NovCare 2015

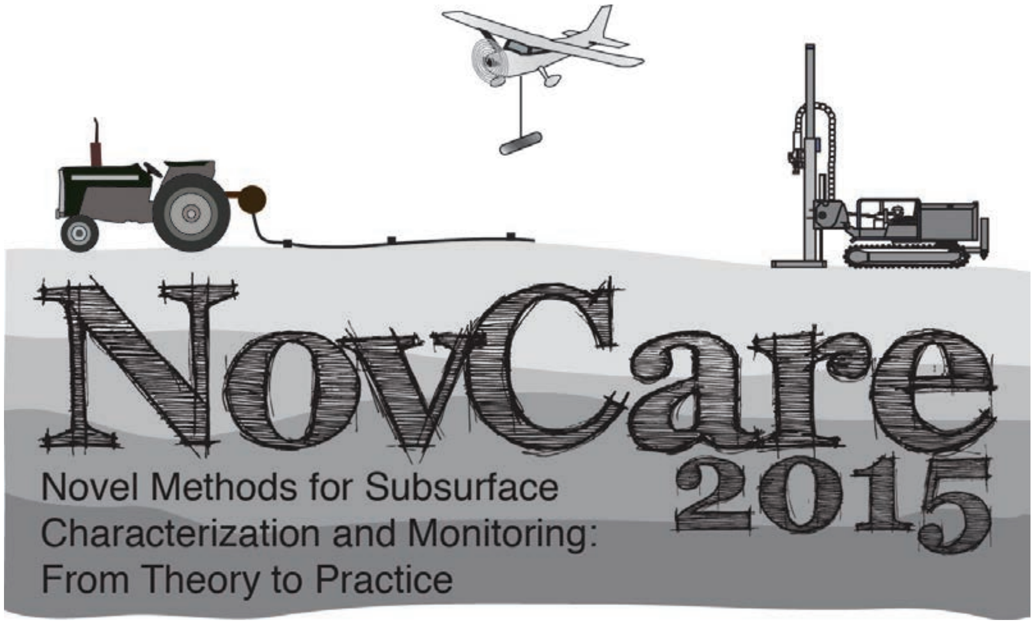
Novel Methods for Subsurface Characterization and Monitoring: From Theory to Practice

NovCare 2015

The Oread Hotel

Lawrence, Kansas

May 19-21, 2015



ORGANIZING COMMITTEE

Conference Chair:

Jim Butler (Kansas Geological Survey, University of Kansas)

Local Committee Members:

Geoffrey Bohling (Kansas Geological Survey, University of Kansas)
Gaisheng Liu (Kansas Geological Survey, University of Kansas)
George Tsoflias (University of Kansas)

Committee Members:

Peter Dietrich (Helmholtz Centre for Environmental Research—UFZ)
David Hyndman (Michigan State University)
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Georg Teutsch (Helmholtz Centre for Environmental Research—UFZ)
Remke van Dam (Gap Geophysics Australia)
Thomas Vienken (Helmholtz Centre for Environmental Research—UFZ)

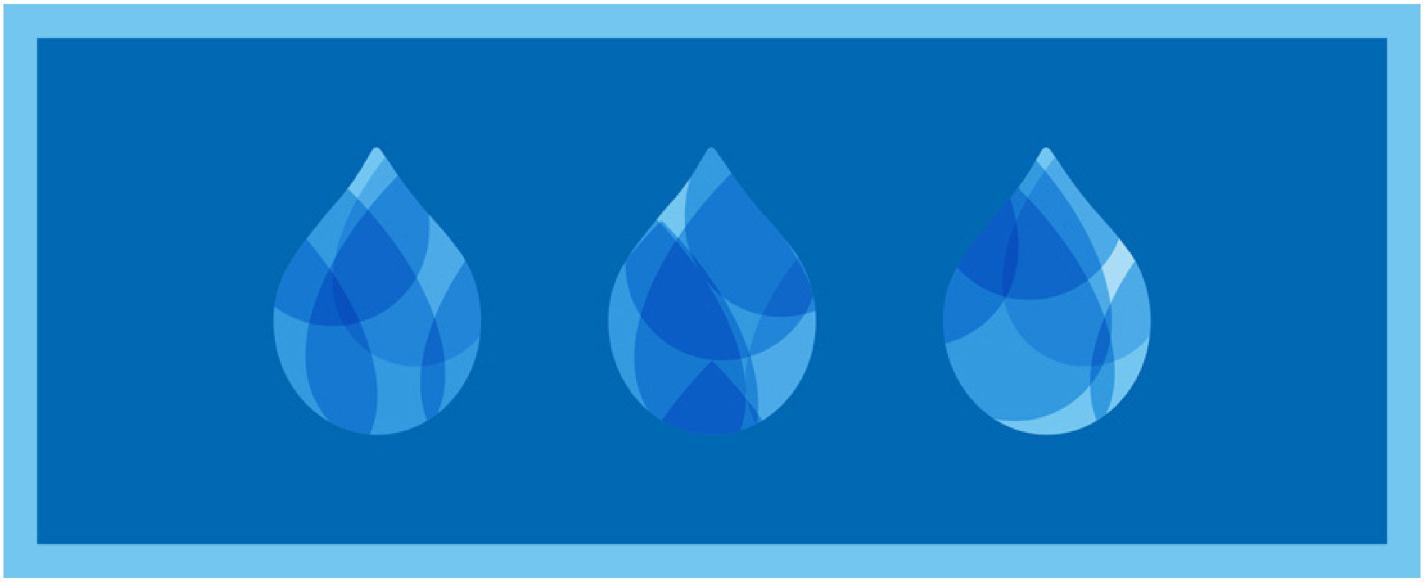
Conference Coordinators:

Steve Knobbe (Kansas Geological Survey, University of Kansas)
Uta Sauer (Helmholtz Centre for Environmental Research—UFZ)

KU KANSAS GEOLOGICAL SURVEY The University of Kansas

KU DEPARTMENT OF GEOLOGY The University of Kansas

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ



The University of Kansas (KU) has many resources for water research. We are home to surveys, centers, and departments that do groundbreaking research on all aspects of the quality, availability, and use of water. Some of the best water-related researchers in the world are faculty and staff at KU. The grand challenge with water research, however, goes well beyond science and engineering. Engagement with the humanities, the arts, the social sciences, and education is also essential. KU has research strengths in all these areas and is bringing them together to think about water in new and challenging ways as part of the Bold Initiatives effort.

In recognition of the importance that water research plays at KU, the following KU entities are providing financial support to the NovCare 2015 Conference.

KU Kansas Geological Survey, The University of Kansas

KU Department of Geology, The University of Kansas

KU Office of the Provost, The University of Kansas

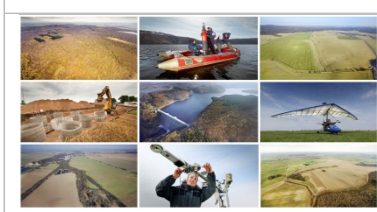
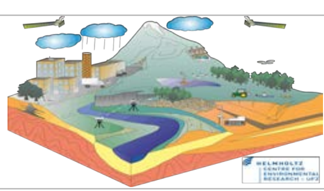
KU Research, The University of Kansas

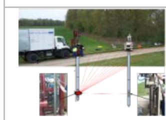
The **Helmholtz Centre for Environmental Research - UFZ** was established in 1991 as the first and only centre in the Helmholtz Association of National Research Centres (Helmholtz Association) to be exclusively devoted to environmental research in a great variety of fields. The mission for the UFZ research is to find a balance between social development and the long-term protection of our natural resources. For this purpose, the UFZ with around 1100 employees is studying the complex interrelationships between humans and the environment and develops tools and strategic concepts for policy makers, the economy and society. They aim to contribute to creating a balance between economical and societal development and long-term protection of our natural resources. The UFZ has a strong focus on interdisciplinary research involving ecologists, social and legal scientists, and economists. The research is done in close cooperation with several universities, other research institutes as well as companies.

Nowadays, humankind more and more uses and alters the shallow subsurface. Especially in densely populated regions, a better understanding of environmental processes in the soil and ground water in view of resource management and life quality plays a big role. Because natural systems are normally very heterogeneous and complicated, their investigation and assessment on a spatial and temporal scale needs great efforts and still is often possible to only some extent.
To meet the rising requirements for environmental research, the **Department Monitoring and Exploration Technologies (MET)** develops unique concepts and strategies to adequately and extensively parameterize and observe natural systems. Therefore, the department develops and uses innovative methods as well as measuring and sensor devices that allow a more efficient collection of environmental data – with experiments, long-term observation platforms on the ground, as well as with the help of aircraft and satellites from the air and from space. An efficient and comparatively fast investigation and assessment of environmental questions could be achieved by the combination of different methods from various research areas, such as geophysics, hydrogeology, Direct Push, remote sensing and biodiversity research.

UFZ has established the **research platform MOSAIC** for the purpose-oriented, rapid site characterization that is a prerequisite for the understanding and the solution of environmental and hydrogeological problems. MOSAIC coordinated by the department MET stands for „Model Driven Site Assessment, Information and Control“. This platform comprises mobile modular data acquisition units for adaptive and modelling-based field investigations. In addition, **TERENO** a network of four terrestrial observatories in Germany for long-term environmental observation (> 15 years) is also coordinated by the department.

Working Groups at the Department Monitoring- und Exploration Technologies:

	***AG 1 : Direct Push and hydrogeological measurement methods*** • Development and evaluation of Direct Push applications and hydrogeological measurement methods • Development of respective measurement and monitoring strategies for the high resolution exploration and characterization of shallow aquifers • Evaluation of resulting effects from an intensive thermal use of the shallow subsurface (e.g. shallow geothermal energy use or heat storage)
	***AG 2 : Geophysics*** • Further development and evaluation of geophysical methods in the context of the investigation of soil, groundwater and biodiversity • Coordination of the research platform MOSAIC
	***AG 3 : On-site analytic processes*** • Development of tools for field analytical chemistry and their application in environmental monitoring and for investigation of transport processes in and between environmental compartments
	***AG 4 : TERENO and soil processes*** • Hydropedological and soil physical studies, development and provision of concepts for the pedosphere-hydrosphere interface, integrated and multiscale long-term monitoring of terrestrial environmental compartments. • Coordination of TERENO Project (TERrestrial ENviromental Observatoria)
	***AG 5 : System analysis & Geotechnics*** • Investigation and observation of environmental systems using different methods and combinations of methods

	***AG 6 : Sensor and Systems Engineering*** • Development of concepts and realization of application study of wireless ad-hoc sensor networks • Further development of novel and existent Direct Push sensor systems • Investigation of innovative measuring concepts in the field of electromagnetic sensor technology
 	***AG 7 : Data Integration and Parameter Estimation*** • Multivariate analyses for probabilistic integration of multi-method data bases • Geoscientifically constrained extrapolation of sparse data • Non-linear joint inversion concepts, i.e. for geophysical model generation • Optimization of geophysical surveying and processing strategies for information return maximization

For more information: www.ufz.de/met
Contact: Prof. Dr. Peter Dietrich *(peter.dietrich@ufz.de,* ++49-341-235-1281*)*

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WELCOME TO LAWRENCE AND NOVCARE 2015

James J. Butler, Jr.
NovCare 2015 Conference Chair
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Steven J. Knobbe
NovCare 2015 Kansas Coordinator
Kansas Geological Survey
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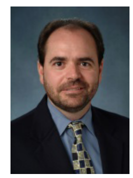


George P. Tsoflias
Associate Professor
Department of Geology
The University of Kansas

It is our great pleasure to welcome you to Lawrence and NovCare 2015. This is the fourth edition of the biennial conference series that began in Leipzig in 2009. Past editions have proven to be excellent forums for exchanging ideas and experiences regarding the opportunities and challenges of subsurface characterization and monitoring. We are hopeful that NovCare 2015 will build on the successes of those previous conferences and again provide attendees the opportunity to learn about the latest and in-development approaches for subsurface characterization and monitoring. We encourage you to use the discussion time and social activities to interact with your fellow attendees and our exhibitors to get the most out of the experience. If you have any questions, please stop any of us during the conference or visit the conference information desk.

Once again, welcome to Lawrence and NovCare 2015!

KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

KU DEPARTMENT OF GEOLOGY
The University of Kansas

WELCOME TO LAWRENCE

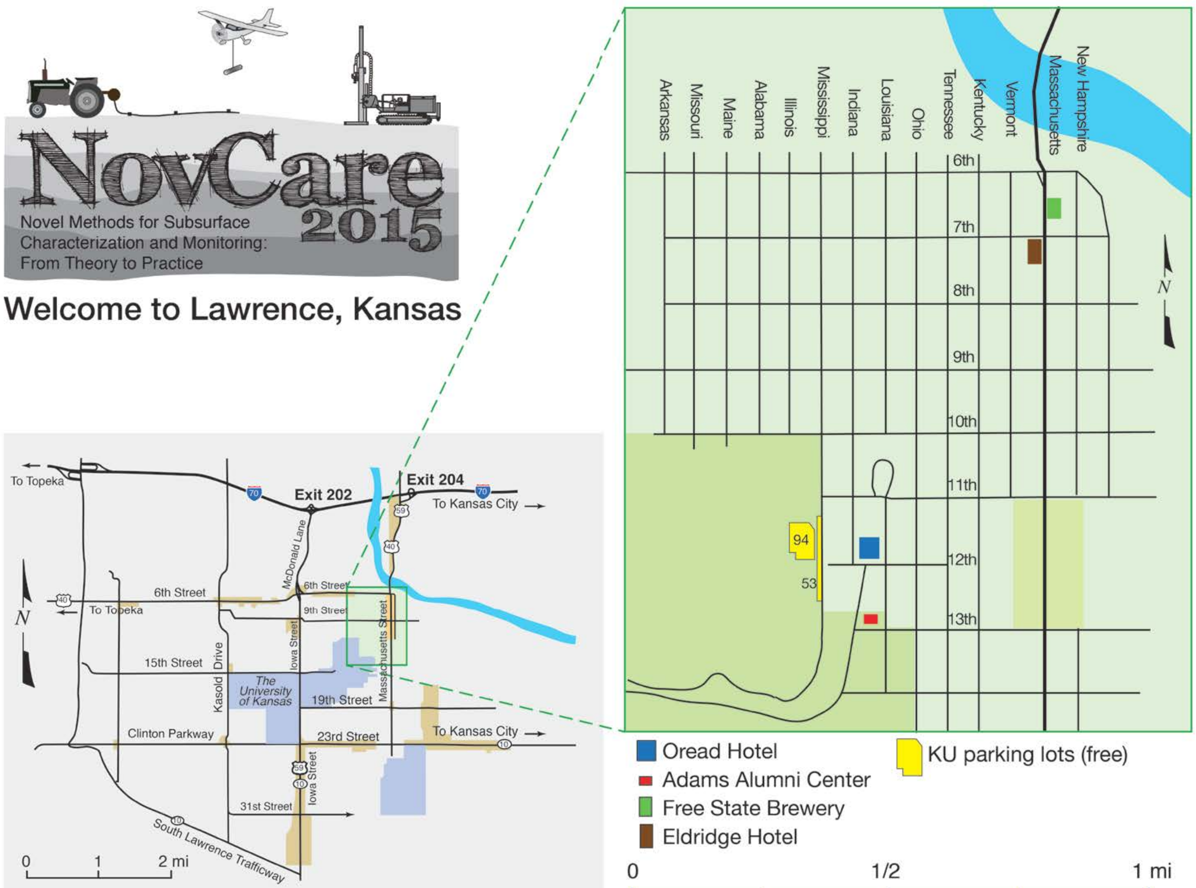
A city of approximately 90,000, Lawrence is located on a rolling landscape 35 miles west of the major metropolitan area of Kansas City and 20 miles east of Topeka, the state capital. Home to the University of Kansas (www.ku.edu) and Haskell Indian Nations University (www.haskell.edu), Lawrence offers the cultural and athletic events of a university setting.

The Territory of Kansas was opened for settlement in May of 1854, and Lawrence was established soon after by a group of abolitionists (opponents of slavery) from Massachusetts, who were determined to see Kansas enter the Union as a free state rather than a slave state. In the years leading up to the Civil War, Lawrence was at the center of the Bleeding Kansas conflicts between "Free Staters" and supporters of slavery, including those in the neighboring state of Missouri and in the Kansas territorial capital of Lecompton, only 10 miles northwest of Lawrence. Conflict in the region continued during the Civil War and, in August of 1863, William Quantrill led a raid on Lawrence, burning down most of the houses and businesses and killing 150 to 200 men and boys. After the raid, the town rebuilt and thrived. The symbol of the city shows a phoenix rising from the flames of Quantrill's raid and the city's motto is "From ashes to immortality." The University of Kansas was established in 1866 on top of a sinuous ridge now known as Mount Oread or "The Hill." KU's current enrollment includes about 25,000 students on the Lawrence campus and 3,000 at the Medical Center in Kansas City. On evenings and weekends, many of those students, along with "townies" and out of town visitors, can be found visiting the shops, restaurants, bars, and music venues of downtown Lawrence or simply strolling along Massachusetts (or "Mass") Street taking in the scene.

For more information about Lawrence, please visit the Lawrence Convention and Visitors Bureau (www.visitlawrence.com) or the City of Lawrence (www.lawrence.com) web pages. More information about Lawrence history can be found at the Watkins Museum of History (www.watkinsmuseum.org) at 11th and Massachusetts Streets.

GETTING AROUND

Downtown Lawrence and the KU campus are very walkable. The Oread Hotel (conference site) is located at the north end of campus. From there, it is a pleasant 20-minute walk to the north end of downtown, where both the Eldridge Hotel and Free State Brewery (banquet site) are located. The walk back is also pleasant, as long as you don't mind the two- to three-block climb at the end. Lawrence also has bus service (lawrencetransit.org). Conference participants would probably be most interested in Route 11, which runs between campus and downtown, stopping at Seventh and Vermont (near the Eldridge Hotel) and the Kansas Union (two blocks south of the Oread Hotel).



PROGRAM SCHEDULE

Monday, May 18, 2015

5:00 PM-8:30 PM Conference Check-in/Ice Breaker (Adams Alumni Center)

Tuesday, May 19, 2015		
	Griffith Ballroom	**Gathering Room 1**
7–8 a.m.	Conference Registration and Check-in/Breakfast	
8–8:15 a.m.	Welcoming Remarks - Dr. Jeffrey Vitter, Provost, University of Kansas	
	Rex Buchanan, Interim Director, Kansas Geological Survey, University of Kansas	
8:15–8:55 a.m.	**Keynote: Measuring K, Monitoring Head: Addressing a Growing Need for Characterization and Monitoring of Groundwater Aquifers** (*Knight, R.; Chen, J.; Fay, E.; Grombacher, D.; Maurer, J.; Zebker, H.*)	
8:55–9 a.m.	*Break*	
	Direct Push	Long-Term Monitoring and Opportunistic Characterization
9–9:20 a.m.	**High Resolution Vertical Profiling: Real Time Data Collection for Comprehensive Environmental Site Assessments** (*Heicher, D.J.*)	**Mobile Wireless Sensor Networks for Event-driven Environmental Monitoring** *(Mollenhauer, H.; Assing, M.; Schima, R.; Remmler, P.; Mollenhauer, O.; Hutschenreuther, T.; Toepfer, H.; Dietrich, P.; Bumberger, J.*)
9:20–9:40 a.m.	**Key developments in DI Tool and MIP Detectors and Advanced MIP Log Interpretation** (*Christy, T.M.; Pipp, D.A.*)	**Getting More from Long-Term Monitoring of Groundwater Levels: Examples from the High Plains Aquifer** *(Butler, J.J., Jr.; Reboulet, E.C.)*
9:40–10 a.m.	**Detection and Measurement of Bulk NAPL in Sediments Using Small Diameter NMR Logging Tools** (*Walsh, D.O.; Grunewald, E. D.*)	**Cost Effective Passive Data Collection to test a Conceptual Site Model** (*Engard, B.; Winslow, D.*)
10–10:25 a.m.	*Break*	*Break*
10:25–10:45 a.m.	**The Hydraulic Profiling Tool-Ground Water Sampler, Updates & Application** (*Christy, T.M.; McCall, W.; Slater, B.; Front, M.; Christensen, A.; Riss, C.; Nancy Hamburger, N.; Johansen, P.*)	**Spatial and temporal continuous real-time water information networks and surrogates** (*Ziegler, A.C.*)
10:45–11:05 a.m.	**Chasing the tracer - combining conventional salt tracer testing with Direct Push electrical conductivity logging for the characterization of a highly permeable fluviatile aquifer** *(Vienken, T.; Huggenberger, P.; Huber, E.; Kreck, M.; Dietrich, P.)*	**Hydrostratigraphic Drilling Record Assessment (HyDRA): Developing Quantitative Aquifer Models Using Drillers' Logs** (*Bohling, G.C.*)
11:05–11:10 a.m.	*Break*	

11:10–11:50 a.m.	**Keynote: Applications of High-Frequency Nutrient Sensors in Surface and Groundwater: A Revolution for Research and Monitoring?** (*Pellerin, B. A.*)	
11:50 a.m.–12:50 p.m.	*Lunch (Hancock Ballroom)*	
12:50–1:30 p.m.	**Keynote: Paradigm shift in the monitoring of temporal changes in the freshwater-saltwater interface** (*Kim,Y.; Yoon,H.; Koh,D.; Kim,G.*)	
1:30–1:35 p.m.	*Break*	
	Characterization at the Interface	New Approaches for Aquifer Characterization
1:35–1:55 p.m.	**A field comparison of multiple techniques to quantify surface water – groundwater interactions** (*González-Pinzón, R.; Ward, A. S.; Hatch, C. E.; Wlostowski, A. N.; Singha, K.; Gooseff, M. N.; Haggerty, R.; Harvey, J. W.; Cirpka, O. A.; Brock, J.T.*)	**Can the Advection-Diffusion Equation explain complex tracer transport behavior?** (*Hyndman, D.W.; Dogan, M.; Van Dam, R.L.; Meerschaert, M.; Bohling, G.C.; Benson, D.*)
1:55–2:15 p.m.	**The use of Point Velocity Probes (PVPs) for quantification of the groundwater-borne contaminant mass discharge to a stream** (*Rønde, V.K.; McKnight, U. S.; Sonne, A. T.; Devlin, J. F.; Bjerg, P. L.*)	**Theoretical Concepts for Measuring Local Scale Anisotropic Hydraulic Conductivity** (*Klammler, H.; Layton, L.; Hatfield, K.*)
2:15–2:35 p.m.	**Characterizing Temporal Variability at the Groundwater/Surface Water Interface** (*Brookfield, A.; Reboulet, E.; Wilson, B.B.*)	**Reassessing the MADE direct-push hydraulic conductivity data using an improved calibration procedure** (*Bohling, G. C.; Liu, G.; Butler, J. J., Jr.*)
2:35–3:05 p.m.	*Break/Exhibitor Visit*	
3:05–3:45 p.m.	**Keynote: A Passive Flux Meter for Measuring Vertical Water and Solute Fluxes in the Hyporheic Zone** (Hatfield, K.; *Klammler, H.; Layton, L.; Cho, J.; Annable, M.*)	
3:45–3:50 p.m.	*Break*	
	Hydrogeological Investigation Techniques	Characterization at the Interface
3:50–4:10 p.m.	**High Spatial Resolution measurements using Flexible Liners** (*Keller, C.*)	**2-D SEAWAT Model of an Altered Mangrove Forest on a Barrier Island Near the Indian River Lagoon, FL** (*Downs, C.; Kruse, S.; Rains, M.*)
4:10–4:30 p.m.	**Using Multi-frequency Sinusoidal Pressure Testing for Improved Aquifer Characterization** (*Fort, M.D.; Roberts, R.M.; Chace, D.A.*)	**Upscaling of Point Velocity Probes (PVPs) measurements for comparison with Darcy-derived groundwater velocity** (*Devlin, J.F.; Schillig, P.C.; Rudolph, D.*)
4:30–4:35 p.m.	*Break*	
4:35–5:15 p.m.	**Keynote: Viruses as Tracers: An Opportunistic Tool to Characterize Fast Groundwater Flowpaths** (*Hunt, R.J.; Borchardt, M.A.; Bradbury, K.R.*)	
5:15–7 p.m.	*Poster Session and Exhibitor Visit (All-Seasons Den)*	

Wednesday, May 20, 2015		
	Griffith Ballroom	**Gathering Room 1**
7–8 a.m.	*Breakfast*	
8–8:05 a.m.	Opening Comments	
8:05–8:45 a.m.	**Keynote: Ground-penetrating radar: a high-resolution geophysical tool to explore near-surface environments** (*Tronicke, J.*)	
8:45–8:50 a.m.	*Break*	
	Integrated Characterization of the Unsaturated and Saturated Zones	Geotechnical Site Characterization
8:50–9:10 a.m.	**Heat transfer in soils: λ thermal conductivity in-situ measurements using direct push technology** (*Chirila, M.A.; Christoph, B.; Vienken, T.; Dietrich, P.; Toepfer, H.; Bumberger, J.*)	**Near-Surface Site Characterization using Downhole Seismic Testing** *(Verbeek, G.; Baziw, E.)*
9:10–9:30 a.m.	**Assessing recharge sources and pathways with high resolution pore fluid geochemistry** (*Stotler, R.L.; Smith, J.J.; Ludvigson, G.A.; Katz, B.S.; Whittemore, D.O.; Butler, J.J.; Hirmas, D.R.*)	**Soil Erodibility Characterization using Electrical Resistivity Imaging** (*Tucker-Kulesza, S.; Karim, M.Z.*)
9:30–9:40 a.m.	*Break*	
9:40–10:20 a.m.	**Keynote: Building Hydrostratigraphic and Geological Models: The Information is in Airborne Electromagnetic** (*Auken, E.; Christiansen, A.V.; Vilhelmsen, T.N.*)	
10:20–10:25 a.m.	*Break*	
	Integrated Characterization of the Unsaturated and Saturated Zones	Geotechnical Site Characterization
10:25–10:45 a.m.	**Electrical resistivity surveys using multiple buried electrodes and sequentially offset surface arrays** (*Kiflu, H.; Kruse, S.; Harro, D.; Loke, M.H.*)	**Testing the Applicability of a $600K Grout Curtain for NYC Underpinning** (*Engard,B.; Roy, D.*)
10:45–11:05 a.m.	**A scientific drilling program in the Cenozoic strata of the High Plains Aquifer: Sedimentologic and hydrostratigraphic characterization of cored sediments from the Ogallala Formation** *(Smith, J. J.; Ludvigson, G.A.; Doveton,J.; Layzell, A.; Stotler, R.L.; Möller, A.; Rittenour, T.M.*)	**Evaluation of Resistivity and Fouling of Railroad Ballast Using a Direct Push Technology** (*Parsons, R.L.; Neupane, M.; Han, J.*)
11:05–11:30 a.m.	*Break/Exhibitor/Poster Visit*	
11:30 a.m.–12:30 p.m.	**2015 Darcy Lecture: Evaluating the Competitive Use of the Subsurface: The Influence of Energy Storage and Production in Groundwater** *(Helmig, R.H.)*	

12:30–1:30 p.m.	*Lunch (Hancock Ballroom)*
1:30–2:05 p.m.	*Travel to GEMS*
2:05–5:05 p.m.	**Field Demonstrations - Geohydrologic Experimental and Monitoring Site (GEMS)** Geoprobe Matrix Environmental Vista Clara University of Kansas Dept. of Geology Kansas Geological Survey
5:05–5:40 p.m.	*Return to Oread*
7:00–9:30 p.m.	Optional Banquet (Free State Brewing Co.)

Thursday, May 21, 2015		
	Griffith Ballroom	**Gathering Room 1**
7–8 a.m.	*Breakfast*	
8–8:05 a.m.	Opening Comments	
8:05–8:45 a.m.	**Keynote: Cutting the Seismic Wavefield Deck of Cards for Optimized Characterizations** *(Miller, R.D.; Ivanov, J.; Peterie, S.L.; Morton, S.L.C.; Livers, A.; Wang, Y.)*	
8:45–8:55 a.m.	*Break*	
	Hydrogeological Investigation Techniques	New Tools for Watershed Characterization
8:55–9:15 a.m.	**Effects from Unsaturated Zone Flow during Oscillatory Hydraulic Testing** (*Lim, D.; Zhou, Y.; Cardiff, M.; Barrash, W.*)	**Characterizing heterogeneities in an alluvial aquifer with repeated distributed thermal perturbation sensing tests** *(Hausner, M.B.; Kryder, L.; Klenke, J.; Reinke, R.; Tyler, S.*)
9:15–9:35 a.m.	**Assessment of Test Initiation Method on Hydraulic Tomography Resolution** *(Paradis, D.; Lefebvre, R.; Gloaguen, E.; Giroux, B.)*	**Watershed Scale Characterization of Glacial and Bedrock Aquifers in Eastern Nebraska** (*Abraham, J.D.; Cannia, J.C.; Cameron, K.; Asch, T.H.*)
9:35–9:55 a.m.	**Oscillatory Flow Testing in a Sandbox – Towards Oscillatory Hydraulic Tomography** *(Zhou, Y.Q.; Lim, D.; Cardiff, M.*)	**Laboratory investigation of distributed temperature sensing to characterize groundwater flux** (*Knobbe, S.; Liu, G.; Butler, J.J., Jr.*)
9:55–10:35 a.m.	*Break/Exhibitor/Poster Visit*	
10:35–11:15 a.m.	**Keynote: Confirmation of Hydraulic, Tracer, and Heat Transfer Characterization of a Fractured Bedrock using Ground Penetrating Radar** (*Becker, M.; Tsoflias, G.; Hawkins, A.; Baker, M.*)	
11:15–11:25 a.m.	*Break*	
11:25 a.m.–12:25 p.m.	**Mini-Course: Geostatistical Methods for High-Resolution Data** *(Gomez-Hernandez, J.)*	
12:25–1:35 p.m.	*Lunch (Hancock Ballroom) and Final Opportunity to Visit Exhibitors*	
1:35–2:35 p.m.	**Mini-Course: Direct Push** *(Dietrich, P.)*	
2:35–2:45 p.m.	*Break*	
2:45–3:30 p.m.	**Roundtable Discussion - "From the Research Community to the User Community - Lessons Learned and Suggestions for the Future"**	
3:30–3:45 p.m.	Closing Remarks	

DARCY LECTURE 2015

EVALUATING THE COMPETITIVE USE OF THE SUBSURFACE: THE INFLUENCE OF ENERGY STORAGE AND PRODUCTION IN GROUNDWATER

Rainer H. Helmig, Ph.D.

Head of the Department of Hydromechanics and Modelling of Hydrosystems Institute for Modelling Hydraulic and Environmental Systems, University of Stuttgart, Germany

The Darcy Lecture at the NovCare 2015 Conference will be free and open to the general public. The lecture will be given at 11:30 a.m. on Wednesday, May 20, in the Griffith Ballroom of the Oread Hotel. The NovCare 2015 Conference will be open to the general public as of 11:00 a.m. on May 20. Individuals not registered for the conference are invited to visit the conference sponsor displays in the All Seasons Den at the Oread Hotel before the lecture. Those displays will be open to the general public as of 11:00 a.m. on May 20.

Gain insight on how advanced numerical models may be used to analyze and predict the mutual influence of subsurface projects and their impact on groundwater reservoirs, and the increasing need to do so, during this presentation.

The subsurface is being increasingly used both as a resource and as an energy and waste repository. With increasing exploitation, resource conflicts are becoming increasingly common and complex, such as thermal energy storage and the effects surrounding hydraulic fracturing in both geothermal and shale gas production.

During this lecture you will learn about:

- Possible utilization conflicts in subsurface systems and how the groundwater is affected
- Fundamental properties and functions of a compositional multiphase system in a porous medium; basic multiscale and multiphysics concepts will be introduced and conservation laws formulated
- Large-scale simulation that shows the general applicability of the modeling concepts of such complicated natural systems, especially the impact on the groundwater of simultaneously using geothermal energy and storing chemical and thermal energy, and how such real large-scale systems provide a good environment for balancing the efficiency potential and possible weaknesses of the approaches discussed.

Biography: *Rainer H. Helmig, Ph.D., is head of the Department of Hydromechanics and Modelling of Hydrosystems at the Institute for Modelling Hydraulic and Environmental Systems, University of Stuttgart, Germany. His research covers fundamental research and applied science in the field of porous-media flow. A major focus is on developing methods for coupling hydrosystem compartments and complex flow and transport processes. This is based on simulation methods and techniques for describing single- and multiphase, multicomponent flow and transport processes in the subsurface, i.e., in porous and fractured-porous media. The fields of application for these modelling concepts cover a wide range from subsurface applications (e.g. NAPL-contaminated soils,* CO_2 *storage, hydraulic fracturing) to technical problems (e.g. water management in PEM fuel cells).*

BUILDING HYDROSTRATIGRAPHIC AND GEOLOGICAL MODELS: THE INFORMATION IS IN AIRBORNE ELECTROMAGNETIC

Esben Auken[1]; Anders Vest Christiansen[1]; Troels Norvin Vilhelmsen[1]

[1]Institute for Geoscience, Aarhus University, CF Møllers Allé 4, 8000 Aarhus C, Denmark, esben.auken@geo.au.dk

Keywords: airborne electromagnetic, data inversion, hydrological modelling

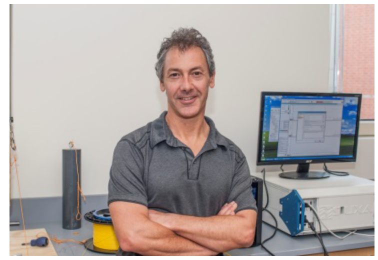
The world faces a major crisis in water supply for drinking, irrigation, and industrial usage. The reasons are numerous, but the most distinct are probably global warming and increased demand due to growing populations and an increase in global wealth. A key part of the solution is to manage groundwater resources, and this is where new mapping technology can play a decisive role. Where airborne electromagnetic (AEM) methods traditionally were seen as expensive and not always yielding successful results, the technology has been dramatically developed over the last 10 years. Today AEM data together with borehole lithology and geophysical information yield all the information necessary to build detailed hydrostratigraphic and geological models in three dimensions. The major challenge is no longer to have enough information; the challenge is to use the information and to make scientists and professionals aware of the new possibilities.

Today AEM is almost synonymous with transient electromagnetic methods, and it is the helicopter systems that have really changed the technology. These systems are easy to mobilize, and they can drape the terrain and fly low giving a good resolution of the shallow geology while still keeping a high production. In this presentation, we will in particular discuss the SkyTEM system. It has a superior technology able to measure unbiased data even while the transmitter is still turning of the current. The system is developed concurrently with the data modeling algorithms, which allow for detailed system modelling and robust inversion.

In the keynote talk, we will discuss the latest research and developments within AEM technology and data inversion capabilities. We will then give an example of how AEM is used together with lithological logs to build hydrostratigraphic models, and we will discuss the performance of these models. Finally, we will give an outlook on the technology applied in other disciplines, such as road and railroad construction, mapping of salt water intrusion, aquifer vulnerability estimation, etc.

Biography: *Esben Auken is professor in hydrogeophysics. The research fields of his group includes airborne electromagnetic, MRS and ERT/IP. The research group develops numerical algorithms for data processing and inversion, instruments and user-friendly GUI software. Projects are worldwide and include regional-scale aquifer mapping in India, permafrost mapping in Antarctica, and 2-D/3-D ERT/IP monitoring of landfill leakage. The group also does extensive research in optimal ways to integrate large-scale AEM geophysical data into hydrological modelling.*

CONFIRMATION OF HYDRAULIC, TRACER, AND HEAT TRANSFER CHARACTERIZATION OF A FRACTURED BEDROCK USING GROUND PENETRATING RADAR



Matthew Becker, Georgios Tsoflias, Adam Hawkins, Matthew Baker

Keywords:

Over the past five years, multiple characterization techniques have been applied to an experimental field site to elucidate flow channeling in bedrock and its influence on contaminant transport and geothermal heat transfer. The field site consists of a 10 x 10 meter five-spot borehole pattern isolated in a single bedding plane fracture in sandstone. The Altona Flat Rock site was developed as a unique field laboratory for testing characterization methods applicable to flow and transport in fractures. The Potsdam Sandstone is exposed at this locale, allowing access to shallow groundwater in bedding plane fractures. Periodic hydraulic tests have shown evidence of preferential flow connections among the wells. This connection was confirmed with multiple ionic tracers, which showed different sweep efficiency among well pairs.

Heated water tracer studies demonstrated that heat exchange was more efficient in the wells that exhibited greater sweep between well pairs.

Finally, surface ground penetrating radar (GPR) was used to map flow in the plane of the fracture by using saline solution to trace flow paths. The implications of the GPR imaging are the focus of this contribution. Reflected radar energy showed a marked change in both amplitude and phase in the presence of saline tracer, allowing flow paths to be imaged. The path followed by the saline tracer was highly anisotropic, presumably following aperture fabrics related to the sandstone depositional environment. Fluid flow, solute migration, and heat transport are all strongly influenced by this anisotropy. These findings highlight the importance of characterizing hydraulic connectivity to predict engineered circulation systems for groundwater remediation, enhanced oil recovery, and geothermal heat extraction.

Biography: *Matt Becker is the Conrey Chair in Hydrogeology and Professor in the Geological Sciences Department at CSU Long Beach. He holds a B.S. in Geology from Michigan State University and M.S. and Ph.D. in Civil Engineering from the University of Texas at Austin. He has held positions with Chevron USA, Los Alamos National Labs, and U.S Geological Survey National Research Program. He was a National Academy of Science Senior Research Associate at NASA Goddard Space Center and was a Fulbright Scholar at the University Trento, Italy. Prior to arriving at the CSULB, he was an Assistant then Associate Professor of Geology at the University of Buffalo. He has been studying fluid flow in fractured rock for 20 years.*

A PASSIVE FLUX METER FOR MEASURING VERTICAL WATER AND SOLUTE FLUXES IN THE HYPORHEIC ZONE

Kirk Hatfield[1], Harald Klammler[1] , Leif Layton[1] , Jaehyun Cho[1] , and Michael Annable[1]

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Keywords: groundwater, surface water, interface, sediment bed, direct-push probe.

The interaction between ground and surface water bodies is an important hydro(geo)logical mechanism allowing for the mutual exchange of both water and solutes (e.g., nutrients or contaminants). Moreover, the hyporheic zone immediately below the interface (e.g., a sediment bed) can provide prosperous conditions for contaminant transformation or degradation. Water and contaminant mass fluxes across the interface are appropriate parameters for quantifying the magnitude of such exchange processes; whereas changes in contaminant mass fluxes as a function of depth below the interface are useful for characterizing reaction processes in the hyporheic zone. At present, taking grab samples of sediment pore water is the standard method for quantifying contaminant concentrations. For quantifying exchange processes, this requires independent knowledge of water fluxes, which is currently obtained from seepage meters or mini-piezometers in combination with measurements of sediment hydraulic conductivity.

The sediment bed passive flux meter (SBPFM) is a novel device that allows for the direct and simultaneous measurement of vertical cumulative water and contaminant mass fluxes across the ground to surface water interface or as a function of depth in the hyporheic zone. In its simplest form, the SBPFM consists of a direct-push probe possessing two short screened intervals along an otherwise impermeable casing. When installed in a sediment bed, the screens are exposed to the prevalent vertical hydraulic gradient. Inside the SBPFM casing, the screens are hydraulically connected by a sorbent column, such that groundwater is captured by one screen, transferred through the sorbent column, and released by the other screen. According to the passive flux meter principle, the sorbent column releases resident tracers at a magnitude proportional to the water flux through the column, while it retains contaminants at magnitudes proportional to respective contaminant mass fluxes through the column. After a desired time of exposure (e.g., days or weeks), the sorbent material is analyzed for tracer masses remaining and contaminant masses retained. A semi-analytical solution to the corresponding three-dimensional axi-symmetric potential flow problem is used to convert water and contaminant mass fluxes through the sorbent column to respective ambient fluxes in the undisturbed sediment. This conversion generally requires knowledge of the anisotropy in sediment conductivity, while a SBPFM may be designed to deliver measurements independent of the absolute values of horizontal and vertical conductivity.

Laboratory bench scale experiments of the SBPFM under controlled conditions and experiments for independently measuring anisotropy ratios in sediment conductivity have been successfully performed using sand-packed buckets. Preliminary field experiments have also shown large potential for practical implementation.

Biography: *Dr. Kirk Hatfield is the Director of the Engineering School of Sustainable Infrastructure and Environment at the University of Florida, the Director of the Florida Water Resources Research Center, and a Professor in the Department of Civil and Coastal Engineering. Dr. Hatfield received his B.S. and M.S. degrees from the University of Iowa and his Ph.D. degree from the University of Massachusetts in Amherst. Following graduation, he joined the University of Florida, Department of Civil Engineering in 1987. Dr. Hatfield's ongoing research activities are in the areas of aqueous environmental monitoring, contaminant fate and transport modeling in the subsurface, environmental remediation, and water resources systems analysis. He has active research collaborations with universities and institutes in Russia, Brazil, Canada, Mexico, England, and Germany. These collaborations have produced several patents and several technical paper awards in 1994, 1998, 2006, and 2011 from ASEE and ASCE and from the editorial board of Environmental Science and Technology. In 2006, the Department of Defense awarded Dr. Hatfield and his colleagues the distinguished "Project of the Year Award" for their research to demonstrate and validate a new technology that provides direct measures of water and contaminant fluxes in aquifers.*

VIRUSES AS TRACERS: AN OPPORTUNISTIC TOOL TO CHARACTERIZE FAST GROUNDWATER FLOWPATHS

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Keywords: virus, tracer, groundwater, fast flowpath, qPCR

Groundwater systems often are characterized by long travel times relative to human timeframes. Most established techniques for dating groundwater work at the decadal to millennial scale: far longer than many management horizons. Currently, there is significant public and regulatory interest in fast groundwater flow, including understanding the vulnerability of water-supply wells to pathogen contamination. Assessing well vulnerability to infectious pathogens requires knowledge of very fast (less than three year) travel times—a timeframe not characterized by common groundwater age dating methods. Recent advances in qPCR virus analysis have facilitated new insights into short travel times in some flow systems. Viruses are attractive tracers of short travel times in aquifers because they have unique genetic signatures, are detectable in trace quantities, and are mobile in groundwater. Virus "snapshots" result from infection and disappearance in a human or animal population over time; therefore, the virus snapshot shed in the fecal wastes of an infected population at a specific point in time can serve as a marker for tracking virus and groundwater movement. Examples of virus tracing demonstrate their ability to characterize travel times in high groundwater velocity settings but are less applicable to low velocity settings due to virus degradation. Because they can trace very short travel times and identify the presence of preferential flowpaths, virus approaches provide new insights about aquifers unavailable from standard hydrogeologic approaches.

Biography: *Dr. Randall Hunt is a Research Hydrologist with the U.S. Geological Survey in Middleton, Wisconsin. He completed his M.Sc. and Ph.D. at the University of Wisconsin-Madison where he currently holds a position of Adjunct Professor within the Department of Geoscience. His areas of expertise focus on conducting research investigating groundwater flow and how it affects natural systems. This research program has used a variety of approaches such as numerical modeling, ion and isotope chemistry, parameter estimation, and stochastic methods. It has emphasized a range of groundwater–surface water settings, including wetland, stream, and lake interactions. His work also includes investigation of ecohydrology, including the effects of groundwater on the biotic/ecologic community in aquatic systems.*

PARADIGM SHIFT IN THE MONITORING OF TEMPORAL CHANGES IN THE FRESHWATER-SALTWATER INTERFACE

Yongcheol Kim[1], Heesung Yoon[1], Dong-chan Koh[1], Gee-Pyo Kim[2]

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Keywords: freshwater-saltwater interface, time series data, “interface egg”

Management of coastal aquifers is becoming increasingly important with the growing prospects of global climate change. Excessive pumping of coastal aquifers often results in saltwater intrusion and saltwater up-coning. Therefore, many countries have installed monitoring wells along coastlines, especially in the vicinity of agricultural and urban areas. Most of the coastal monitoring wells are equipped with a single sensor measuring water pressure, temperature, and/or electrical conductivity at a certain depth in the well. However, such single-depth measurement methods can only give us the information that the freshwater-saltwater interface is either above or below the sensor. A multi-depth measurement approach, in which several sensors are placed at different depths in the well, can be used to monitor the interface. This method, however, typically has poor vertical resolution (depends on distance between sensors); high-resolution vertical profiles require many sensors and are thus expensive. Geophysical logging can be used to monitor the interface, but it gives us the location of the interface only at a specific time instead of time series data. A new method has been developed using a probe, an “interface egg,” to monitor temporal changes in the position of the freshwater-saltwater interface. The probe is designed to float on the interface and thus can move up and down along with the movement of the freshwater-saltwater interface. Even in cases where there is a relatively wide transition zone between fresh water and salt water, the probe can give us the real-time location of the upper boundary of the interface, which is critical for saltwater intrusion monitoring. The temporal change in the thickness of the freshwater lens and the transition zone can be calculated using a combination of another interface egg and depth-fixed sensors. This method has been tested and validated at a monitoring well in Jeju Island, Korea. It can be used as an early warning system for saltwater intrusion and/or freshwater decline when the probe is integrated with a predictive numerical model and a remote communication technology.

Biography: *Yongcheol Kim received his Ph.D. (2004) in hydrogeology from Seoul National University, South Korea. In 2003–2005, he was a post-doctoral researcher at CESEP (Center for Experimental Study of Subsurface Environmental Processes) at the Colorado School of Mines, Golden, Colorado, USA. Since 2005, he has been a researcher in the Department of Groundwater, Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, Korea. His research interests include managed aquifer recharge, coastal aquifer management, flow and transport in saturated/unsaturated porous/fractured media, DNAPL problems, tracer tests, and hydraulic tests for site characterization.*

MEASURING *K*, MONITORING HEAD: ADDRESSING A GROWING NEED FOR CHARACTERIZATION AND MONITORING OF GROUNDWATER AQUIFERS

Rosemary Knight[1], Jingyi Chen[1], Emily Fay[1], Denys Grombacher[1], Jeremy Maurer[1], Howard Zebker[1]

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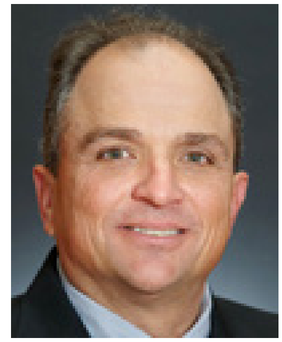
Keywords: NMR, InSAR, groundwater, hydraulic conductivity

California has recently passed new groundwater legislation that requires local agencies to assess conditions in their basins and adopt management plans. This will drive an unprecedented need for efficient ways to acquire data to both characterize and then monitor groundwater systems in the state. Of specific interest in our research is the development of two relatively new approaches to subsurface characterization and monitoring: 1) the use of nuclear magnetic resonance (NMR) as a means of mapping out variation in hydraulic conductivity *K* and 2) the use of interferometric synthetic aperture radar (InSAR) as a means of monitoring head. NMR measurements can be made in a borehole or from the ground surface and provide a direct sensitivity to water content and an indirect link to *K*. Two issues that need to be addressed for the widespread adoption of borehole and/or surface NMR, and the focus of current research, are determining the link between the NMR measurement and *K* and developing methodologies for the acquisition of high quality surface NMR data. While measurement of water content and *K* with NMR can provide estimates of the volume of producible water, an essential part of sustainable groundwater management is the ability to monitor changing head levels in groundwater aquifers. Satellite-based InSAR measurements provide high-resolution images of cm-scale changes in elevation of the ground surface; these can be related to changing head levels in the underlying confined aquifer. With recently developed algorithms for the processing of InSAR data, we have been able to map out changing head levels in the San Luis Valley of Colorado over a 20-year time period, covering 10,000 square kilometers of the valley with spatial resolution on the order of 100s of meters. NMR and InSAR represent new, efficient ways of acquiring data needed for the characterization and monitoring of groundwater aquifers.

Biography: *Rosemary Knight received a B.Sc. and M.Sc. in Geological Sciences from Queen's University, Canada, and a Ph.D. (1985) in Geophysics from Stanford University, U.S.A. She is currently the George L. Harrington Professor of Earth Sciences in the Department of Geophysics at Stanford and senior fellow, by courtesy, in the Woods Institute for the Environment. Research interests include laboratory and theoretical studies of the properties of fluid-saturated rocks and the use of geophysical methods for near-surface environmental applications. She is the founding director of the Center for Groundwater Evaluation and Management (gemcenter.stanford.edu), a research initiative to develop and demonstrate news ways of using geophysical methods for groundwater applications.*

CUTTING THE SEISMIC WAVEFIELD DECK OF CARDS FOR OPTIMIZED CHARACTERIZATIONS



R. D. Miller[1], J. Ivanov[1], S. L. Peterie[1], S. L. C. Morton[1], A. Livers[1], and Y. Wang[1]

[1]*Kansas Geological Survey, University of Kansas*

Over the 50-plus years that near-surface seismic data have been used to characterize the shallow subsurface, acquisition, processing, analysis, and interpretations have almost exclusively been focused on a single, targeted component of the seismic wavefield. Many times the portion of the wavefield of greatest interest represents a small percent of the total recorded energy. Optimizing the signal recorded and focusing processing and analysis routines on specific arrival packets limit the overall potential contained within the entire seismic. State of the practice normally requires a portion of the source-generated wavefield to be discarded as noise that for a different seismic method would be considered signal.

Until Full Wavefield Inversion can be routinely applied—with key properties of the seismic wavefield measured with high resolution and accuracy—cutting up the wavefield and analyzing specific small portions of data sets will continue to be the state of the practice. This practice effectively leaves large portions of the recorded data "on the table," classified as noise but containing important and sometimes unique information about the shallow subsurface.

Advancing quite rapidly over the last decade has been the cutting of the seismic wavefield into each component, processing various components independently, and then analyzing/interpreting them either with the aid of joint inversion or simply coincident interpretations. In this talk, we will demonstrate how through no sleight of hand we can cut up the seismic wavefield and solve for the physical property of the near surface using different methods and part of the wavefield and integrate those uniquely determined calculated properties to both extend the analysis depths (both shallow and deep) and to improve the spatial accuracy of the property matrix.

Surface-wave and body-wave energy components of the wavefield come in both compressional- and shear-wave suits. Arrival characteristics, including disturbances in the uniform propagation of the wavefield, encompass all the mechanical properties of the subsurface. Changes in material velocity will alter the dispersive characteristics of the surface wave and the travel time and propagation pattern of body waves. By analyzing changes in the propagation patterns of each component of the wavefield, it is possible to identify changes in material composition or structures and even variation in rock properties, at high fidelity.

Physical properties needed for empirically-based, 2-D numerical models used for applications from engineering to transport and fate requires the populating of a numerical matrix that is divided into cells as small as the data resolution will justify. Each of these cells, or voxels, for elastic models contains measured and estimated values for V_P, V_S, Q_P, Q_S, and reasonable estimates of error for each. The degree of heterogeneity and the resolution potential of the method, to a large degree, dictate the density and therefore the size of the voxels necessary to accurately represent the subsurface.

APPLICATIONS OF HIGH-FREQUENCY NUTRIENT SENSORS IN SURFACE AND GROUNDWATER: A REVOLUTION FOR RESEARCH AND MONITORING?

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Keywords: sensors, water quality, nutrients

Recent advances in sensor technology and communications have enabled the routine collection of environmental data in ways that were unforeseen just a decade ago. In particular, the ability to continuously measure a wide variety of water-quality parameters *in situ* and transmit those data in real time has the potential to revolutionize our understanding and management of water quality. At the forefront are sensors for nitrate and orthophosphate that are proving useful for real-time monitoring of drinking water, calculating nutrient loads to coastal ecosystems, assessing aquatic nutrient retention, and understanding nutrients as drivers of quality impairment. However, the widespread application of these sensors in surface and groundwater has generally been limited by the complexity of the instruments themselves and/or the high purchase and maintenance costs.

Current efforts such as the Nutrient Sensor Challenge (http://www.act-us.info/nutrients-challenge/) aim to accelerate the development and adoption of lower cost nutrient sensors over the next few years. Yet, the need for high-frequency, real-time nutrient data remains dependent on the time scales of variability in water quality, data quality specifications, and the question of interest. Here, I will show several examples from surface-water and groundwater studies that demonstrate the information gained by making high-frequency, *in situ* nutrient measurements for nutrient loading, subsurface transport, and drinking-water needs. In addition, I will also highlight applications where the slow rates of change in water quality, and/or the questions being asked, may not benefit from investments into the purchase, operation, and data management of high-frequency nutrient sensors.

Biography: *Brian Pellerin is a Research Scientist with the U.S. Geological Survey in the California Water Science Center. He received a B.S. (1998) and Ph.D. (2004) in Earth Systems Science from the University of New Hampshire and an M.S. (2000) in Soil Science from the University of Maine. He has been at the USGS since 2004 as an NRC Post-Doc and as a Research Scientist since 2007. Most of his current work is on the use of in situ optical sensors for carbon and nutrients in small watersheds and large coastal rivers across the country.*

GROUND-PENETRATING RADAR: A HIGH-RESOLUTION GEOPHYSICAL TOOL TO EXPLORE NEAR-SURFACE ENVIRONMENTS

Jens Tronicke[1]

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Keywords: Near-surface geophysics, ground-penetrating radar, site characterization

In the past decades, ground-penetrating radar (GPR) has evolved into one of the key geophysical techniques for exploring shallow subsurface environments. The success of the GPR method is largely related to its ability to provide subsurface images with a spatial resolution at the decimeter scale; i.e., under favorable site conditions, GPR provides the highest spatial resolution of any near-surface geophysical technique. The technique has proven to provide valuable information in many different fields of application and is increasingly used in archaeological, environmental, engineering, geological, and hydrological site characterization.

Here, after briefly reviewing the methodological basics of modern GPR data acquisition, processing, and interpretation, we present selected case studies illustrating the potential but also the limitations of surface- and borehole-based GPR surveying. These examples cover a variety of typical applications and demonstrate how GPR data can help to better understand subsurface architecture, properties, and processes. In addition to classical applications such as imaging subsurface geologic structures in soil and sedimentary environments, we will also address more challenging problems tackled in current geophysical research. Such problems include the translation of GPR images into selected petrophysical properties, which still is one of the most challenging methodological tasks, and the imaging of complex hydrological processes, which requires special acquisition and processing strategies to successfully isolate the information of interest. Because GPR is a steadily developing method, we conclude that further methodological progress can be expected broadening the applicability of GPR in a variety engineering and research problems.

Biography: *Jens Tronicke received a Diploma (1997) in geophysics from the University of Münster, Germany, and a Ph.D. (2001) from the University of Tübingen, Germany. In 2001–2005, he worked as a postdoctoral researcher in the applied and environmental geophysics group at the Swiss Federal Institute of Technology (ETH), Zurich. In 2002, he received a visiting scientist fellowship by the German science foundation at the Center of Geophysical Investigations of the Shallow Subsurface (CGISS) at Boise State University. Since 2005, he has been a professor for applied geophysics at the Institute of Earth and Environmental Science, University of Potsdam, Germany. His research interests include GPR, electrical, and seismic techniques as well as the application of integrated geophysical techniques for archaeological, environmental, and hydrogeological site characterization.*

DIRECT PUSH FOR SUBSURFACE INVESTIGATIONS—A PURPOSE-ORIENTED DISCUSSION OF METHODS

Peter Dietrich[1]

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Eberhard-Karls-University of Tübingen, Tübingen, Germany

Whether the issue is the risk posed by a site of suspected groundwater contamination or the load-bearing characteristics of an area under consideration for critical urban infrastructure, information about subsurface conditions is essential. One of the daunting challenges for investigation and monitoring technologies for near-surface geoscience applications is the characterization of subsurface conditions and the identification and parameterization of relevant physical-chemical-biological processes. Experience has repeatedly shown the great importance of high-resolution methods for such activities.

A promising option for the high-resolution investigation of shallow (depths of up to 50 m) unconsolidated formations is the use of Direct Push (DP) technology. This technology refers to a growing family of tools advanced by pushing and/or hammering small-diameter hollow steel rods into the ground. A sensor or probe at the lower end of the rod string enables information about subsurface conditions to be obtained at a high vertical resolution (often at the scale of a few cms). Generally, the applicability of DP technologies strongly depends on the characteristics of the subsurface material and the purpose of the investigation.

This mini-course will be a primer on DP methods aimed at helping attendees understand the advantages and limitation of these methods. Different methods will be discussed and case studies will be presented to illustrate how to select and use the most effective DP approach for a particular application (e.g., risk assessment, management of contaminated sites, planning and monitoring of remediation activities).

Biography: *Peter Dietrich is the Head of the Department of Monitoring and Exploration Technologies at the Helmholtz Centre for Environmental Research—UFZ in Leipzig, Germany. His research interests are centered on the development and evaluation of integrated investigation and interpretation approaches, and the further development of geophysical methods for subsurface monitoring. He received a diploma degree in Geophysics from the Mining Academy (Technical University) of Freiberg (1992) and a Ph.D. in Applied Geology (1999) from the Faculty of Geosciences at the Eberhard-Karls-University of Tübingen. In 1999, he established the Hydrogeophysics group at the Center of Applied Geoscience in Tübingen. He led that group until 2005, when he moved to the UFZ, where under his leadership the Department of Monitoring and Exploration Technologies was established (www.ufz.de/met). The task of the department is to develop and validate applied methods, technologies, and strategies for the monitoring and investigation of the natural environment, with a focus on soil, water, and air, as well as their interactions. Since 2012, Dr. Dietrich also has served as a Professor of Environmental and Engineering Geophysics at the University of Tübingen.*

MULTIPLE-POINT GEOSTATISTICS: HOW TO TAKE ADVANTAGE OF HIGH-RESOLUTION SPATIAL DATA

J. Jaime Gómez-Hernández

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Predicting solute transport in heterogeneous formations has proven to be challenging. Geostatistics offers one means of representing formation heterogeneity in groundwater flow and transport models. Contrary to standard geostatistics, multiple-point geostatistics uses high-order statistics to capture spatial patterns that cannot be characterized by a variogram or covariance model. The problem faced by multiple-point geostatistics is the difficulty of inferring those high-order statistics for a particular site. The solution is to use what has been referred to as training images (TI), an exhaustive representation of heterogeneity patterns that are representative of the site; this TI could be derived in many ways, but one such possibility is to use the high-resolution data from the tools that have been discussed at this conference. From the information collected by these tools, we can build a training image that can serve as the pattern setter for the heterogeneity that will be translated into the representation of the site. These patterns could be related to cross-bedding, braided channels, specific facies sequencing, high-continuity of extreme values, etc., which are features that standard geostatistics cannot capture.

This mini-course will be a primer in multiple-point geostatistics aimed at helping attendees understand how high-resolution spatial data can be used to better characterize sites in heterogeneous formations. Software for multiple-point geostatistics will be discussed and field examples will be presented to illustrate how to use these methods.

Biography: *J. Jaime Gómez-Hernández is full professor of Hydrogeology at the Universitat Politècnica de València (UPV) in Spain. He received a Civil Engineering degree from UPV (1983), and a M.Sc. in Applied Hydrogeology (1987) and a Ph.D. in Geostatistics (1990), both from Stanford University. He joined UPV in 1994, where he has devoted his research career to the fields of applied geostatistics, inverse modeling, stochastic groundwater modeling, and nuclear waste disposal. In addition to his research and teaching activities, Dr. Gómez-Hernández served one term as Vice-Chancellor for Graduate Studies and Faculty Affairs at UPV and also one term as the Vice-Secretary for Science and Technology for the Regional Government of Valencia. Dr. Gómez-Hernández is spending his sabbatical this spring and early summer as a visiting scientist in the Geohydrology Section at the Kansas Geological Survey.*

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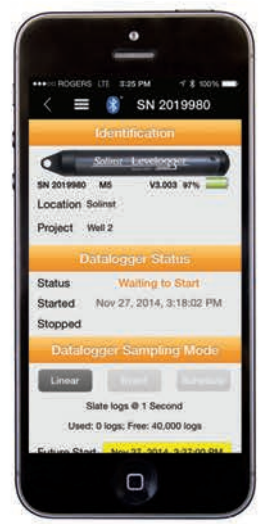

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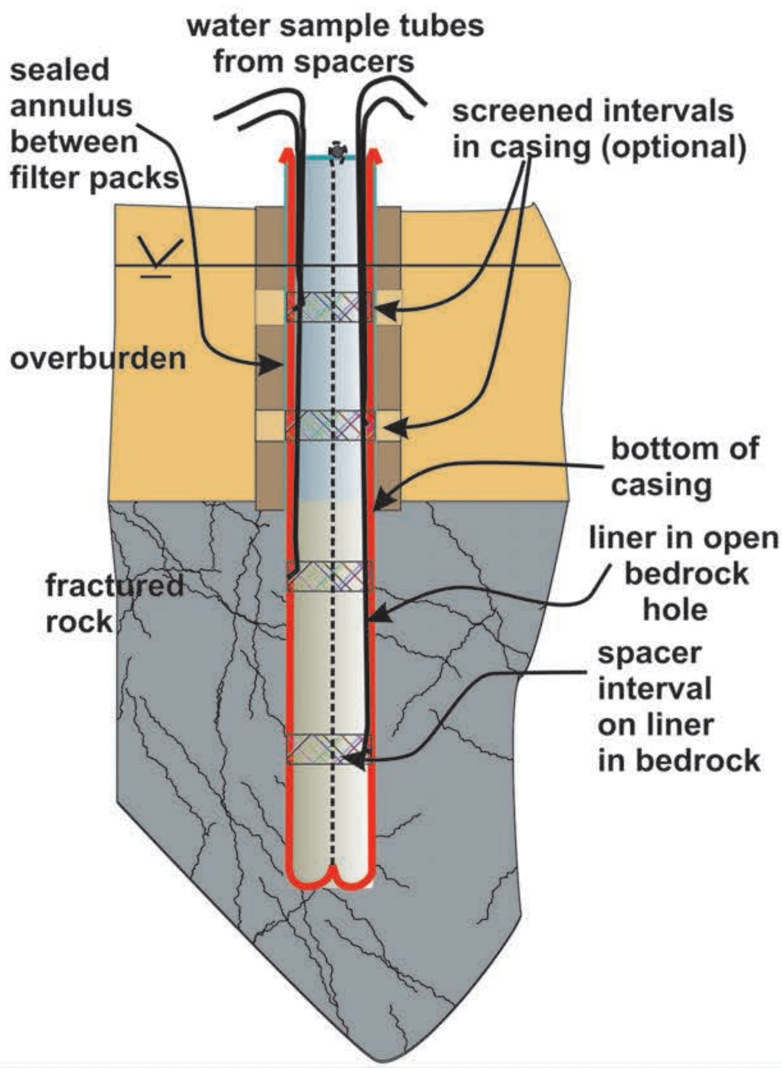

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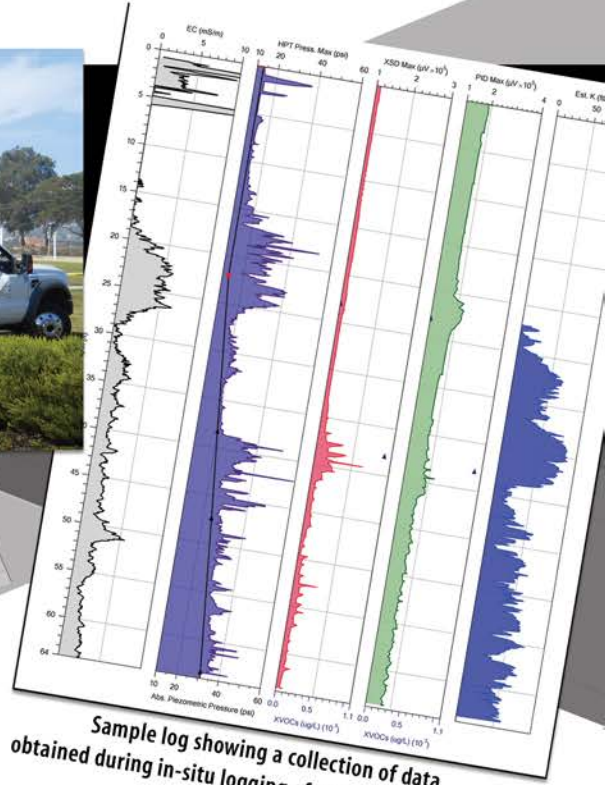

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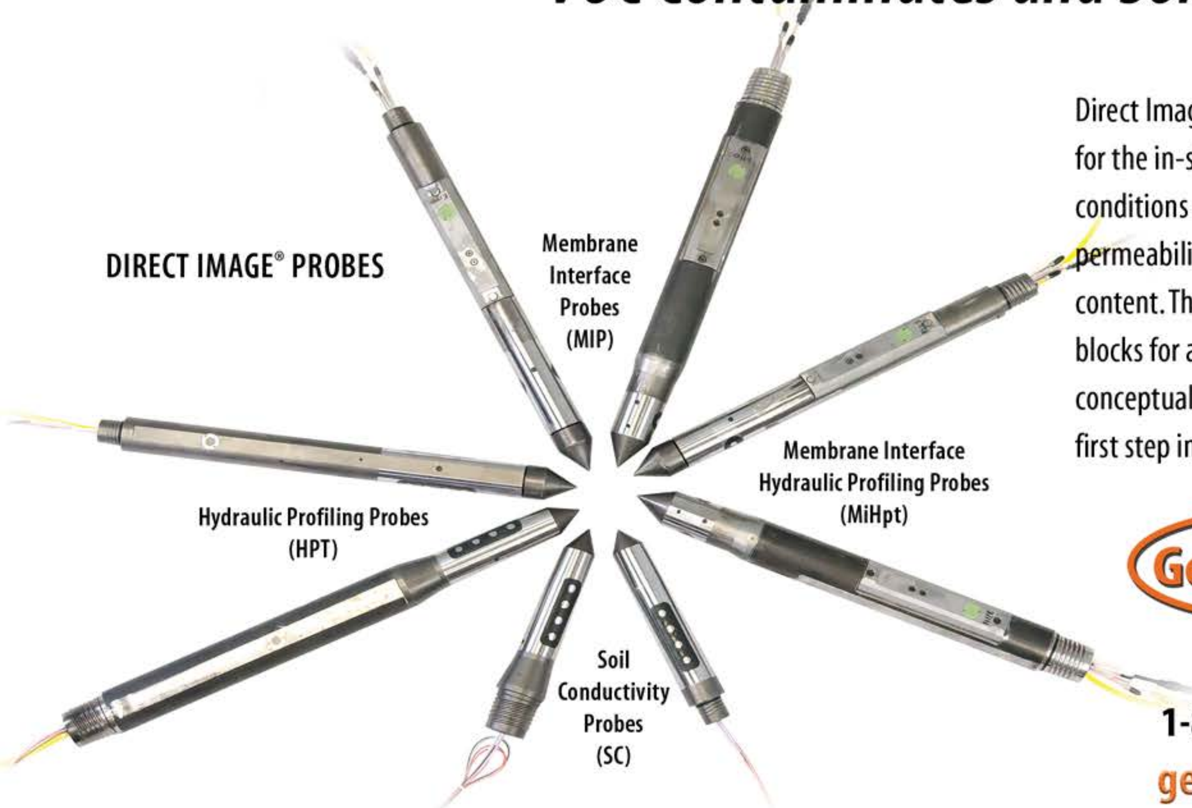

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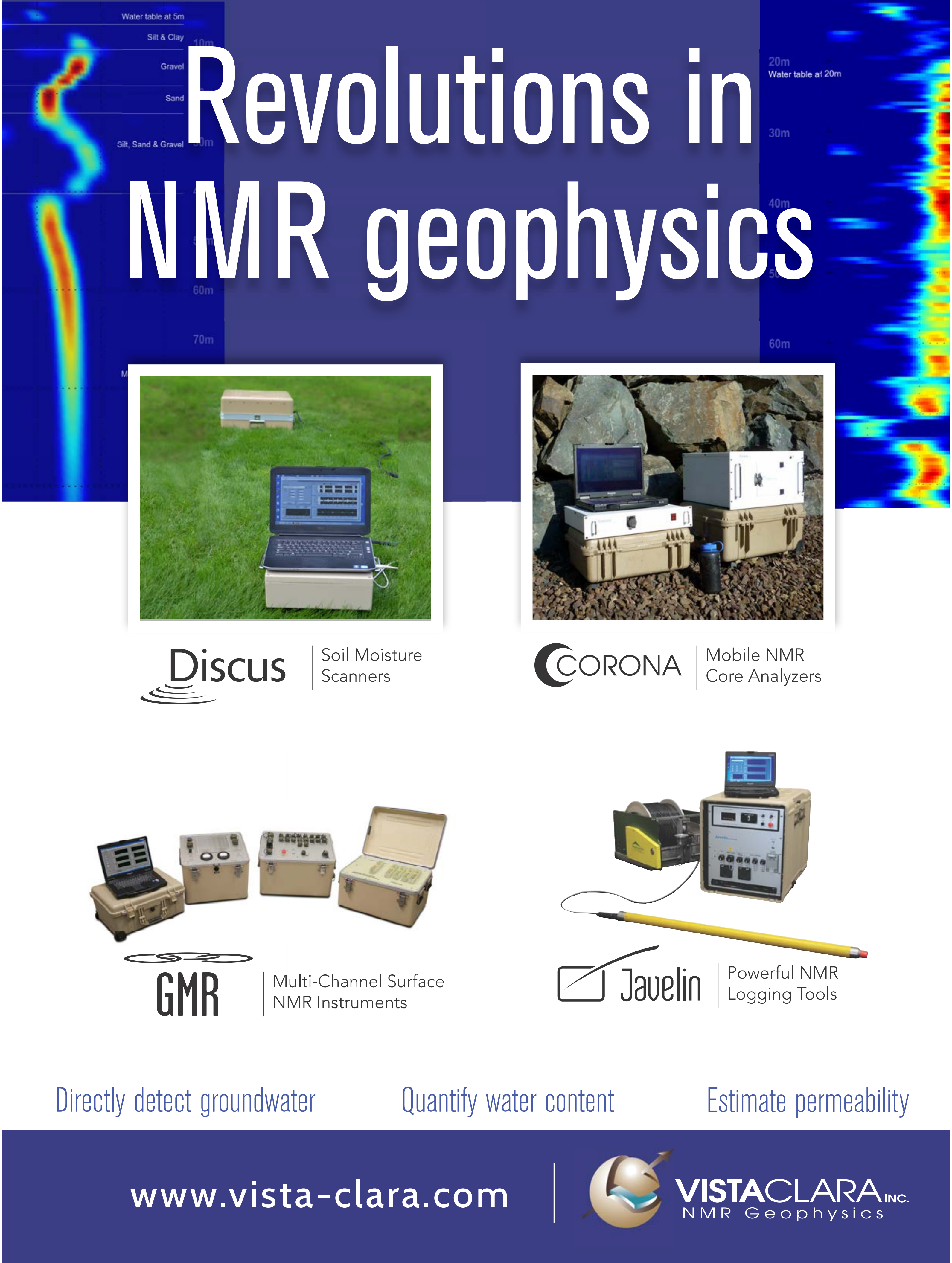

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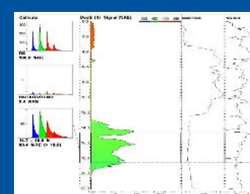

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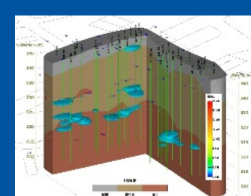

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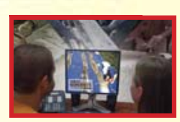

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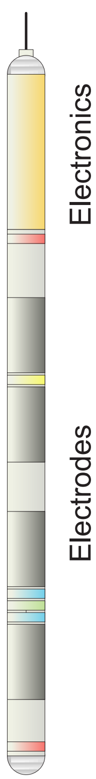

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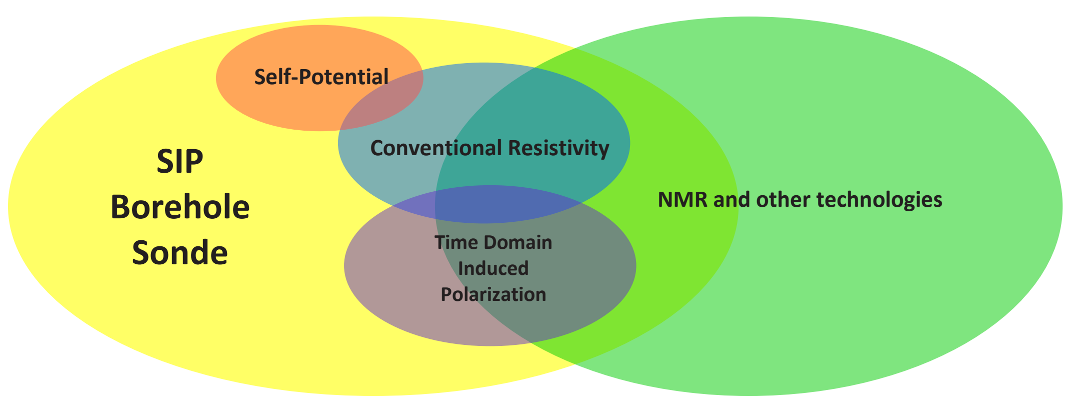

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TUESDAY, MAY 19, 2015

DIRECT PUSH

9 a.m.–11:05 a.m. Griffith Ballroom

HIGH RESOLUTION VERTICAL PROFILING: REAL-TIME DATA COLLECTION FOR COMPREHENSIVE ENVIRONMENTAL SITE ASSESSMENTS

David J. Heicher [1]

[1] *HRSC Regional Manager, Matrix Environmental, LLC, 11253 91st Ave. N, Maple Grove, Minnesota 55369; dheicher@matrixenv.com*

Keywords: MIP, HPT, UVOST, LIF, HRVP

Chlorinated solvents and fuel-related volatile organic compounds (VOCs) have contaminated subsurface soils and groundwater at thousands of sites all over the world. Traditional methods for location and delineating subsurface VOC contamination during a site characterization are time consuming and costly. Current site assessment techniques include drilling, sampling, and laboratory analysis. Lithologic and hydrogeologic data at a site are usually limited, hindering the optimal placement of initial soil bores and groundwater monitoring wells. To expedite site investigation activities, increase the quality and quantity of data collected, and develop a more comprehensive conceptual site model, innovative High Resolution Vertical Profiling (HRVP) technologies (also known as Direct Sensing) have been used at contaminated sites over the past 15 years. These systems are designed to collect data in real time and high definition continuously throughout the subsurface vertical profile. Semi-quantitative data are collected, recorded, and subsequently incorporated into modelling software to generate real-time, 2-D–3-D graphics that reveal plume geometry as an investigation is taking place.

Three HRVP systems currently are used to provide chemical, hydraulic, and lithologic data of the subsurface. The Membrane Interface Probe (MIP) is designed to screen for dissolved-phase petroleum hydrocarbons, halogenated compounds, and methane. Laser Induced Fluorescence (LIF) is used on contaminated sites to identify zones of Light Non-Aqueous Phase Liquids (LNAPL) petroleum, while the Hydraulic Profiling Tool (HPT) is used to determine hydraulic and lithologic properties of the subsurface. All three technologies collect and record data at high resolution to generate large data sets that provide the most comprehensive horizontal and vertical delineation of contamination in the subsurface.

HRVP has proven to be a cost-effective, efficient strategy for comprehensive site characterization at contaminated sites. Using real-time, high-density data collection enables real-time decision making to create a dynamic work plan that identifies and delineates subsurface VOC contamination, usually in one site visit. Compared to conventional sampling methods, which involve relatively limited soil and groundwater sample collection, HRVP technologies collect exponentially more data points to reduce uncertainty in assessment efforts, determine specific zones of contamination, and aid in focused remediation efforts. In addition, data are collected and recorded over depth throughout the vertical profile of the subsurface and then incorporated into modelling software to generate real-time, interactive graphics in much higher resolution than traditional assessment procedures and protocol.

KEY DEVELOPMENTS IN DI TOOL AND MIP DETECTORS AND ADVANCED MIP LOG INTERPRETATION

Thomas M. Christy[1], P.E., and Daniel A. Pipp[2]

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2 Geoprobe Systems, 1835 Wall St., Salina, Kansas 67401 USA, pippd@geoprobe.com

Keywords: VOC investigation, MIP, MIP developments, advanced log interpretation, groundwater contamination

The Membrane Interface Probe (MIP) has become a key tool for the detection and mapping of subsurface volatile organic compound (VOC) contamination. MIP technology has seen significant advancement in the last eight years, including key developments that have resulted in improved system robustness. We will explore how MIP technology has changed and how those changes have improved reliability of the tool as well as improved the log profile by enhancing contaminant definition.

One of the most important developments is the addition of the Halogen Specific Detector (XSD) to the MIP detector series. We will look at how the XSD operates and compare its response and dynamic range to the Electron Capture Detector (ECD). We will discuss the use of all detectors in log interpretation and explore questions of MIP log carryover, MIP detection limits, and MIP response in non-aqueous phase liquid (NAPL) zones.

DETECTION AND MEASUREMENT OF BULK NAPL IN SEDIMENTS USING SMALL-DIAMETER NMR LOGGING TOOLS

David O. Walsh[1] and Elliot D. Grunewald[1]

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Keywords: nuclear magnetic resonance, NMR, geophysics, non-aqueous phase liquids, groundwater remediation, geophysics

Nuclear magnetic resonance (NMR) logging tools are commonly used in the oil and gas exploration industry to estimate reservoir hydraulic properties and to determine hydrocarbon saturations by discriminating oil and water based on their fluid diffusion constants. More recently, small-diameter NMR logging tools have been developed and applied to measure hydraulic properties of near-surface aquifers and water content in the unsaturated zone. There is now interest in using groundwater NMR logging tools and similar diffusion measurement approaches to detect hydrocarbons present as contamination in the form of light non-aqueous phase liquids (LNAPLs). Initial tests were performed using a man-portable NMR logging device to establish the feasibility of using these tools with NMR diffusion measurement pulse sequences to differentiate and measure the volume fractions of water and a diesel fuel. NMR measurements were performed with varying mixtures of water and diesel fuel contained in a vessel, with and without natural sand media. NMR measurements were performed using a static gradient diffusion encoding pulse sequence, and water and NAPL signals were differentially estimated using a two-dimensional T2-diffusion inversion. The results indicate that the volumetric fluid content of diesel represents a significant fraction of the total fluid content (i.e., 40 %) and that the water and diesel fluid contents can be readily distinguished and reliably measured via the significant differences in their diffusion constants. This result was true when the two fluids were mixed as bulk fluids and when the mixed fluids were saturating a medium- to coarse-grained natural sand. Expanded bench-scale testing will be conducted to refine the lower threshold for detection of diesel in both coarse- and fine-grained sediments and to assess the ability of NMR logging measurements to detect the NAPL types.

THE HYDRAULIC PROFILING TOOL–GROUND WATER SAMPLER, UPDATES & APPLICATION

Thomas M. Christy[1], P.E.; Wesley McCall[1], P.G.; Blake Slater[1], Eng.; Malene Front[2], Env. Eng.; Anders Christensen[2], P.E.; Charlotte Riss[2], P.E.; Nancy Hamburger[3], Eng.; and Peder Johansen[3], Eng.

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[3]*Capital Region of Denmark, Department of Regional Development, Kongens Vaenge 2, DK-3400 Hilleroed, Denmark, nancy.hamburger@regionh.dk, peder.johansen@regionh.dk*

Keywords: groundwater profiling, HPT logging, EC logging

The HPT-GWS (Hydraulic Profiling Tool–Ground Water Sampler) probe and system provide both an HPT pressure log and electrical conductivity (EC) log as the 2.25-in (57mm) diameter probe is advanced into the subsurface. Viewing the HPT pressure log and EC log on-screen as the probe is advanced enables the operator to identify zones in the formation that are sufficiently permeable to permit groundwater sampling. Probe advancement is halted at selected intervals so that groundwater may be sampled. Sampling groundwater at multiple depths during one log (profiling) may be conducted as the probe is advanced. Water-quality measurements and samples for multiple analytes of interest may be obtained at each depth.

Feedback from clients and a coordinated field test in Denmark with NIRAS and the Department of Regional Development–Capital Region of Denmark indicated that the HPT-GWS probe was not providing the desired flow rate for sampling groundwater under some site conditions. The mechanical bladder pump (MB470) often used for sampling with the HPT-GWS, especially when water levels are below 8 m, provided some challenges in the field that reduced operational efficiency of the system.

Subsequently, Geoprobe has modified the HPT-GWS probe design to improve yield for groundwater sampling in moderate- to high-permeability unconsolidated formations. Small modifications to the mechanical bladder pump and changes to operational protocol in the field have led to notable improvements in sampling performance at depth. The multiport design of the HPT-GWS probe may enable field operators to perform discrete interval tests for determination of hydraulic conductivity (K) at groundwater sampling intervals and other depths of interest.

Recent probe modifications and changes in field operation of the system will be reviewed along with selected water-quality data and analytical results from profiling operations.

CHASING THE TRACER—COMBINING CONVENTIONAL SALT TRACER TESTING WITH DIRECT PUSH ELECTRICAL CONDUCTIVITY LOGGING FOR THE CHARACTERIZATION OF A HIGHLY PERMEABLE FLUVIATILE AQUIFER

Thomas Vienken[1], Peter Huggenberger[2], Emanuel Huber[2], Manuel Kreck[1], and Peter Dietrich[1,3]

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[2]*University of Basel, Basel, Switzerland*

[3]*Eberhard Karls University of Tübingen, Tübingen, Germany*

Keywords: direct push, tracer testing, electrical conductivity

Tracer testing is a well-established and commonly applied technique for the hydraulic characterization of the subsurface. However, in areas with limited or no prior knowledge about the hydraulic regime, layout of the tracer test field, i.e. positioning of monitoring wells, can be challenging. This is especially true for highly dynamic fluviatile systems, where hydrological conditions may change rapidly. Typical examples for this are the highly conductive gravelly and sandy deposits of the Tagliamento River, Italy.

Here tests were performed near the city of San Daniele del Friuli to characterize hydraulic properties of the channel-adjacent deposits. No information was available on groundwater gradient and flow-field prior to well installations and stream gage level changes can be observed within short time periods. For enhanced subsurface characterization, conventional salt tracer testing was combined with direct push electrical conductivity logging. Therefore, a salt tracer was injected in a 2-in direct push-installed well. After tracer injection, direct push high-resolution vertical electrical conductivity profiling was performed in concentric hemicycles around the injection well to identify the main direction of tracer propagation, tracer velocity, and tracer plume geometry. Based on the results, positions of monitoring wells were rapidly adapted. Results show that the combined use of conventional salt tracer testing with direct push electrical conductivity logging is an efficient strategy for the characterization of highly conductive sedimentary deposits with groundwater velocities of several meters/hour.

LONG-TERM MONITORING AND OPPORTUNISTIC CHARACTERIZATION

9 a.m.–11:05 a.m. Gathering Room 1

MOBILE WIRELESS SENSOR NETWORKS FOR EVENT-DRIVEN ENVIRONMENTAL MONITORING

Hannes Mollenhauer[1], Martin Assing[2], Robert Schima[1], Paul Remmler[1], Olaf Mollenhauer[2], Tino Hutschenreuther[3], Hannes Toepfer[4], Peter Dietrich[1,5], and Jan Bumberger[1]

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[5]*5Eberhard Karls University, Centre of Applied Geosciences, Tübingen, Germany*

Keywords: wireless sensor networks, environmental monitoring

For an adequate characterization of ecosystems, it is necessary to detect individual processes with suitable monitoring strategies and methods. Due to the natural complexity of all environmental compartments, single point or temporally and spatially fixed measurements are mostly insufficient for an adequate representation. The application of mobile wireless sensor networks for soil, plant, and atmosphere sensing offers significant benefits, due to the simple adjustment of the sensor distribution, the sensor types, and the sample rate (e.g., by using optimization approaches or event triggering modes) to the local test conditions. Particularly high mobility and ease of installation of such network nodes can be essential for the monitoring of heterogeneous environmental systems and the worldwide increasing short-term, dynamic events in ecosystems. One significant advantage in the application of mobile ad-hoc wireless sensor networks is their self-organizing behavior. Thus, the network autonomously initializes and optimizes itself. Due to the localization via satellite, a major reduction in installation and operation costs and time is generated. In addition, single-point measurements with a sensor are significantly improved by measuring at several optimized points continuously. Performing analog and digital signal processing and computation in the sensor nodes close to the sensors can result in a significant reduction of the data to be transmitted, which leads to better energy management of nodes. Furthermore, the miniaturization of the nodes and energy harvesting are current topics under investigation. First results of field measurements are given to present the potentials and limitations of this application in environmental science. In particular, collected in situ data with numerous specific soil and atmosphere parameters per sensor node (more than 25) recorded over several days illustrates the high performance of this system for advanced soil sensing and soil-atmosphere interaction monitoring. Moreover, investigations of biotic and abiotic process interactions and optimization of sensor positioning for measuring soil moisture are scopes of this work. Initial results of these issues will be presented.

AQUIFER CHARACTERIZATION BY CONTINUOUS MONITORING OF GROUNDWATER LEVELS: EXAMPLES FROM THE HIGH PLAINS AQUIFER IN KANSAS

J. J. Butler, Jr.[1], and E. C. Reboulet[1]

[1] *Kansas Geological Survey, University of Kansas, Lawrence, Kansas, 66047*

Keywords: aquifer characterization, hydrograph interpretation

Recently, a concerted effort has been initiated in the United States to develop networks of observation wells to monitor water-level changes in the major aquifers of each state. Many of these wells are or will be equipped with sensors that provide a continuous record of water levels through time. The maintenance of these networks is far from trivial, so considerable resources must be dedicated just to the task of keeping network wells operational. The result is that little attention may be given to the interpretation of the acquired data. This is unfortunate as such records can provide valuable information about the impact of groundwater development at a scale of relevance for management activities. At the Kansas Geological Survey, we are actively engaged in assessing the information about an aquifer system that can be embedded in hydrographs from continuously monitored wells. Previously, we have shown that interpretation of these hydrographs using methods developed for pumping-test analyses can provide insights that are difficult to obtain via other means. In this presentation, we will focus on the insights that can be gleaned from nothing more than a careful hydrograph inspection. The hydraulic conditions in an aquifer (confined versus unconfined) can often be readily identified by the hydrograph form produced by nearby pumping activity. In cases in which there is little nearby pumping, the water-level response to barometric pressure changes can help identify hydraulic conditions. Insights about aquifer continuity can also be obtained from hydrograph inspection when a clear pumping response is observable. Records from transducer-equipped wells at sites in the High Plains aquifer in central and western Kansas will be used to illustrate these points. The results of this study demonstrate that insights of considerable practical value can often be obtained through careful inspection of hydrographs from continuously monitored wells.

COST EFFECTIVE PASSIVE DATA COLLECTION TO TEST A CONCEPTUAL SITE MODEL

Brett Engard[1], PG, and Dr. David Winslow[1], Ph.D., PG

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Keywords: passive, conceptual, model, fate, transport

Historical resources and publications were used to develop a Conceptual Site Model (CSM) to describe the hydrogeologic framework at an industrial site in the New Jersey highlands. Passive data were collected from an off-site weather station, an adjacent stream, on- and off-site production wells, and on-site groundwater monitoring wells to make inferences about the hydrogeologic framework and to test the CSM.

The site is located along a stream in a narrow glacial sediment-filled bedrock valley with Precambrian bedrock comprising the valley floor, walls, and peaks. The valley walls act as groundwater divides to adjacent watersheds and the local-regional groundwater flow system. The stream valley contains four hydrogeologic units; in ascending order, these units are: 1) Precambrian fractured and weathered bedrock, 2) a lower aquifer of glacial outwash/till derived sands and gravels, 3) confining glaciolacustrine silts, clays, and fine sands, and 4) an upper aquifer of glacially

derived outwash sands and gravels partially reworked as Quaternary alluvium. Surface and groundwater in this area of New Jersey is plentiful and is used for industrial and municipal purposes.

The facility use of surface water for industrial purposes is augmented by a bedrock industrial well and a lower aquifer domestic well. The protection of lower aquifer water quality from poor water quality in the upper aquifer is of particular interest in the water supply region. Therefore regulators requested a determination of the impact of pumping of on-site supply wells on fate and transport and on groundwater movement in shallow groundwater. A simple cost-effective field study was developed on behalf of the client to address the request without installing new infrastructure and creating minimal investigation-derived waste. We used pressure transducers and geophones to monitor water-elevation fluctuations and pumping events at the site.

Our evaluation indicated that the upper aquifer is directly influenced by short-term fluctuations in stream conditions. Head relationships indicate that there is an upward regional potentiometric gradient between the lower and upper aquifers. On-site and off-site groundwater withdrawals from the fractured bedrock and the lower aquifer produced no perceivable change in any upper aquifer monitoring well. In short, the confining layer effectively isolates the upper aquifer from the lower aquifer. Thus, based on our cost-effective evaluation, pumping in the lower aquifer does not appear to influence groundwater movement in the upper aquifer and will not cause low-quality water to impact the quality of lower aquifer.

SPATIAL AND TEMPORAL CONTINUOUS REAL-TIME WATER INFORMATION NETWORKS AND SURROGATES

Andrew C. Ziegler[1]

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Keywords: continuous, in situ real-time monitoring, satellite, surrogate

In the past, science, environmental, and water-supply information needs were met by combining discrete water data from measurements or samples with techniques of interpolation between these data points to arrive at generalizations of water quantity and quality. Systematic continuous data collection and recording devices for surface water quantity began 125 years ago at the U.S. Geological Survey (USGS) continuous streamflow gage in the Rio Grande River at Embudo, New Mexico. About 40 years ago, USGS began to systematically collect and transmit in near real time in situ water levels, stage, continuous temperature, specific conductance and other easily measured water properties to describe water quantity and quality in surface water and groundwater. Spatial density of information was limited to mapping of these properties at these discrete and continuous data collection points. Today, continuous spatial coverage from LANDSAT8 (http://landsat.usgs.gov/landsat8.php) and other satellites and temporally dense information are available from these measurement points to interpolate between measurement points and assess current water and environmental information to answer science and society's questions. USGS websites and National Water Quality Monitoring Council and National Groundwater Monitoring Network portals (waterwatch.usgs.gov, water.usgs.gov/waterwatch.usgs.gov/wqwatch, groundwaterwatch.usgs.gov, http://www.waterqualitydata.us/, http://cida.usgs.gov/ngwmn/) provide measured in situ information furnished by USGS, EPA, NRCS, and many state and local agencies for water quantity and quality to form necessary collaborative monitoring networks. Surrogates or proxy measurements are available using in situ measurements combined with discrete sample data and statistical modeling tools to estimate concentrations of constituents with a defined uncertainty. These surrogate estimates improve characterization of the heterogeneity of our environment, challenge and improve our understanding of water movement, improve real-time water management and treatment processes, and better define interactions of water in the environment. To enhance national assessments, the following are needed:

1. increased number of data collection "calibration" points,
2. enhanced use of surrogate or proxy measurements for spatial and in situ information,

3. consistent statistical and modeling techniques to develop surrogate measures that enable interpolation in time and space,
4. more sensors both in situ and on satellites, and
5. the ability to share common data collection and quality-assurance practices to enhance collaborative spatial networks.

These networks of in situ measurements and surrogates coupled with spatial satellite data and interpolation tools will continue to provide information in real time for flooding, inundation mapping, adaptive treatment strategies for water supply (for example, response to harmful algal blooms), aquifer storage, altered withdrawals or releases from reservoirs, or treatment of wastewaters for potable supplies. This presentation provides a brief USGS historical perspective on collection of in situ water information, examples of in situ surface and groundwater measurements and surrogates, surrogate or proxy calibration techniques, collaborative networks, and sensor needs.

HYDROSTRATIGRAPHIC DRILLING RECORD ASSESSMENT (HYDRA): DEVELOPING QUANTITATIVE AQUIFER MODELS USING DRILLERS' LOGS

Geoffrey C. Bohling[1]

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Keywords: drillers' logs, aquifer characterization

The Hydrostratigraphic Drilling Record Assessment (HyDRA) project is a three-year study to develop improved methods for building groundwater flow models from drillers' logs. Groundwater models require extensive subsurface geologic information, a rich source of which can be found in drillers' lithologic logs. The challenge is converting this highly qualitative information into quantitative data. The purpose of this project is to develop and test procedures for employing this information in the development of quantitative three-dimensional depictions of subsurface properties for estimation of aquifer yield and use in flow models. Drillers' logs from wells in the vicinity of a continuously monitored "index" well in the High Plains aquifer in Thomas County, Kansas, are used in this project. Log information from 250 wells in the vicinity of the index well, including descriptions of sediments and lithologies, have been standardized and categorized into five hydraulic property categories. The volumetric proportions of the hydraulic property categories were computed over regular 10-foot intervals for each well. These volumetric proportions were then interpolated from the wells to the model grid, so that each grid cell is populated by a vector of category proportion values. The model can then be calibrated by adjusting the category-specific hydraulic property values, using a proportion-weighted power average to compute average property values in each cell. Calibration data for the Thomas County model include hourly water-level observations from two continuously monitored wells from January 2010 to February 2011 and water levels measured in January 2010 and January 2011 in 15 wells distributed throughout the area. Work on model development and calibration is continuing.

CHARACTERIZATION AT THE INTERFACE

1:35 p.m.–2:35 p.m. Griffith Ballroom

A FIELD COMPARISON OF MULTIPLE TECHNIQUES TO QUANTIFY SURFACE WATER–GROUNDWATER INTERACTIONS

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Keywords: surface water–groundwater interactions, hyporheic exchange, tracers, distributed temperature sensing, electrical resistivity

Surface water-groundwater interactions in streams are difficult to quantify due to the heterogeneity in hydraulic and reactive processes that operate across a range of spatial and temporal scales. The challenge of quantifying these interactions has led to the development of several techniques, from centimeter-scale probes to whole-system tracers, including chemical, thermal, and electrical methods. We co-applied several of these techniques within a single experimental reach in a third-order stream. The techniques that we used included conservative and "smart" reactive solute tracer tests, measurement of hydraulic heads, distributed temperature sensing, vertical profiles of solute tracer and temperature in the streambed, and electrical resistivity imaging. Results from the field experiment consistently indicated that surface water-groundwater interactions were not spatially expansive but were high in flux through a shallow hyporheic zone surrounding the 450-m study reach. The NaCl and resazurin tracers suggested different surface-subsurface exchange patterns between the upper two-thirds and lower third of the reach. Subsurface sampling of tracers and vertical thermal profiles quantified relatively high fluxes through a 10–20 cm deep hyporheic zone with chemical reactivity of the resazurin tracer indicated at 3, 6, and 9 cm sampling depths. Monitoring of hydraulic gradients along transects starting ~ 40 m away from the stream indicated that groundwater discharge prevented the development of a larger hyporheic zone, which was shown (from MINIPOINT samples) to progressively decrease from the stream thalweg toward the banks. Finally, FO-DTS did not detect extensive inflow of groundwater into the stream and electrical resistivity imaging showed limited large-scale hyporheic exchange. From the experience gained in our experiment, we recommend the following reasoning to decide which technique(s) should be implemented in a particular study: 1) clearly define the nature of the questions to be addressed, i.e., physical, biological or chemical processes, 2) identify the spatial and temporal scales to be covered explicitly and those required to provide an appropriate context for interpretation, and 3) engage in collaborative research efforts that maximize the generation of mechanistic understanding and reduce the costs of implementing multiple techniques.

THE USE OF POINT VELOCITY PROBES (PVPS) FOR QUANTIFICATION OF THE GROUNDWATER-BORNE CONTAMINANT MASS DISCHARGE TO A STREAM

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Keywords: Point-Velocity Probe, contaminant mass discharge, stream-aquifer interactions.

The application of Point-Velocity Probes (PVP) for both groundwater velocity and groundwater-borne contaminant mass discharge quantification was investigated. The PVP is a novel method to directly measure groundwater velocity at the centimeter scale based on a small-scale tracer test (Labaky et al., 2007), and it has not previously been used to quantify aquifer-stream interactions or contaminant mass discharges.

In this study, 122 injection experiments were conducted in 14 PVPs installed at 2–4 m depth at the bank of Grindsted stream. The 10 m wide and 1.7 m deep stream, located in the Region of Southern Denmark, is highly impacted by xenobiotic organic contaminants from two large contaminated sites: Grindsted landfill and Grindsted factory site, located 2 and 1.5 km south and north of the stream, respectively. Results from the injection experiments suggest that groundwater flows to the stream with average seepage velocities between 0.07 and 3.0 m/d. The seepage velocities obtained from PVPs were found to compare reasonably well with those obtained from temperature profiling and Darcy's law. PVP-based velocities were 1.1 times larger than the former and 6 times smaller than the latter. Differences may be related to scale differences of the methods, temporal variations as well as uncertainties in the hydraulic conductivity. This latter concern does not apply to PVP measurements, which are based on tracer transport times, making PVPs a useful addition to these kinds of investigations. To quantify the groundwater-borne contaminant mass discharge, seepage velocities estimated from PVP-derived velocities were combined with groundwater concentration of chlorinated ethenes and BTEX in groundwater. High cis-DCE and VC concentrations were measured in the groundwater over a short reach of the stream, approximately 50 m in length, suggesting that a narrow, highly reduced plume embedded in a larger plume accounts for most of the contaminant mass discharge to the stream. Preliminary estimates of the contaminant mass discharges for VC, total chlorinated ethenes and benzene were smaller than the mass discharges calculated from observed stream concentrations, suggesting an underestimation of the mass discharge. In addition to large spatial variations in groundwater velocity and contaminant concentrations, two other reasons may account for the underestimation: 1) the core of the plume may be located deeper than the measuring points; 2) none of the PVPs are located within the high concentration zones, where the groundwater velocity may be higher than in the zones with lower concentration. Though it is clear that further investigation at greater depth is needed to improve the estimation of the contaminant mass discharge, this study illustrates the high potential of PVPs for groundwater velocity quantification near streams as well as for contaminant mass discharge quantification.

Reference:

Labaky, W., Devlin, J. F., and Gillham, R. W., 2007, Probe for measuring groundwater velocity at the centimeter scale: Environmental Science and Technology, v. 41, no. 24, p. 8,453–8,458.

CHARACTERIZING TEMPORAL VARIABILITY AT THE GROUNDWATER/SURFACE WATER INTERFACE

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Keywords: Groundwater/surface water interface, temporal variability, real-time analysis

The movement of water between groundwater and surface water bodies is complex and can play an important role in regulating the quality and quantity of water resources. In recognition of the need to understand both spatial and temporal variations in groundwater/surface water (gw/sw) interactions, researchers, including those at the USGS Office of Groundwater and the Kansas Geological Survey (KGS), have examined the feasibility and utility of widespread real-time groundwater monitoring at streambank wells coupled with real-time surface water monitoring at active streamgages. In this work, three real-time coupled gages were installed along the Arkansas River in Kansas to capture temporal and spatial variations in groundwater and surface water levels. Changes in gw/sw interactions were then quantified using a combination of stream-aquifer response functions, gradient analyses, and a multiple regression approach. The sites chosen share the same surficial geology and regional climate yet represent a variety of surface water conditions along the river from weakly ephemeral where surface water flows less than once per year (Larned, Kansas) to perennial (Nickerson, Kansas). Temporal variability in gw/sw interactions along the stream varied from site to site in response to changes in climatic and hydrologic conditions. The use of multiple approaches provides insight into the processes driving gw/sw interactions and why they differ among the three similar locations. This work illustrates the benefits of analyzing groundwater and surface water level data using more than one method to better understand the underlying mechanisms and better characterize the gw/sw interface.

NEW APPROACHES FOR AQUIFER CHARACTERIZATION

1:35 p.m.–2:35 p.m. Gathering Room 1

CAN THE ADVECTION-DIFFUSION EQUATION EXPLAIN COMPLEX TRACER TRANSPORT BEHAVIOR?

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Keywords: MADE site, flow and transport, highly heterogeneous media, fractal methods, advection-dispersion

Solute transport through porous media is generally explained by the advection-dispersion equation. Although the advection-dispersion equation is capable of representing the physical phenomena in low heterogeneity

systems, application to highly heterogeneous aquifers can be very challenging and requires the addition of various assumptions, such as preferential flow paths and dual domain mass transfer. This study combines novel site characterization data with fractal stochastic methods and shows that it is possible to accurately simulate flow and transport through highly heterogeneous media without adding more complex mathematical and physical processes. These simulations rely solely on field data and high-resolution hydraulic conductivity parameter fields used to create high-resolution advective velocity fields. The new approach is illustrated using data from the Macro Dispersion Experiment (MADE) site in Mississippi, a highly heterogeneous unconfined aquifer extensively studied due to the anomalous transport behavior observed in several natural gradient tracer tests.

THEORETICAL CONCEPTS FOR MEASURING LOCAL SCALE ANISOTROPIC HYDRAULIC CONDUCTIVITY

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Keywords: injection test, single-well technique, direct-push probe, horizontal and vertical conductivity

Hydraulic conductivity is a fundamental parameter for groundwater flow and transport modeling. Its spatial heterogeneity and anisotropy strongly affect the mixing and dispersion properties of an aquifer. Currently, the most direct method for measuring local (< 1 m) scale conductivity in situ is by hydraulic injection or slug tests over short well screen intervals (e.g., delimited by a pair of packers) or using direct-push probes. Multiple measurements at variable locations and depths may, thus, provide an efficient characterization of hydraulic conductivity and its heterogeneity. In contrast, methods for measuring local scale anisotropy in conductivity are very limited. Here we present a series of theoretical concepts that show the potential for characterizing local scale anisotropy (i.e., horizontal and vertical conductivities K_h and K_v separately) from injection tests performed in the saturated zone at single wells or using direct-push probes.

The concepts are based on the principle that a single piece of information (e.g., an injection head to injection flow rate ratio) is not enough for uniquely determining K_h and K_v. Instead, a second and independent piece of information is required, which may be obtained in one of two ways: 1) from a second injection test at the same location, but imposing a different flow field or 2) from a single injection test, where an additional flow or head measurement is taken. Potential flow theory for axisymmetric conditions is used for combining the two independent pieces of information to estimate the anisotropy ratio ρ and, subsequently, K_h and K_v. Under category (1) the methods considered are 1.1) subsequent injection from two screens of different geometries (i.e., aspect ratios length over radius), 1.2) subsequent injection from a lateral screen and through the bottom of a borehole, and 1.3) subsequent injection through two nearby screens and recirculation of flow between the screens. Under category (2) the methods considered are 2.1) single injection through a screen with separate flow measurements over the center and extreme parts of the screen, 2.2) single injection from a screen with one additional head measurement along the well/probe casing near the screen, and 2.3) single injection from a screen with two additional head measurement along the well/probe casing near the screen.

Charts and equations are presented for test design optimization and interpretation. From a theoretical standpoint, no single best method can be identified. Instead, the methods are compared regarding their sensitivity to anisotropy, expected benefits/drawbacks for practical implementation, and effects of undesired head losses due to injection screen resistance and/or soil disturbance near the screen. Results also provide the means for explaining discrepancies in conductivity estimates at a certain location, but from different methods, by potential effects of anisotropy.

REASSESSING THE MADE DIRECT-PUSH HYDRAULIC CONDUCTIVITY DATA USING AN IMPROVED CALIBRATION PROCEDURE

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Keywords: direct-push, inverse problems, hydrogeophysics

In earlier work, we presented and analyzed high-resolution hydraulic conductivity (K) profiles derived from direct-push profiling at the MADE site. The K profiles represent transformations of direct-push injection log (DPIL) profiles, acquired at a vertical sample interval of 1.5 cm, with co-located direct-push permeameter (DPP) tests at selected depths providing the calibration data. The calibration procedure used in our earlier work assumed a linear relationship between lnK and ln(Q/P), where Q/P represents the ratio of the DPIL injection rate and the injection-induced pressure response, with the coefficients of that linear relationship being adjusted to optimize the match between the observed DPP test pressure responses and those simulated using the calibrated K profile. However, although we expect the true ln(Q/P)—lnK relationship to be smooth and monotonic, it is not necessarily linear. In fact, we know that the assumption of linearity has at least one significant flaw. The DPIL injection rates are not high enough to induce measureable pressure responses in the highest K zones, leading to an upper limit on accurately measureable Q/P values. Thus, the true relationship should show ln(Q/P) values leveling out to a roughly constant value above a certain lnK threshold. We are reanalyzing these data using an improved calibration technique that incorporates a smoothing spline representation of the ln(Q/P) versus lnK relationship. This spline function is iteratively adjusted during the course of the inversion process, as the unknown lnK values are adjusted to produce a good match to the observed DPP test pressure responses, allowing for the development of a calibration relationship without requiring specification of its exact form prior to performing the inversion. The resulting ln(Q/P) versus lnK relationship reflects our physical expectations and the calibrated profiles appear to more accurately reflect the high-K zones. We will present a statistical summary of the revised DP K data, comparing it with the results based on the linear calibration procedure and those based on the earlier flowmeter data obtained at the site.

HYDROGEOLOGICAL INVESTIGATION TECHNIQUES

3:50 p.m.–4:30 p.m. Griffith Ballroom

HIGH SPATIAL RESOLUTION MEASUREMENTS USING FLEXIBLE LINERS

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Keywords: groundwater quality, hydrologic characterization, head profiles, transmissivity profiles, multi-level sampling, in situ measurements, hydro-geologic investigation, mapping NAPL contamination, fractured rock investigations, vadose fluid samples

Spatial resolution of water quality and formation hydraulic conductivity are important to contaminant plume assessment, contaminant transport, drinking water supply well design, and mining and hydrocarbon extraction. Flexible Liner Underground Technologies, FLUTe, has developed a variety of unique and well-tested methods for mapping contaminant distribution and flow path characterization in geologic formations. Blank liners are used to quickly and completely seal boreholes to prevent confusing cross connection and contaminant propagation. The blank liner installation procedure is also used to obtain a continuous map of the transmissivity distribution of the geologic formation intersected by the borehole. Liners are also used with a reactive cover to map in two dimensions

the spatial DNAPL distribution. An activated carbon felt strip can be incorporated with the NAPL reactive cover to obtain a replica of the contaminant dissolved phase distribution in the pore space of the formation. Multi-level sampling liners provide depth discrete water-quality samples and head distributions in sealed holes. A new technique uses the blank liner stepwise removal to map the formation head distribution after the continuous transmissivity distribution was measured during the blank liner installation. Transparent liners allow unique mapping of flow zones between boreholes. A new air coupled transducer technique can dramatically reduce the lifetime cost of continuous multi-level transducer measurements of formation head histories by locating the recording transducers at the surface for reuse, repair, or recalibration. These liner methods are used in vertical, angled, and horizontal holes. Advantages of these methods are that they are installed relatively quickly and therefore with reduced labor costs and with a minimum time for the borehole to be open for cross connection. These methods are used in karst formations and highly fractured rock formations with little concern about leakage past the continuous sealing liners. This paper briefly describes how these several measurements are performed and how the data are reduced to hydro-geologic properties. Examples of the results are provided.

USING MULTI-FREQUENCY SINUSOIDAL PRESSURE TESTING FOR IMPROVED AQUIFER CHARACTERIZATION

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Keywords: sinusoidal, oscillatory, characterization

Successful modelling of groundwater flow and transport depends on the accurate determination of aquifer parameters. Pumping tests are expensive and slug tests may not provide representative values, particularly in wells with significant skin factors or in formations with a high degree of heterogeneity. As an alternative to other forms of testing, we examine the use of multiple-frequency, pneumatically-generated sinusoidal tests performed using HydroResolutions' PneuSine technique. Sinusoidal testing has many advantages over other types of testing. It produces a distinct and unambiguous signal that can be superposed on long-term transients and that can be filtered to remove noise. A sinusoidal signal can propagate farther than a slug and the use of multiple frequencies allows for the systematic characterization of different formation volumes. In addition, the PneuSine technique has the advantage that it produces no water and does not require a downhole pump or rig. Single well tests are of particular interest because observation wells are expensive and often unavailable. In this presentation, we use the method of images to show how the presence of boundaries near a single well test affects both the phase difference between the flow rate and the pressure and the amplitude of the pressure. We then examine these effects in tests performed near a known boundary at the well-characterized H-19 well pad located in the southeastern portion of the Waste Isolation Pilot Plant (WIPP) site in southeastern New Mexico.

CHARACTERIZATION AT THE INTERFACE

3:50 p.m.–4:30 p.m. Gathering Room 1

2-D SEAWAT MODEL OF AN ALTERED MANGROVE FOREST ON A BARRIER ISLAND NEAR THE INDIAN RIVER LAGOON, FL

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Keywords: mangrove, SEAWAT, barrier island, impoundment, hypersaline

The role of root-zone hydrology in salt mobility and overall subsurface salinity structure in an anthropogenically altered mangrove forest is not well understood. Tidal flushing is significantly reduced during the dry season, and it is unknown whether salts concentrate around mangrove roots producing a shallow hypersaline zone and/or sink providing the vertical flow necessary to keep root-zone salinities levels stable. A two-dimensional (2-D) groundwater model was created using SEAWAT to simulate subsurface flow and salt mobility beneath a barrier island mangrove forest in Fort Pierce, Florida. Conventional barrier island hydrogeology cannot be assumed because surface exchange between the brackish Indian River Lagoon and mangrove forest has been cut off due to a man-made dike. Seasonal pumping from the lagoon inundates vegetation and salt pans and has altered mangrove salinity patterns. The groundwater model attempts to simulate freshwater influx via precipitation and tidal flushing and outflux via evapotranspiration (ET) and tidal forcing. SEAWAT accounts for variable-density flow and simulates the movement and concentrations of salts. ET rates control the majority of salt concentration in the first half meter where mangrove tree roots reside. Precipitation is the only source of freshwater and rates are exceeded by ET during high noon, resulting in lower heads and higher salt concentrations. Model results will be compared against resistivity and electromagnetic measurements.

UPSCALING OF POINT VELOCITY PROBES (PVPS) MEASUREMENTS FOR COMPARISON WITH DARCY-DERIVED GROUNDWATER VELOCITY

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Keywords: direct velocity measurement, PVP, tracer test, upscaling

Risk assessment at contaminated sites depends on knowledge of groundwater velocity. Typically, this knowledge is acquired by the measurement of hydraulic heads to determine the hydraulic gradient across an area and then applying Darcy's Law, corrected for porosity, to arrive at an average linear groundwater velocity for the area. Alternatively, natural gradient tracer tests may be performed to obtain more direct evidence of groundwater speed and direction. Both of these approaches have proven to be effective over years of applications in both research and commercial projects. However, both methods have limitations. Darcy calculations represent intermediate- to large-scale averages that can overlook the effects of important small-scale geologic features. Furthermore, Darcy calculations are based on assumptions that are commonly given little scrutiny, such as the equivalency of hydraulic heads and potential, and they are subject to errors arising from measurement uncertainty, such as in the estimation of

hydraulic conductivity (K). Tracer tests tend to be time and labor intensive to perform and so tend to be limited to the larger projects or to research efforts.

A relatively recent addition to the toolbox for groundwater velocity measurements is the inexpensive point velocity probe (PVP). The probe works by performing a mini-tracer test on the surface of a cylindrical body (essentially a well casing) installed in an aquifer. Several years of laboratory and field experience have shown the probe to be a viable and reasonably accurate instrument. However, the measurements are made at the centimeter scale, raising questions about its general applicability and comparability to larger scale Darcy and tracer test estimations of velocity. This issue was addressed at the Woodstock Ontario site, where a glacial outwash aquifer was characterized by all three methods. The site is of particular interest because it was used to pilot test an in situ denitrification treatment system. Using 75 PVP velocity measurements, a comparison was made between velocities determined by the three methods. In all three cases, the direction of flow was found to be to the southeast. However, the tracer test and PVP methods identified a narrow zone of high velocity that was not evident from the Darcy analysis. This zone led to average PVP and tracer test velocities that were higher than the Darcy estimate, suggesting a failure to scale. However, the apparent failure actually resided with the Darcy approach in this case, showing it should not be the benchmark for comparison, especially in heterogeneous sediments where in situ remediation is planned.

WEDNESDAY, MAY 20, 2015

INTEGRATED CHARACTERIZATION OF THE UNSATURATED AND SATURATED ZONES
8:50 a.m.–9:30 a.m. Griffith Ballroom

HEAT TRANSFER IN SOILS: λ THERMAL CONDUCTIVITY IN SITU MEASUREMENTS USING DIRECT-PUSH TECHNOLOGY

Marian Andrei Chirila[1], Benjamin Christoph[1], Thomas Vienken[1], Hannes Toepfer[2], Peter Dietrich[1,3], and Jan Bumberger[1]

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Keywords: thermal conductivity, heating, heat pumps, subsurface parameters, direct push

During the last decade, the market for geothermal heat pump systems in Europe has increased as geothermal energy is presented as an alternative to fossil energy resources. The use of shallow geothermal resources without knowing the key parameter of thermal conductivity affects the design and optimization of geothermal heat pump systems by decreasing the performance coefficient. Commercial sensors that use a transient hot wire technique for in situ measurement of this parameter are not suitable to be pushed and hammered in unconsolidated sediments for great depths. Reports suggest using a thermal response test to measure thermal conductivity and for calculating borehole thermal resistance. However, an average value of this parameter refers to the entire heat exchange system. This project is focused on the development of a minimally invasive sensor system and finding a method for in situ measurements of thermal properties of subsurface by using direct-push technologies.

We used a simulation model of a robust specimen probe combined with laboratory scale experiments with the probe placed in different media, monitored by the calibrated temperature sensors and power measurement device. In addition, we calibrated the model with the parameters obtained from experiments by using heating curves. After the calibrating was done, we used parameter sweep option in the model for thermal conductivity and volumetric heat capacity to generate a fixed number of heating curves. The heating curves were approximated and the coefficients were saved in a database. Our results suggest that by taking the heating curve from an experiment, approximated and searching in the database, the value of thermal conductivity can be obtained.

As a summary, the robust sensor presented in this work can serve as a prototype for direct-push machines to measure the thermal conductivity parameter in a vertical profile with an acceptable uncertainty. We conclude that this profile can help geothermal system designers in heat exchanger design, optimization, and placement of geothermal systems.

ASSESSING RECHARGE SOURCES AND PATHWAYS WITH HIGH-RESOLUTION PORE FLUID GEOCHEMISTRY

Randy L. Stotler[1], Jon J. Smith[2], Greg A. Ludvigson[2], Britney S. Katz[1], Donald O. Whittemore[2], James J. Butler, Jr.[2], and Daniel R. Hirmas[3]

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Keywords: Ogallala–High Plains aquifer, saturated and unsaturated zone characterization, pore fluids, stable isotopes, recharge

Steep water-level declines due to irrigation from the Ogallala–High Plains aquifer (HPA) are of increasing concern to water resource managers and users. Since widespread irrigation began in the 1960s, water levels have dropped more than 30 m in some areas, resulting in depths to water between 60 and 100 m below ground surface (bgs). With a thick vadose zone, combined with a semi-arid climate, sources and rates of recharge to the HPA are currently poorly constrained. The goal of this research is to better understand recharge pathways to the HPA.

To identify recharge rates and sources to the HPA, results of high-resolution geochemical and isotopic sampling of pore fluids in cores through the saturated and unsaturated zones were compared with results obtained through standard well-water sampling techniques. Vadose zone core samples were obtained using an Acker soil max, wire-line split-spoon sampler advanced ahead of a hollow stem auger. Plastic core tubes are capped and then sealed in the field using pvc tape. In some instances, samples for pore fluid analysis were collected from the drill shoe in two Ziplok™ double-seal freezer bags with all of the air pushed out. Vadose zone water stable isotopes ($^{2}H/^{1}H$, $^{18}O/^{16}O$) were determined using a vapor equilibration method, and recharge rates were estimated using a chloride mass balance. At one site, in the saturated zone, core samples were obtained using a Sonic drill rig with an aqua-lock piston sampler. Pore fluid samples were gravity drained on site with the assistance of a peristaltic pump.

Results of the high resolution sampling clearly identify distinct sources of water in the upper (0–10 m bgs), intermediate (10–30 m bgs), and deeper (30–60 m bgs) portions of the vadose zone, as well as distinct sources within the HPA itself. Moisture in the shallow vadose zone is predominantly modern meteoric recharge, while in the deeper vadose zone, it is incompletely drained groundwater. Significantly, the geochemical signature of the deep vadose zone indicates virtually no input from modern recharge. These results indicated the dominant recharge pathways to the HPA at these locations were neither irrigation return flow nor widespread diffuse recharge.

The high-resolution sampling of pore fluids provided invaluable insight into processes affecting recharge to the HPA that were not possible with measurements for individual well waters (monitoring or irrigation). The ability to identify hydrostratigraphically significant units within the aquifer was an added benefit of comparing the high-resolution saturated zone pore fluid samples with water from nearby high-capacity irrigation wells. Continued sampling and analysis of pore fluid and monitoring and irrigation well water samples will provide additional insights into recharge pathways.

GEOTECHNICAL SITE CHARACTERIZATION

8:50 a.m.–9:30 a.m. Gathering Room 1

NEAR-SURFACE SITE CHARACTERIZATION USING DOWNHOLE SEISMIC TESTING

Gerald Verbeek[1], and Erick Baziw[2]

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Keywords: site characterization, downhole seismic testing

It is widely perceived that for near-surface site characterization the Spectral Analysis of Surface Waves is more suitable than Downhole Seismic Testing (DST). However, recent studies have found that with a larger radial offset of the seismic source, DST can be used successfully to characterize the soil at shallow depths provided the appropriate data analysis methods are applied. This finding is very relevant as it means that DST can be applied to assess the potential for near-surface liquefaction, which is the main cause of foundation damage in case of seismic event.

In this presentation, the authors will present the theory behind both the larger seismic source offset and the appropriate data analysis methods. The larger offset allows the source wave to refract and travel within stratigraphic layers for an extended time, which dramatically increases the characterization of the layer or depth under analysis. Moreover larger offsets significantly decrease near field amplitudes resulting in significantly higher signal-to-noise ratios of the recorded seismic data. At the same time, the implementation of Fermat's Principle must be taken into account when analyzing the data obtained when applying larger radial sensor-source offsets. These aspects will be illustrated with both theoretical and actual data sets that will clearly demonstrate the suitability of DST for near-surface site characterization.

SOIL ERODIBILITY CHARACTERIZATION USING ELECTRICAL RESISTIVITY IMAGING

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Keywords: erosion, electrical resistivity imaging, in situ

Electrical resistivity imaging is becoming increasingly popular for geotechnical site characterization, including as a method to estimate geotechnical properties to reduce the amount of necessary tests. Similarly, electrical resistivity imaging can be used to estimate the erosion rate, or erodibility, of soils as many of the geotechnical properties that control the bulk electrical resistivity of soils are also variables that influence soil erodibility. Determining soil erodibility is a key factor in assessing the performance of much of the nation's infrastructure, including bridges for scour. Scour is the removal of soil due to water flow around foundations. Estimating scour potential is critical as approximately 60% of all bridge failures are due to scour. The current methodology for estimating bridge scour relies on empirical equations because specialized testing is typically time consuming and costly. As electrical resistivity imaging becomes more common for geotechnical site characterization, there is a need to explore additional applications of the method. The objective of this research is to correlate the bulk electrical resistivity of soil with erodibility measured in the Kansas State University Erosion Function Apparatus (KSU-EFA). The KSU-EFA directly measures the erosion rate of a soil by inserting a Shelby tube sample into an opening in a flume. The

soil is kept flush with the flume as water flows over the sample and the amount of soil eroded over a specified period is measured. The KSU-EFA is unique due to the addition of turbidity sensors and other features to increase the accuracy of the measured soil erosion and reduce the operator dependency.

This presentation will discuss the preliminary data from the bulk electrical resistivity and erodibility correlation study. Three electrical resistivity surveys were conducted at bridges selected by the Kansas Department of Transportation. After each survey, soil samples were collected in thin walled Shelby tubes at 0.610 m intervals to a minimum of 3.05 m for KSU-EFA testing. Small samples from each tube were used to classify the soils and establish the in situ water content. The preliminary data show that electrical resistivity imaging can be used as a geotechnical site characterization method for estimating soil erosion potential, though more data are needed to support these findings. An additional 13 bridges are scheduled for testing to increase the database. This study is significant as bridge scour is a critical issue across the state of Kansas and nationally. The rapid in situ data obtained from an electrical resistivity survey can be used to estimate the soil erodibility for bridge design or to determine which existing bridges should be closed or closely monitored for scour potential during a flood event.

INTEGRATED CHARACTERIZATION OF THE UNSATURATED AND SATURATED ZONES

10:25 a.m.–11:05 a.m. Griffith Ballroom

ELECTRICAL RESISTIVITY SURVEYS USING MULTIPLE BURIED ELECTRODES AND SEQUENTIALLY OFFSET SURFACE ARRAYS

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Keywords: 3-D resistivity, covered karst, urban geophysics

3-D electrical resistivity surveys are used where the need for better resolution of the subsurface outweighs the extra cost and time compared to 2-D surveys. A well-planned 3-D electrical resistivity survey will usually give a result that is superior to conventional 2-D surveys by avoiding 1) artifacts from offline objects and 2) misinterpretation of 3-D features with low continuity perpendicular to the survey line. 3-D surface arrays suffer, however, from some of the same fundamental limitations of 2-D resistivity surveys, namely a decrease in resolution and sensitivity with depth. Loss of sensitivity with depth is particularly acute in areas with shallow conductive layers. In this paper, we introduce a 3-D resistivity method in which a 3-D surface array is combined with a 2-D rapidly implanted buried electrode array. This method is an expansion of a previously described geometry in which a 2-D buried array is installed directly beneath a 2-D surface array (a method we refer to as MERIT). Once a deep array is installed, parallel surface arrays are set up laterally offset from the buried array. Optimal sets of readings have been computed for this array geometry. Numerical, laboratory, and field studies with simple geometries and karst features show that this approach has significant advantages in resolution near the ends of the survey and at depth compared to both 2-D MERIT and 3-D surface resistivity arrays. Results will be shown in particular for covered karst settings, where clays that drape over limestone tend to reduce sensitivity of traditional arrays to underlying limestone. Imaging heterogeneity in both clays and limestone is a high priority in covered karst, because breaches in the clay layer function as conduits for focused recharge into the underlying aquifer.

A SCIENTIFIC DRILLING PROGRAM IN THE CENOZOIC STRATA OF THE HIGH PLAINS AQUIFER: SEDIMENTOLOGIC AND HYDROSTRATIGRAPHIC CHARACTERIZATION OF CORED SEDIMENTS FROM THE OGALLALA FORMATION

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Keywords: Ogallala, hydrostratigraphy, stable isotopes, zircon dating

The Kansas Geological Survey, with funding from the Kansas Water Office, the U.S. Geological Survey, the U.S. Bureau of Land Management, and the U.S. National Science Foundation, is carrying out a scientific coring program to improve understanding of the hydrostratigraphic architecture and chronostratigraphy of sediments comprising the High Plains aquifer and to investigate the recharge sources of contained vadose and phreatic groundwater. To date, 26 long continuous cores totaling almost 4,000 linear feet have been collected from seven counties, including several in western Kansas showing the highest water-level declines in the state. Cores were retrieved in plastic tubes by hollow stem auger with wireline retrieval of split-spoon core barrels (unsaturated zone) or rotosonic drill with hydraulic piston core barrel (water-saturated zone). Both drilling technologies employ no drilling fluids, enabling collaborating hydrogeologists to extract in situ pore fluids from cores at spacings ranging from 60 cm to 2 m. Sedimentologic studies include centimeter-scale logging, with subsampling at 30 cm spacings for measurement of organic $\delta^{13}C$, carbonate wt.%, total organic carbon wt.%, and sediment particle size. Where present, vertically-stacked pedogenic carbonates from buried soils in the succession have also been profiled for $\delta^{13}C$ and $\delta^{18}O$ values. Supporting geochronologic studies have been carried out on selected samples using Optically-Stimulated Luminescence dating of Quaternary horizons, along with LA-ICP-MS U/Pb-dating of zircons and cosmogenic nuclide dating of quartz grains from older Cenozoic units. Selected sand samples have been impregnated with blue-dyed epoxide resin to prepare thin sections for analysis of porosity and detrital modes of sand deposits.

Contained pore fluides have been analyzed for δD and $\delta^{18}O$ values, along with ionic hydrochemistry.

Chemostratigraphic records of the $\delta^{13}C$ of pedogenic calcite and sedimentary organic matter do show the expected long-term Cenozoic temporal trend from lower values more characteristic of a C_3 paleoflora to higher values more characteristic of C_4 paleoflora, although the timing of this transition in the core is uncertain at this time. Hydrogeochemical data from vadose and phreatic pore waters are being used to characterize groundwater recharge sources and rates. Selected core samples of more mature paleosols were split to extract contained microscopic zircon crystals. Paleosols are condensed stratigraphic intervals in terrestrial stratigraphic successions and offer the potential to produce stratigraphically useful radiometric dates from volcanogenic zircons. The formation regionally is highly variable, making correlation of water-bearing and water-confining units difficult. Depositional ages derived from U-Pb isotope data will allow long-distance correlation of significant hydrostratigraphic subunits within the Ogallala aquifer on a regional scale.

GEOTECHNICAL SITE CHARACTERIZATION
10:25 a.m.–11:05 a.m. Gathering Room 1

TESTING THE APPLICABILITY OF A $600K GROUT CURTAIN FOR NYC UNDERPINNING

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Keywords: underpinning, dewatering, remote, monitoring, excavation

A 167-year-old historic residential structure, located on the last privately held park in New York City, was purchased by a new owner who initiated a gut-renovation. The renovation would include construction of an additional two basement levels to accommodate a swimming pool, wine cellar, home gym, and mechanical room. This required excavation of about 30 vertical feet and underpinning of existing neighboring building foundations that abut the site. A previous geotechnical investigation, performed by others, failed to determine both bedrock and groundwater levels at the site. Construction commenced at the site and was subsequently stopped because of large groundwater flows into the initial underpinning pit.

We reviewed the geotechnical report and existing design drawings to determine the feasibility of the proposed foundation and underpinning construction considering dewatering and potential impacts to sensitive neighboring buildings designated as landmarks. The client requested us to become increasingly involved in the project and our full scope of work on the project included groundwater modeling, installation of vertical and battered piezometers, remote pumping tests and dewatering monitoring, and landmark building protection plan preparation and monitoring.

The dewatering contractor suggested installation of 230 tube à manchette grout injection points to prepare a "grout curb" on bedrock. The grout curb would act as a groundwater cutoff, reducing the groundwater drawdown under adjacent structures and minimizing any potential settlement of neighboring buildings. The contractor estimated cost to install the entire grout curb was approximately $600,000. GZA proposed that a preliminary 30-foot grout section be installed prior to implementing the full plan. We performed preliminary groundwater modeling (using MODFLOW) based on test boring data, then updated the models following the completion of the grout test section and extraction pumping tests. We also monitored groundwater dewatering effluent for turbidity, which may represent the presence of fines in extracted water. Based on the low turbidity values measured in the extracted water, a modest groundwater drawdown, and the absence of fine-grained soils (that are more susceptible to settlement due to increase in effective stresses at the site), we recommended to the client that a grout curb was not necessary and the proposed foundation construction and underpinning work can be performed safely using a deep well point dewatering system. The decision to go with dewatering saved the client more than $600,000.

Vibrating wire piezometers were installed in numerous vertical and batter well points to monitor groundwater levels during construction. GZA also installed an online turbidity meter, with telemetry capabilities, for long-term monitoring during construction. These sensors were then automated via a data-logger system using cellular telemetry (ARGUS) for remote data monitoring through ARGUS web access. Our remote monitoring set-up saved the owner labor costs by reducing the need for full-time on-site data monitoring.

EVALUATION OF RESISTIVITY AND FOULING OF RAILROAD BALLAST USING A DIRECT PUSH TECHNOLOGY

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Keywords: resistivity, ballast, fouling, drainage, track

Maintaining rail track in good condition is essential for ensuring the overall performance and safety of railway operations. Track support, structural integrity, and effectiveness of the foundation structure depend on the characteristics and performance of the ballast and sub-ballast layers. The ballast of the rail track may be fouled due to intrusion of fine particles from outside the ballast as well as particles produced within the layer due to breakage over time. This fouling can cause track support degradation and permanent settlement. Since there are limited methods for fouling detection and these methods are time consuming, tedious, and require significant manpower, a simple approach of identification of ballast fouling within a few minutes at low cost will be discussed.

Research at the University of Kansas (KU) has shown that resistivity and fouling are correlated. A vertical probe was designed by the KU Civil, Environmental, and Architectural Engineering Department to measure the resistivity of the fouled ballast. The probe was tested using both horizontal and vertical configurations and worked well for estimating resistivity using the fall of potential method. Resistivity tests using a Wenner 4 probe array in horizontal alignment and fall of potential method with a vertical probe and vertical alignment were carried out.

The result of the vertical probe was consistent on most of the test samples with the Wenner 4 point array method. A boundary moisture content, termed as optimum moisture content for resistivity (OMCR), was determined. The resistivity of the fouled ballast can be estimated for moisture contents greater than OMCR. The dynamic modulus, static modulus, and the CBR of the ballast decreased significantly for moisture contents greater than OMCR. Static and dynamic moduli peaked near the OMCR for all types of fouling, while the CBR was constant to slightly increasing with moisture content up to the OMCR.

THURSDAY, MAY 21, 2015

HYDROGEOLOGICAL INVESTIGATION TECHNIQUES

8:55 a.m.–9:55 a.m. Griffith Ballroom

EFFECTS FROM UNSATURATED ZONE FLOW DURING OSCILLATORY HYDRAULIC TESTING

David Lim[1], YaoQuan Zhou[1], Michael Cardiff[1], and Warren Barrash[2]

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Keywords: oscillatory hydraulic tomography

In analyzing pumping tests on unconfined aquifers, the impact of the unsaturated zone is often neglected. Instead, desaturation at the water table is often treated as a free-surface boundary, which is simple and allows for relatively fast computation. Richards' equation models, which account for unsaturated flow, can be compared with saturated flow models to validate the use of Darcy's Law.

In this presentation, we examine the appropriateness of using fast linear steady-periodic models based on linearized water table conditions to simulate oscillatory pumping tests in phreatic aquifers. We compare oscillatory pumping test models, including the following: 1) a 2-D radially symmetric phreatic aquifer model with a partially penetrating well, simulated using both Darcy's Law and Richards' Equation in COMSOL; and 2) a linear phase-domain numerical model developed in MATLAB. Both COMSOL and MATLAB models are calibrated to match oscillatory pumping test data collected in the summer of 2013 at the Boise Hydrogeophysical Research Site (BHRS), and we examine the effect of model type on the associated parameter estimates. The results of this research will aid unconfined aquifer characterization efforts and help to constrain the impact of the simplifying physical assumptions often employed during test analysis.

ASSESSMENT OF TEST INITIATION METHOD ON HYDRAULIC TOMOGRAPHY RESOLUTION

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Keywords: aquifer characterization, heterogeneity, hydraulic tomography, resolution analysis

Hydraulic tomography is receiving increasing attention to characterize the heterogeneity of hydraulic properties at local scale. While recent advances have been promising, few efforts have been dedicated to understanding the impact of fundamental controls on hydraulic property resolution, such as the magnitude and anisotropy of hydraulic properties and experimental configuration. In this presentation, we focus on the impact of the test initiation method used to induce head perturbations in an aquifer, on the resolution of hydraulic properties that can be obtained from hydraulic tomography experiments. In particular, we compare respective sensitivities and associated resolution for tomographic experiments carried out with pumping and slug tests. Tomographic pumping and slug tests are indeed expected to present distinct resolution characteristics due to their different sensitivity patterns. To have a common basis of comparison for both tests, an equivalent constant pumping rate is first calculated to obtain identical steady-state drawdowns and initial heads in stressed intervals. Then, a resolution analysis based on truncated singular value decomposition of the sensitivity matrix with a noise level representative of typical field measurements is computed

using synthetic data mimicking a known littoral aquifer composed of sand and silt. To approximate the hydraulic behavior of a real aquifer system, synthetic tomographic experiments and their associated sensitivity matrix are generated using a radial flow model that accounts for wellbore storage in a plane encompassing a stressed well and an observation well. Results of synthetic experiments lead to several important conclusions. First, although drawdowns induced by pumping in observation intervals are three times larger than head changes from slug tests in the same intervals, sensitivity magnitudes for K_h, K_v/K_h, and S_s are comparable. Therefore, resolution for the two different test initiation methods are similar, except for S_s, where pumping tests have much smaller resolution than slug tests due to wellbore storage effects that hinder S_s aquifer responses recorded in stressed intervals. However, head responses in observation intervals for slug tests must be larger than the noise level of measurements to ensure proper resolution, which may require closer test wells or large initial heads. Secondly, tomographic slug tests require up to 50 times less water (9 L/slug test versus 450 L/pumping test) to perform a tomographic experiment with the same resolution. This could be a huge benefit for projects in which disposal or injection of water is an issue. Even though the pumping rate could be lowered to reduce the water used for testing, lowering drawdowns in observation intervals would lead to poorer resolution. For identical drawdowns and heads in observation intervals, resolution from tomographic pumping tests is indeed half the resolution of tomographic slug tests. This study shows that slug tests provide an interesting alternative to commonly used pumping tests for hydraulic tomography experiments.

OSCILLATORY FLOW TESTING IN A SANDBOX—TOWARDS OSCILLATORY HYDRAULIC TOMOGRAPHY

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Keywords: Oscillatory Hydraulic Tomography, sandbox, periodic pumping, subsurface characterization

Spatial hydraulic properties in shallow subsurface have been extensively studied in the past two decades. A recent approach proven to be effective to characterize subsurface properties is hydraulic tomography. Many laboratory sandbox studies have explored the performance of hydraulic tomography under different controlled conditions (e.g., Liu et al., 2002; Illman et al., 2007, 2008, 2010a, 2010b). Cardiff et al. (2013) recently proposed a modified tomography approach named Oscillatory Hydraulic Tomography (OHT) to characterize aquifer properties. Its advantages over hydraulic tomography are 1) no net injection or extraction of water; 2) little movement of existing contamination; 3) minimal impact of model boundary conditions; and 4) easy extraction of oscillatory signals from noisy data.

To evaluate the effectiveness of OHT, in which periodic pumping signals of different frequencies are used for stimulation, we built a 2-D laboratory sandbox to test its performance. The focus of the research presented here is to provide an experimental confirmation of the theory of OHT. In our setup, we use an instrumented laboratory sandbox, filled with sand of known hydraulic properties, and measure aquifer responses due to an oscillatory stimulation at a variety of frequencies. Pressure oscillation time-series are then inverted tomographically to obtain estimates of aquifer heterogeneity by using a fast and physically accurate "steady periodic" groundwater flow model.

NEW TOOLS FOR WATERSHED CHARACTERIZATION

8:55 a.m.–9:55 a.m. Gathering Room 1

CHARACTERIZING HETEROGENEITIES IN AN ALLUVIAL AQUIFER WITH REPEATED DISTRIBUTED THERMAL PERTURBATION SENSING TESTS

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Keywords: heat as a tracer, groundwater tracer, distributed temperature sensing, distributed thermal perturbation sensing

To better understand the groundwater resources of southern Nye County, Nevada, a multi-part thermal perturbation sensing (DTPS) test was performed on a complex of three wells. These wells penetrate an alluvial aquifer that drains the Nevada National Security Site (formerly known as the Nevada Test Site), and characterizing the hydraulic properties and flow paths of the regional groundwater flow system has proven very difficult. The well complex comprised one pumping well and two observation wells, both located approximately 18 m from the pumping well. Using fiber-optic cables and line heaters, DTPS tests were performed under both stressed and unstressed conditions. Each test injects heat into the water column over a period of one to two days and observes the rising temperature during heat injection and falling temperatures after heating ceases. Aquifer thermal properties are inferred from temperature patterns in the cased section of the wells, and fluxes through the 30 m screened section are estimated based on a model that incorporates conductive and advective heat fluxes. Vertical variations in flux are examined on a scale of tens of centimeters. The actively flowing zones of the aquifer change between the stressed and unstressed test, and anisotropy in the aquifer permeability is apparent from the changing fluxes between tests. The fluxes inferred from the DTPS tests are compared to solute tracer tests previously performed on the same site The DTPS-based fluxes are congruent with the fastest flow paths identified in the tracer test but appear to overestimate the mean flux through the system.

WATERSHED SCALE CHARACTERIZATION OF GLACIAL AND BEDROCK AQUIFERS IN EASTERN NEBRASKA

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Keywords: airborne, geophysics, glacial, bedrock, aquifers

Glacial deposits covering the eastern portion of Nebraska overlie various bedrock units of Mesozoic and Paleozoic age. The watersheds and aquifers are difficult to characterize due to multiple stages of erosion and glaciation within this region. There has been a program within the Conservation and Survey Division (CSD), School of Natural Resources, University of Nebraska-Lincoln for 75 years to collect high-quality test holes throughout the region, but still more information is required to make informed management decisions on the watersheds and aquifers in

eastern Nebraska. The Eastern Nebraska Water Resources Assessment (ENWRA) project was formed in 2006 with sponsors from six Natural Resources Districts (Lewis and Clark, Lower Elkhorn, Papio-Missouri River, Lower Platte North, Lower Platte South, and Nemaha) and cooperating agencies including CSD and the U.S. Geological Survey. The long-term goal of the project is to develop a geologic framework and water budget for the glaciated portion of eastern Nebraska. In 2014–2015, a large-scale reconnaissance airborne electromagnetic survey was undertaken over the glaciated portion of Nebraska. The AEM survey, composed of ~2,200 line-km of ~32 km spaced lines, flew over many of the test-hole transects that have been collected by CSD over the years. A time-domain AEM system was selected to penetrate the electrically conductive materials within the glacial tills and to delineate the character of the deeper bedrock aquifers. The depth of investigation was ~350 meters. The AEM imaged the Quaternary, Tertiary, Cretaceous, Pennsylvanian, and Mississippian units in the area. The inversion models were compared with available data that included lithology and stratigraphy logs; cross sections, geological maps, and oil and gas wells. The comparison showed excellent correlation and allowed interpretation of the bedrock geological units along the AEM lines as well as for interpretation of the aquifer materials within the quaternary glacial materials. On the watershed scale, these data provide a tie between the historical data and also provide mapped connections between the surface water and groundwater. The management of the area is enhanced due to the ability to identify areas for groundwater availability assessments. These would include areas of sand/gravel within the quaternary and sandstones and fractured carbonates within the bedrock. Also on the watershed scale, a mapped area of groundwater protection was identified where the thick glacial tills and loess overlay aquifer materials and shale units overlay other bedrock units. The enhanced hydrogeological framework will also be incorporated into the groundwater models within the area. This study provides the roadmap for the management and future assessment of the multiple watersheds within the glaciated portion of eastern Nebraska.

LABORATORY INVESTIGATION OF DISTRIBUTED TEMPERATURE SENSING TO CHARACTERIZE GROUNDWATER FLUX

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Keywords: distributed temperature sensing, groundwater velocity

Hydrogeologists often use easily detectable environmental tracers, such as heat or chemicals, as an indirect way to estimate groundwater flow since directly measuring velocity at the field scale is a difficult task. In the last decade, heat increasingly has been used because of the emergence of lower-cost instrumentation for temperature measurement. One method, distributed temperature sensing (DTS), uses fiber-optic cables to collect temperature data at high spatial and temporal resolutions. We have been developing DTS-based probes to characterize variations in groundwater flow along the screened interval of a well.

Previously, we constructed a high-resolution groundwater flux characterization (GFC) probe with wrapped fiber-optic and heating cables and tested its ability to detect the vertical variation in horizontal flow in a well at a field site in eastern Kansas. The results correlated well with and showed much more detail than results from prior hydraulic testing done in the same well. In this work, we adapted the GFC probe for use in a laboratory sand box where we investigated its performance under different flow conditions. The heating-induced temperature change became smaller as the ambient flow rate increased, consistent with modelling results. Importantly, we developed a new measurement procedure for separating advection from other thermal processes so that groundwater flux can still be accurately characterized when the thermal properties of aquifer materials vary with depth.

HIGH RECHARGE RATE EXPERIMENTS INVOLVING SMALL-DIAMETER WELLS

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Keywords: artificial recharge, infiltration, direct-push, field test

Artificial recharge has been used for different purposes such as enhancement of water quantity in various regions throughout the world. Especially in arid and semi-arid regions, artificial recharge is increasingly used to combat water scarcity. Beside this, quality management of aquifers and treatment of contaminated areas may require infiltration of water and substitutes. Recently, a new artificial recharge technique using small-diameter wells has been introduced. Corresponding numerical studies showed the high recharge potential of such wells under different subsurface conditions when compared to a common surface infiltration method. However, there were concerns regarding the functionality of the small-diameter wells in longer-term applications. Therefore, an experimental validation of the technique was performed and is described.

For this purpose, at the test site in Pirna, Germany, two infiltration tests using a small-diameter well (ID 1 in) were performed. The aquifer comprises a heterogeneous but high conductive gravel and sand layer of 4 to 5 m thickness with an average hydraulic conductivity of $2x10^{-3}$ m/s. This layer is overlain by a silty layer of reduced hydraulic conductivity (approx. $5x10^{-4}$ m/s). Tap water and groundwater were used as the recharge experiments were intended to involve clean water with low turbidity. Water was provided by a 1 m^3 tank closely attached to the well and measurements were taken for water level within the well by a pressure sensor and infiltration rate by a water clock. First, a short-time test was performed. Stepwise increasing infiltration rates (0.03 l/s up to 0.7 l/s) were used and showed only a slight increase in well water level. In a second test, groundwater was pumped out of a dug well sufficiently far away, stored temporarily in the tank and was finally infiltrated. The infiltration rate of 0.75 l/s was continuously stable over a period of 14 days and led to an infiltrated water volume of 900 m^3. This highlights the high performance potential of the small-diameter wells. Furthermore, no significant well water-level rise could be observed with time, leading to the conclusion that clogging processes are negligible.

MONITORING OF INCREASED CO_2 CONCENTRATION LEVELS BY MEANS OF ATMOSPHERIC MONITORING METHODS DURING A BACK PRODUCTION EXPERIMENT

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Keywords: carbon capture and storage (CCS), atmospheric monitoring, OP FTIR, eddy covariance, pilot site Ketzin

In recent years, global concerns about greenhouse gas emissions have stimulated considerable interest in carbon capture and storage (CCS) as a climate change mitigation option that can be used to reduce man-made CO_2 emissions. The reliable detection and assessment of potential CO_2 leakages from storage formations require the application of various monitoring tools at different spatial scales. Especially, atmospheric monitoring in the vicinity of the storage project is designed to detect and quantify emissions from potential leakage sources (e.g., permeable faults, abandoned wells) over large areas. Within the framework of the MONACO project (Monitoring Approach for Geological CO_2 Storage Sites Using a Hierarchical Observation Concept), an integrative hierarchical monitoring concept was developed and validated at different field sites. The project aim was the establishment of a modular observation strategy including investigations in the shallow subsurface, at ground surface level, and in the atmosphere. The atmospheric methods integrated in this MONACO hierarchical concept are 1) open-path Fourier-transform infrared (OP FTIR) spectroscopy, which is based on the analysis of ambient (passive mode) or artificial infrared radiation (active mode) in the 700–4,000 cm^{-1} wave-number range along optical pathways and 2) the eddy covariance (EC) method, which is a micrometeorological technique to measure and determine fluxes in the atmospheric boundary layer (surface layer or constant flux layer). The continuously monitored results of the active and passive ground-based OP FTIR spectroscopy and EC method could provide promising results for identifying areas with increased atmospheric CO_2 levels. The poster presentation will introduce the OP FTIR method and show first monitoring results during a back production experiment in October 2014 at the CCS pilot site in Ketzin, Germany.

AN INTEGRATED GEOPHYSICAL STUDY FOR INFERRING THE SUBSURFACE SETTING OF WATER-BEARING AQUIFERS: CASE STUDY AT WADI ALDWASIR AREA, SAUDI ARABIA

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Keywords: aquifer, basement, gravity data, aeromagnetic, magnetic data

Wadi Aldwasir area is a very important province in Saudi Arabia. It contains an aquifer with a significant groundwater reserve (Wajid aquifer). This study aims to investigate the subsurface features of this aquifer (thickness, depth to basement, overlying section, and the structural elements) using an integrated gravity survey (2-D profiles) and aeromagnetic interpretation (RTP, low pass, and high-pass maps). Gravity data are measured in the field using CG-5 AutoGrav, while magnetic data are taken from a survey made by the Saudi Geological Survey. The interpretation of aeromagnetic data revealed structural elements trending toward N-S, NNE-SSW, WNW, and NNW-SSE directions. Positive magnetic anomalies are found indicating the presence of anticlinal blocks and strike-slip fault patterns. These structural elements are associated with the prevailing Najd fault and the transform fault systems.

Gravity data showed that the depth to basement varies from 600 m to 1,150 m, giving rise to a considerable range for aquifer thickness of 250 m to 700 m. Local basins of good thicknesses are indicated. Finally, a basement relief map is constructed based on an integrated interpretation of the magnetic and gravity outputs. It shows an increase of depth from south to north (good aquifer thickness).

ADAPTIVE SITE INVESTIGATION FOR MULTI-SCALE CHARACTERIZATION OF SEDIMENTARY STRUCTURES

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Keywords: direct push, cone penetration test, adaptive site investigation, electrical resistivity tomography, ground penetrating radar

Hydrogeological tasks, such as ground water management, require a detailed and profound understanding of ground water flow within the subsurface. However, this preconditions a thorough understanding of the (hydro)geological structures within the subsurface, which has been a challenging task for hydrogeologists for several decades. This is especially true at sites with complex geological settings or intricately constructed sedimentary deposits, e.g. fluviatile regimes in which hydraulic conductivity can change over short horizontal and vertical distances in several orders of magnitude. Here, knowledge about hydraulic conductivity and its distribution in space is needed on a high-resolution scale at which many conventional techniques fail in resolution and/or reliability. Against this background, exploration and monitoring technologies must be developed to meet the challenges that arise from the heterogeneity and dimensions of the investigated geological systems. This study describes the application of a combined use of geophysics and minimum-invasive direct-push technology for an adaptive site investigation of a typical heterogeneous fluviatile sedimentary system at the banks of the River Mulde, near the city of Löbnitz, Germany, to demonstrate its feasibility. The main task of the investigation was to characterize the adjacent river deposits and, in particular, to map the extent and hydraulic properties of an aggradated oxbow using a three-phase investigation approach as presented in Kreck (2011) and Vienken et al. (2014).

References:

Kreck, M., 2011, Geotechnical and hydraulic subsurface characterization at the Löbnitz embankment using geophysical and direct push based investigation to enhance structural flood protection (Original: Geotechnische und hydraulische Charakterisierung des Untergrundes am Deich Löbnitz mittels Geophysikalischer und Direct Push gestützter Erkundung als Ergänzung zum baulichen Hochwasserschutz): master’s thesis, Martin Luther University Halle-Wittenberg, 69 pp.

Vienken, T., Kreck, M., Hausmann, J., Werban, U., and Dietrich, P., 2014, Innovative strategies for high resolution site characterization: application to a flood plain: Acque Sotterranee - Italian Journal of Groundwater, v. 138, no. 4, p. 7–14.

TECHNIQUE, ANALYSIS ROUTINES, AND APPLICATION OF DIRECT-PUSH DRIVEN IN SITU COLOR LOGGING

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Keywords: in situ, direct push, colorimeter, color logging, sediment characteristics

Direct-push technologies have recently seen a broad development providing several tools for in situ parameterization of unconsolidated sediments. One of these techniques is the measurement of soil colors—a proxy information that reveals soil/sediment properties. We introduce the direct-push driven color logging tool (CLT) for real-time and depth-resolved investigation of soil colors within the visible spectrum. Until now, no routines exist on how to handle high-resolution (millimeter-scale) soil color data. To develop such a routine, we transform raw data (CIEXYZ) into soil color surrogates of selected color spaces (CIExyZ, CIEL*a*b*, CIEL*c*h*, sRGB) and denoise small-scale natural variability by Haar and Daublet4 wavelet transformation, gathering interpretable color logs over depth. However, interpreting color log data as a single application remains challenging. Additional information, such as site-specific knowledge of the geological setting, is required to correlate soil color data to specific layers properties. Hence, we provide results from a joint interpretation of in situ obtained soil color data and state-of-the-art direct-push based profiling tool data and discuss the benefit of additional data. The developed routine is capable of transferring the provided information obtained as colorimetric data into interpretable color surrogates. Soil color data proved to correlate with small-scale lithological/chemical changes (e.g., grain size, oxidative and reductive conditions), especially when combined with additional direct-push vertical high-resolution data (e.g., cone penetration testing and soil sampling). Thus, the technique allows enhanced profiling by means of providing another reproducible high-resolution parameter for analyzing subsurface conditions. This opens potential new areas of application and new outputs for such data in site investigation. It is our intention to improve color measurements by means method of application and data interpretation, useful to characterize sediment characteristics.

GROUNDWATER MONITORING IN FORSMARK

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Keywords: monitoring, repository, hydrogeology, hydrochemistry, characterization

In 2009, SKB selected Forsmark, northern Uppland, Sweden, as the site for building a final repository for spent nuclear fuel. In March 2011, an application under the Environmental Code and the Nuclear Activities Act was submitted. At the moment, plans are to start construction in 2020, and meanwhile the monitoring to establish necessary base lines continues in order to establish reliable descriptions of natural undisturbed conditions in the bedrock and at the surface. The subject for this poster presentation is groundwater monitoring at the Forsmark site.

The site selection was preceded by careful studies of the geosphere and biosphere, performed during 2002–2007, at both Forsmark and Laxemar in the south of Sweden, aiming at localizing and characterizing a suitable site for a final repository for spent nuclear fuel. Hundreds of investigations were conducted during this period, and a monitoring program was established with the purpose to enable frequent and repeated long-term measurements and observations (here denoted monitoring) of a number of geoscientific and ecological parameters and states.

Groundwater monitoring (monitoring of groundwater levels, groundwater flow, and groundwater chemistry) in Forsmark is performed in cored boreholes and percussion-drilled boreholes in crystalline bedrock, as well as in groundwater wells in Quaternary deposits. The cored and percussion boreholes are sectioned with one-meter long rubber packers that straddle different fractures and fracture zones penetrated by the borehole. The system allows monitoring of groundwater levels, groundwater sampling for chemical analyses, and measurements of the natural groundwater flow from individual fractures or deformation zones in isolated borehole sections. The measurement data are transferred to SKB´s HMS-system and stored in a database for further analyses.

The groundwater levels and flow conditions are, together with the hydrochemical composition of the groundwater, fundamental factors when modelling and verifying hydrogeological models, thus assessing the long-term safety of a final repository for nuclear waste. The hydrochemical characteristics of the groundwater at the Forsmark site are complex, and groundwater samples from different depths in boreholes situated at different parts of the site indicate that the groundwater is a mixture of groundwater types of at least four different origins. The distribution of a particular groundwater mix is dependent on the groundwater flow conditions, which in turn are governed by structural-geological, hydrogeological, meteorological, and hydrological factors.

RESULTS OF PRELIMINARY TESTS OF WIRELESS SENSOR NETWORKS WITH RING OSCILLATOR PROBES FOR SOIL MOISTURE MONITORING

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Keywords: soil moisture, wireless sensor networks, environmental monitoring

Ecosystems are often characterized by their high heterogeneity, complexity, and dynamic. Hence, single-point measurements are often not sufficient for their complete representation. The application of wireless sensor networks in terrestrial and aquatic environmental systems offer the opportunity to cover heterogeneous areas with several sensor nodes, due to the simple adjustment of the sensor distribution, the sensor types, and the sample rate. Other advantages of wireless ad-hoc sensor networks are the easy handling and the easy installation of the devices as well as their self-organizing behavior, resulting in a major reduction in installation and operation costs and time. One of the key parameters in environmental science is the soil moisture. To achieve a comprehensive monitoring in space and time in heterogeneous landscapes, it is necessary to reduce the sensor costs. A cost-effective solution of measuring soil moisture could be the use of low-cost ring oscillator probes, which are based on a frequency domain technology. For highest accuracy, a soil-specific calibration of each probe is necessary.

This work will present analyses of preliminary tests of wireless sensor networks with ring oscillator probes under two different site conditions. The data measured with ring oscillator probes were compared with common Time Domain Reflectometry data. The dataset allows an evaluation of the sensor accuracy.

HYPOTHESIS TESTING IN FIELD CAMPAIGN DESIGN

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Keywords: site characterization, field campaigns, uncertainty quantification

Advances in geophysics and new site characterization methods (e.g., direct-push technology) have demonstrated the ability to characterize groundwater systems more quickly and at reduced cost compared to traditional methods (e.g., pumping tests). Incorporating these technologies into field campaigns can potentially enable practicing hydrologists to more economically characterize contaminated groundwater sites for risk assessment and remediation design. Because these methods can provide various types of information at various scales, it can be difficult to determine how much data is needed or how to design field campaigns optimally. Field campaign design determines what type of measurements, what quantity of measurements, and what locations of measurements are to be acquired. Field campaign optimality should strike a balance between cost and accepted level of uncertainty in the relevant hydrologic variables (e.g., contaminant arrival time or concentration).

However, the process by which field data are assimilated into models to make these predictions can be complex, as is the process by which field data reduce uncertainty in site characteristics and in turn reduce uncertainty in modeling predictions, making it difficult to predict how much data will be necessary. To address these challenges, we use the statistical tool of hypothesis testing due to its simplicity and flexibility in handling uncertainty. One benefit of using hypothesis testing is that it can simply communicate predicted model outputs along with uncertainty levels associated with such predictions, which can enable informed decisions by managers and policy makers, who may not have a background in all aspects of field and modeling methods. We will present current research in how hypothesis testing can be formulated in the case of predicting aquifer contaminant arrival time and how to incorporate all sources of uncertainty when calculating the level of significance of the test. Initial results from a synthetic case study will be presented. Future research will involve a case study with real field data.

INTERPRETATION OF THE GRAVITY DATA TO IMAGE GEOLOGIC STRUCTURES OF THE COASTAL ZONE IN AL QUNFUDHAH AREA, SOUTH WEST SAUDI ARABIA

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Keywords: faults, basement, gravity data, coastal zone 2-D modeling

The objective of the present study is to map the basement depth and structure of the coastal area between Lat. 19˚–19˚.45’ N and Long. 40˚ .45’–41˚.20’ E, in the southwestern part of Saudi Arabia, as a potential aid to groundwater assessment. This objective was achieved through intensive interpretation of the available gravity survey data for the study area using modern analysis and interpretation techniques (filtering and depth estimation) finalized by 2-D modeling. The gravity data were corrected to eliminate the inherent effect of the crustal thickness variation in the costal zones (isostatic correction). Then, the data were enhanced using band-pass and the high-pass filter in frequency domain to emphasize the shallow structure affecting the top of the basement rocks. Furthermore, source edge location and depth estimation techniques such as source edge detection, power spectral analysis, and Euler deconvolution have been applied to the filtered gravity data to locate and outline different causative sources as well as to estimate their depths and trends. In addition, 2-D modeling was conducted along 13 representative gravity

profiles to provide the topography and depth variations of the basement surface along these profiles.

From these investigations, it can be concluded that the depth to the basement rocks of the study area range from 0 to 2,200 m under the ground surface. In general, the depth to the basement increases toward the west through local emulations related to the tilted-faulted blocks structure dominant in the Red Sea rift zone. Moreover, two faulting systems were recognized in the area. The first is a normal faulting system trending in a north-northwest–south-southeast direction and is related to the Red Sea rift. The second represents the cross-cut oblique faulting system trending in a northeast-southwest direction.

The interaction between the aforementioned fault systems resulted in formation of a set of closed basins elongated in the north-northwest–south-southeast direction and terminated by the northeast-southwest faulting system. The geomorphology and sedimentary section of these basins qualify them for potential groundwater accumulation. Accordingly, further geophysical studies using resistivity techniques and drilling are recommended to prove the groundwater accumulation in the interpreted basins and evaluate its potential.

FIELD DEMONSTRATIONS

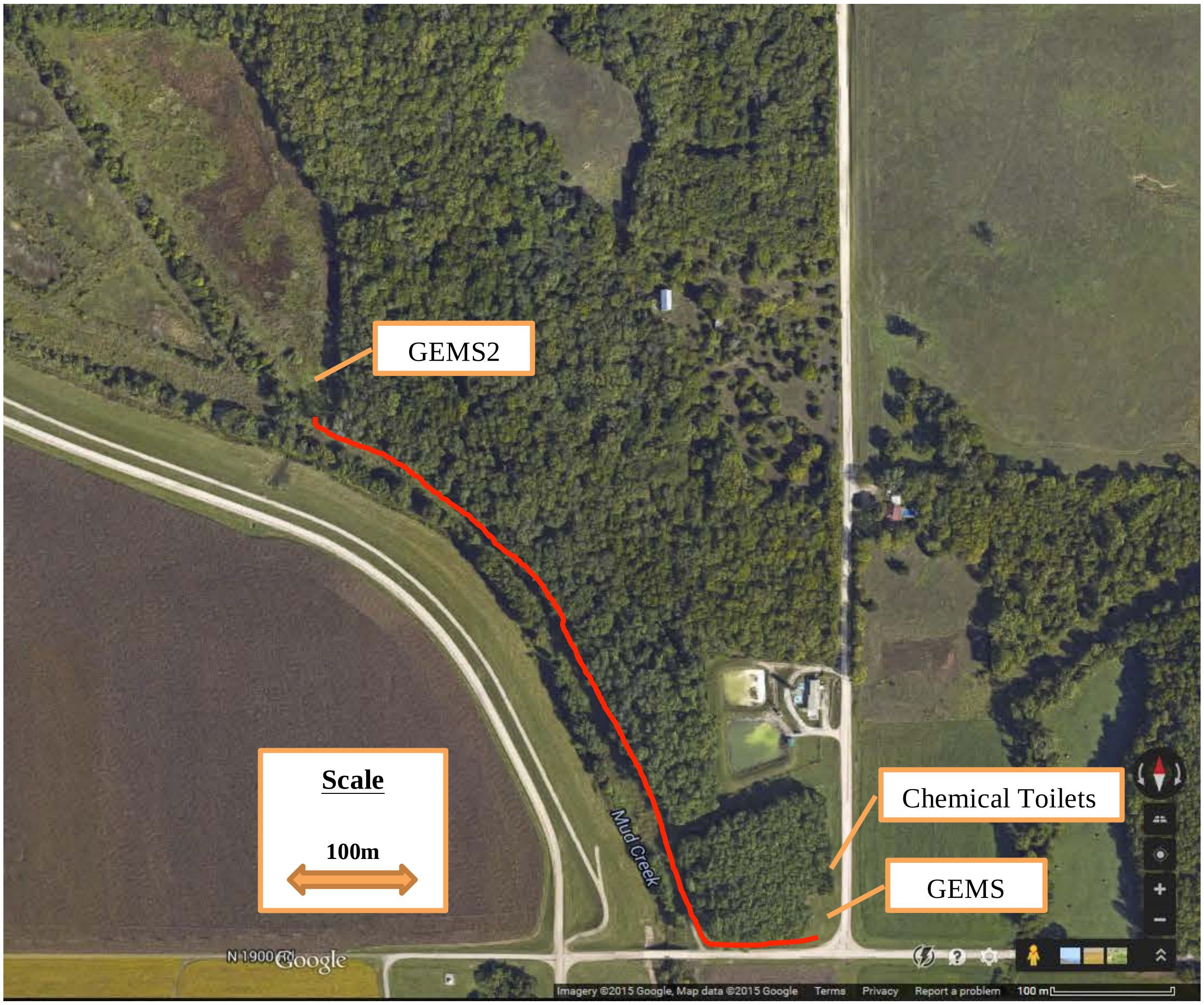
Field demonstrations will take place at the Geohydrologic Experimental and Monitoring Site (GEMS) of the Kansas Geological Survey located in the floodplain of the Kansas River, a short bus ride from the Oread Hotel. Over the last two decades, GEMS has been the site of extensive research on groundwater flow and transport in heterogeneous formations. Much of this work has been summarized in the Butler chapter in the Rubin and Hubbard (2005) Hydrogeophysics book. More recent work includes direct-push hydraulic and NMR profiling summarized in the Liu et al. (2012—Grundwasser) and Knight et al. (2015—Groundwater) papers, respectively.

The shallow subsurface at GEMS consists of ~10.7 m of alluvial sand and gravel overlain and hydraulically confined by ~11.5 m of silt and clay and underlain by low-K (hydraulic conductivity) limestone and shales; the water table is ~6 m below land surface. More detailed information is provided in the next section.

Buses will drop off and pick up attendees at GEMS, which is split into two demonstration areas: GEMS and GEMS2. The walk between GEMS and GEMS2 is approximately 700 meters. Portable chemical toilets will be located on the northeast corner of GEMS. See map for additional details.

Six field demonstrations are planned (each number corresponds to a map location):

1. Sonic drilling—Geoprobe will demonstrate their new sonic technology for drilling in both unconsolidated and consolidated formations.
2. Hydraulic and water chemistry profiling—Geoprobe will demonstrate their new HPT-GWS probe, a groundwater sampling tool for obtaining information about K, electrical conductivity, and water chemistry of unconsolidated formations.
3. NMR methods for subsurface investigations—Vista Clara will demonstrate their tool for downhole profiling to obtain information about water-filled porosity and hydraulic conductivity, as well as their surface-based systems to assess near-surface water content.
4. Site characterization using laser-induced fluorescence (LIF) and electrical conductivity (EC)—Matrix Environmental will demonstrate the combined UVOST (Ultra-Violet Optical Screening Tool) and EC tool for rapidly characterizing non-aqueous phase liquids (NAPLs) in the subsurface.
5. Point velocity probes—Professor Rick Devlin of the Department of Geology of the University of Kansas will demonstrate probes for obtaining in-situ point measurements of groundwater velocity.
6. Distributed temperature sensing (DTS) and high-resolution K (HRK) probes—the Geohydrology Section of the Kansas Geological Survey will demonstrate two recently developed tools: 1) the DTS probe for assessing vertical variations in groundwater flux within the screened interval of a well, and 2) the HRK direct-push probe for obtaining high-resolution vertical profiles of K.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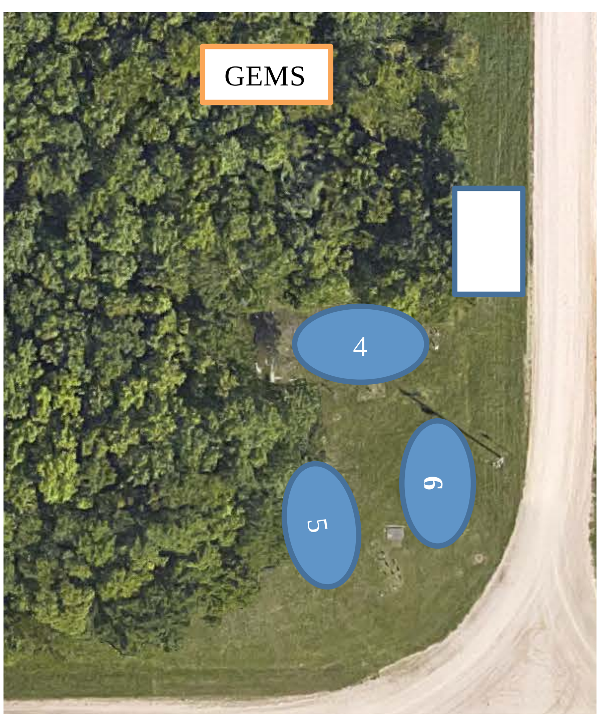
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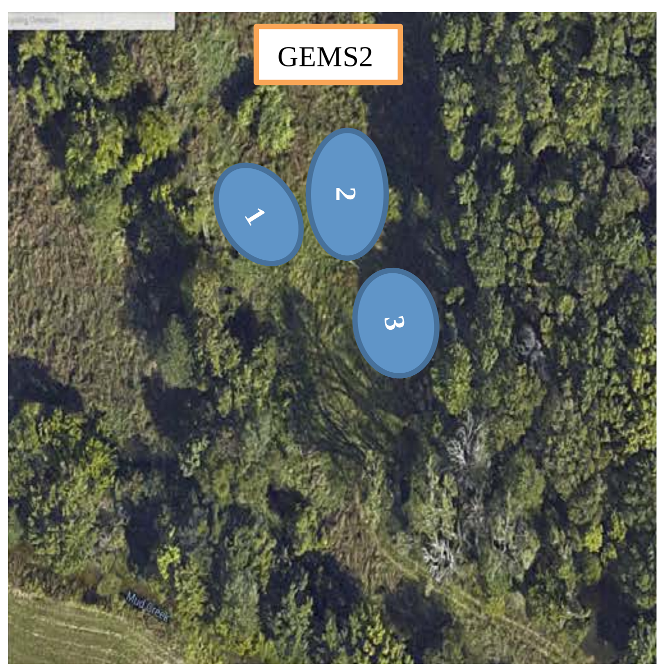
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THE GEOHYDROLOGIC EXPERIMENTAL AND MONITORING SITE

The Geohydrologic Experimental and Monitoring Site (GEMS), a research area established in 1988 by the Kansas Geological Survey (KGS), will be used as the field site for demonstrating recent technological developments for subsurface characterization. GEMS is located just northeast of the Lawrence Municipal Airport, a short bus drive from the Oread Hotel (fig. 1). The site rests on Pleistocene terrace deposits of the Kansas River valley (fig. 2) and overlies approximately 22.2 m of unconsolidated alluvial deposits that rest on Pennsylvanian bedrock (limestone and shale). The alluvial facies assemblage is a complex system of stream-channel sand and overbank deposits that essentially consist of ~11.5 m of clay and silt (with minor amounts of silty sand) overlying ~10.7 m of sand and gravel (fig. 3). The sand and gravel zone is hydraulically confined by the low-permeability clay and silt.

Since its inception, GEMS has been the site of an extensive program of research directed at the development and refinement of equipment and field methods for the characterization of the hydraulic properties of saturated flow systems. The underlying motivation for this research is to improve our ability (as a discipline) to get the information needed to better realize the potential of mathematical modeling of groundwater flow and transport. A large number of approaches have been explored, ranging from hydraulic testing methods (Butler, 2005; Bohling et al. 2007) to direct-push technology (Schulmeister et al. 2004; Butler et al. 2007; Liu et al. 2012) to fiber-optic distributed temperature sensing (Liu et al. 2013) to nuclear magnetic resonance logging (Knight et al. 2015). The detailed list of publications based on this work can be found in the online vitae of Jim Butler, Gaisheng Liu, and Geoff Bohling (see staff listing for the KGS Geohydrology Section, www.kgs.ku.edu/Staff/gh.html).

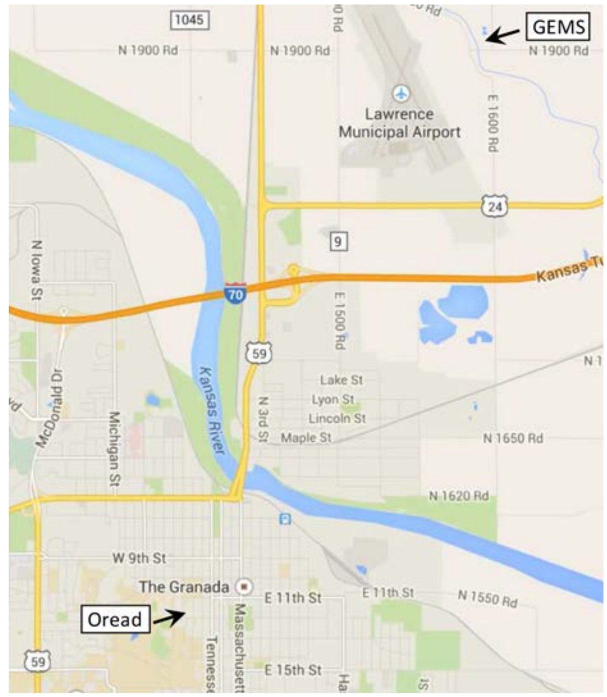

Figure 1. Google Map of GEMS.

GEMS is also used as the field site for classes in the Geology Department at the University of Kansas.

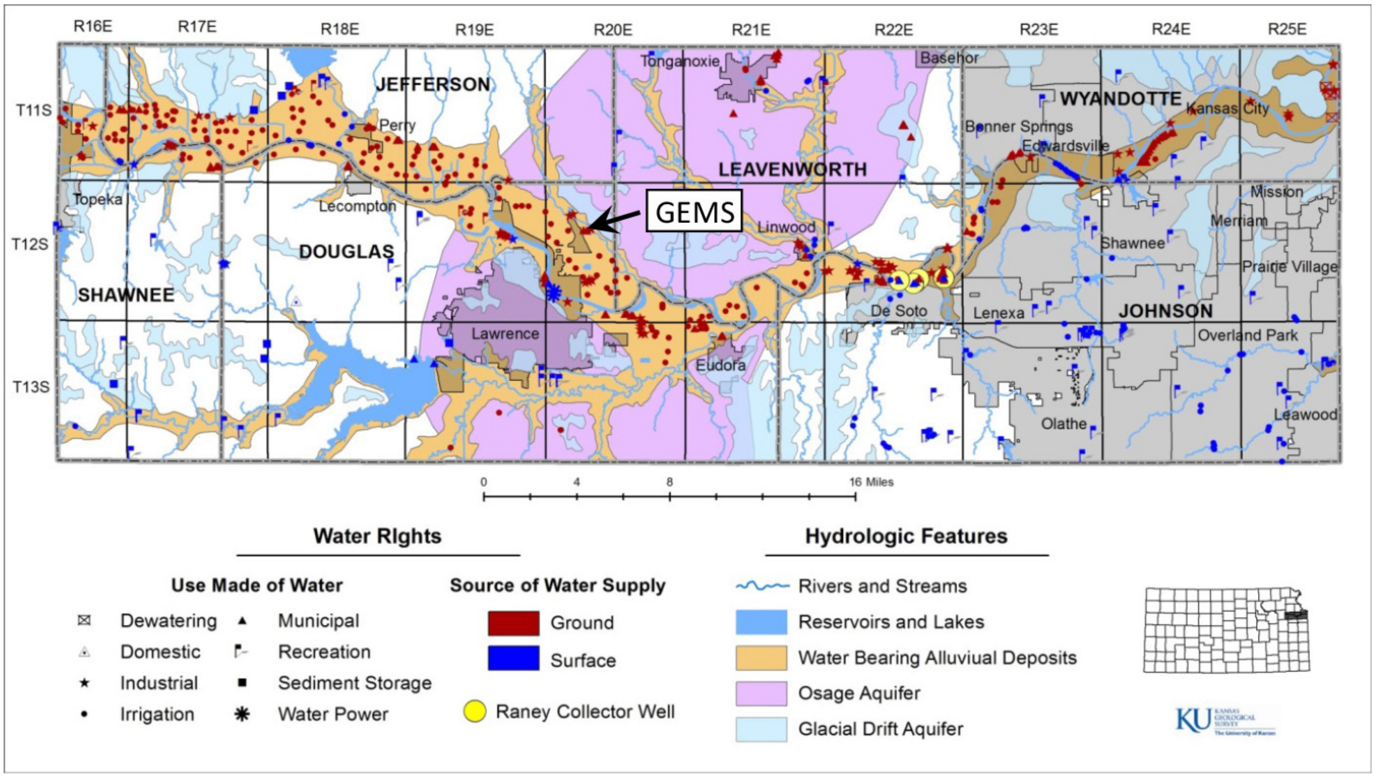

Figure 2. Hydrologic features and location of water rights in the corridor of the lower Kansas River valley in northeast Kansas. GEMS is located near the edge of the Kansas River valley. Note the substantial number of groundwater rights (red circles) within the alluvial deposits of the Kansas River valley (the main alluvial feature crossing the map).

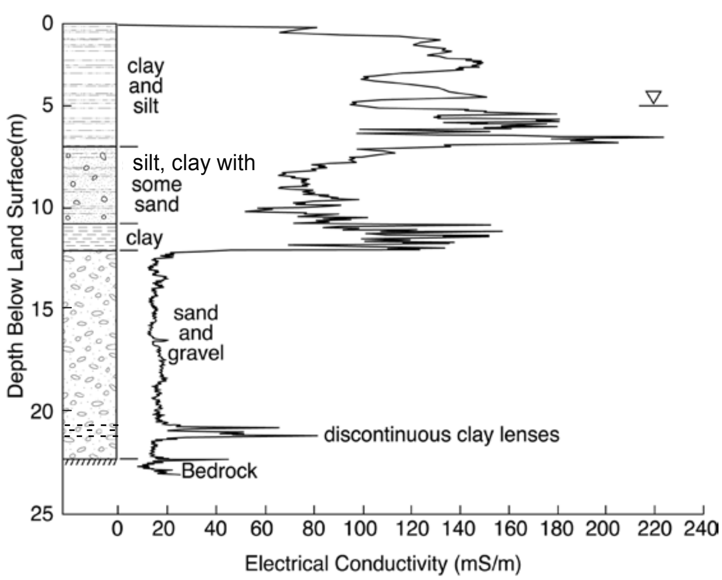

Figure 3. Generalized stratigraphy of the Kansas River alluvium at GEMS (Butler, 2005). The water table is shown by the inverted triangle. The sand and gravel interval responds to pumping as a semi-confined aquifer.

ICEBREAKER RECEPTION

Date: May 18, 2015
Time: 5:00–8:30 p.m.
Place: Adams Alumni Center
Cost: Included in registration

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The Office of the Provost of the University of Kansas is sponsoring an Icebreaker Reception for NovCare 2015 that is open to all conference participants. The reception will be held in the Summerfield Room of the Adams Alumni Center, a five-minute walk from the Oread Hotel along Jayhawk Boulevard. At the reception, you can receive your registration materials and meet fellow attendees while enjoying drinks and light appetizers. Reception attendees can park in the Alumni Center parking lot at no cost.

POSTER AND EXHIBITOR RECEPTION

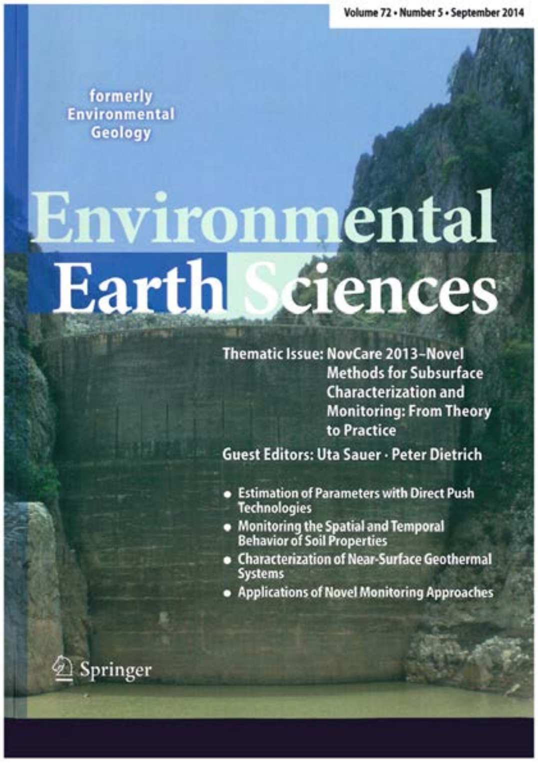
Date: May 19, 2015
Time: 5:00–7:00 p.m.
Place: Oread Hotel
Cost: Included in registration

The Poster and Exhibitor Reception, which is open to all conference participants, will be held in the All Seasons Den of the Oread Hotel at the end of the first day of the conference. At the reception, you can partake of drinks and light appetizers while viewing the posters and exhibitor booths.

CONFERENCE BANQUET

Date: May 20, 2015
Time: 7:00–9:30 PM
Place: Free State Brewery
Cost: Separate charge

The banquet will be held at the end of the second day of the conference at the Free State Brewery in historic downtown Lawrence. A bus will be available to transport attendees between the Oread Hotel and the Brewery. Although the Brewery is about a 20-minute walk from the Oread Hotel, the return walk has a significant ascent in its latter portions.



Special Issue about NovCare 2015

- Publication in ISI journal Environmental Earth Sciences (Springer, Impact Factor: 1.572)
- Papers related to the NovCare 2015 conference themes are invited
- Submission directly to the journal
- All papers have to pass reviewing process

Information about intention to contribute:
June 30, 2015 (to uta.sauer@ufz.de)
Deadline for Submission:
September 30, 2015
Publication of Special Issue:
Beginning 2016