team. MPART is a multi-agency task force charged with investigating PFAS contamination, overseeing clean-up and other response activities aimed at protecting Michigan's drinking water.

Ms. Hendershott has focused on PFAS response activities since 2017 and led the team responsible for Michigan's largest PFAS contamination response todate, the investigation into the former Wolverine Worldwide tannery in Rockford. In that role, her team was responsible for a $113 million legal settlement establishing clean-up plans and municipal water connections for thousands of residents in northern Kent County.

She supervised the Remediation and Redevelopment Division's Grand Rapids district office and has more than 25 years of project management experience for complex environmental remediation projects