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***Washington State Convention Center – October 5-8, 2014 – Seattle, Washington***

# Event Handbook:

- **Agenda**
- **Abstracts**
- **Attendee list**

*The GWPC provides a forum for stakeholder communication and research exchange to improve governments' role in the protection and conservation of groundwater.*

Ground Water Protection Council * *13308 N. MacArthur Blvd., Oklahoma City, OK 73142, * 405 516 4972 * www.gwpc.org **

## Sunday, October 5

Registration opens at 7:00am

8:00-12:00 State Oil & Gas Regulatory Exchange Induced Seismicity Working Group (workgroup members only) ROOM 618

SOGRE
State Oil and Gas Regulatory Exchange

StatesFirst
An initiative of the IOGCC & GWPC

8:30-12:00 ROOM 617
GWPC ASR & Aquifer Exemption Working Group
(State workgroup members only)

1:00-5:40 ROOM 619-620

Groundwater Training Spotlight series

Abstracts 1: Mike Wireman – National Groundwater Expert

1:00-3:30 Basic Principles of Groundwater Occurrence and Flow
What is groundwater?
Hydrologic cycle
Geology and groundwater
Groundwater hydrology
Groundwater –surface water interaction
Groundwater quality

4:00-5:40 Transport and Fate of Contaminants in Groundwater
Natural groundwater chemistry
What is meant by transport and fate?
Controls on contaminant transport and fate
Chemical, physical, biological processes that control transport & fate
Contaminant plumes
Contaminant transformation
Groundwater microbiology

1:30-5:40 ROOM 618

Board of Directors Meeting

1:30-5:40 ROOM 615-616
Professional Development Training
*Communicating Relative Environmental Risk* Spotlight series

*Best practices in risk communication of water related risks.*
Todd Norton, Washington State University
Jason Sampson, Washington University
Module I: When water becomes a human health threat.
Categorizing contaminants
Mapping contaminants, vectors, and exposures.
Discussion of infographic for public information.
Module II: Social dynamics impacting human behavior in persistent/non-persistent, organic/synthesized, and toxins/non-toxins.
Module III: Communicating water risk to publics

Abstracts 1: Assessing and Communicating Relative Risk of Hydraulic Fracturing by Oil and Natural Gas Development – Bill Rish, Hull Risk Analysis Center

Abstract 2: NETL's Variable Grid Method Tool for Simultaneous Visualization and Assessment of Spatial Trends and Uncertainty - Jennifer R. Bauer and Kelly Rose, National Energy Technology Laboratory

5:45-7:30 pm *YOU ARE INVITED...* to the *2014 GWPC Annual Forum Welcome Reception*
Atop of the Sheraton Hotel in the Cirrus Ballroom with breathtaking views of downtown Seattle

GROUNDWATER RESEARCH & EDUCATION FOUNDATION

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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Ground Water Research & Education Foundation
Spotlight series

Chesapeake ENERGY

*Thank you for caring about Groundwater!*

## Monday, October 6

**Morning Reception 7:00 – 9:20 West Lobby – upper level**

8:00–9:20 ROOM 619-620

Nutrients in Groundwater – Moderator John Barndt, DE DNREC

Abstracts 2: Nitrogen Dynamics at a Manured Grass Field Overlying the Sumas-Blaine Aquifer in Northwest Washington - Barbara M. Carey, Washington State Department of Ecology.

Abstracts 3: Nitrates in Nebraska groundwater and a small town's plight to avoid treatment - Ryan Chapman, Nebraska Department of Environmental Quality

Abstracts 3: The Washington Nitrate Prioritization Project - Laurie Morgan, Washington State Dept. of Ecology

Abstracts 4: Is It Working?: Lysimeter Monitoring in the Southern Willamette Valley Groundwater Management Area Susanna L. Pearlstein, University of Arizona

8:00-9:20 ROOM 615-616

Oil Gas Produced Water Management & Reuse

Spotlight series

The oil and gas industry is not only in the energy production business, they are also in the WATER management business. GWPC advocates the BEST and most efficient management of this precious natural resource for beneficial use if not utilized now, managed for the future.

The Oil and Gas industry manages a vast quantity of produced water now. Unfortunately there are often barriers including technical, economic, storage/location, regulatory, etc. that prevent the most beneficial use or management of produced water.

Abstracts 5: Observations and Thoughts on Produced Water Management - John Veil – Veil Environmental, LLC

State Panel: Leslie Savage (TX), Mark Bohrer (ND), Joe Lee (PA), & Tim Baker (OK)

9:20–9:30 Break

9:30-11:00 ROOM TBA

NRWA/GWPC Session

USDA – Rural Utility Services Forum: New Funding Opportunities

9:30-11:00 ROOM 615-616

Induced Seismicity Technical Session (Open session)

Abstracts 5: Assessing and Communicating Relative Risk of Induced Seismicity by Oil and Natural Gas Development – Bill Rish, Hull Risk Analysis Center

Abstracts 5: Ground Movement and Induced Seismicity – Arthur Frankel, USGS

Abstracts 6: Seismic Studies Program at the Alberta Geological Survey - Dr. Todd Shipman, Alberta Geological Survey, Alberta Energy Regulator

Abstracts 6: Seismicity and the SWD-C4A Well: An ongoing UIC Case Study in the Denver Basin, Colorado Chris Eisinger, Stuart Ellsworth, and Bob Koehler, Colorado Oil and Gas Conservation Commission

11:10-1:20– Metropolitan Ballroom A – Sheraton 3rd level

Opening Session and Luncheon: *Groundwater Sustainability… a critical component of the ecosystem Metropolitan A*

Federal Groundwater Initiatives Panel Abstracts 7:

Moderator Leslie Savage, Chief Geologist, Railroad Commission of Texas, and GWPC President

Peter Grevatt, Director Office of Ground Water and Drinking Water, Environmental Protection Agency

Nancy Johnson, Environmental Science and Policy Analyst, United States Department of Energy

Bill Cunningham, USGS Chief of the Office of Groundwater, United States Geological Survey

Lunch Presenter Clarita Lefthand-Begay, Navajo Nation

Ground Water Research & Education Foundation Spotlight series

*Select sessions are part of the Spotlight Series…*
*…the technology transfer initiative of the*
*Ground Water Research & Education Foundation*

GROUNDWATER RESEARCH & EDUCATION FOUNDATION

| Monday, October 6 | |
|---|---|
| 1:40-3:20 ROOM 619-620 ROOM 615-616<br>Groundwater Management and Sustainability – Moderator Marty Link, NE<br><br>Abstracts 8: Keeping the Pump Primed: Aquifer Sustainability - John Jansen, Cardno Entrix<br><br>Abstracts 8: The Forest Service Proposed Groundwater Directive: Status, Intent, and Path Forward - Chris Carlson, USDA Forest Service<br><br>Abstracts 9: A Groundwater Balancing Act: Using the Groundwater Requirements of Wetlands to Set Limits to Groundwater Alteration - Allison Aldous, The Nature Conservancy, Portland, OR. & Chris Carlson, USDA Forest Service<br><br>Abstracts 9: Alabama Groundwater Sustainability: A Strong Scientific Foundation for Water Resource Management and Policy to Secure Alabama's Water Future - Marlon R. Cook, Geological Survey of Alabama | 1:40-3:20 ROOM 615-616<br>Oil and Gas Environmental Workshop<br><br>Abstracts: Introduction and Overview of the Course & Pre and Post Drill Sampling, Monitoring, and Interpretation of Results: Paul Jehn, GWPC<br><br>Abstracts 12: EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil & Gas on Drinking Water Resources - Ramona Trovato, Acting Principal Deputy Assistant Administrator, USEPA Office of Research and Development<br><br>Abstracts13: State Baseline Water Quality Programs for Oil & Gas Operations- Bob Puls, Oklahoma Water Survey<br><br>Abstracts13: State and Local Regulations for Pre and Post Drill Monitoring - Kate Konschnik, Harvard Law |
| 3:20-3:40 Break | |
| 3:40-6:00 ROOM 619-620 Water Sustainability (cont.)<br><br>Abstracts 9: NGWA Informational Resources: Defining Managed Aquifer Recharge and Best Suggested Practices for Aquifer Storage and Recovery - William Alley, Ph.D., National Ground Water Association and Steven P. Musick, P.G., Ground Water Protection Council<br><br>Abstracts10: ASR & Agriculture: How Washington Farmers are Moving to Smarter Water Solutions – Tuck Russell, Winery Owner<br><br>Abstracts10: Can the Ogallala Aquifer Sustain Long Term Ground Water Production? Jay Lazarus, PhD, Glorieta Geoscience, Inc.<br><br>Abstracts11: Conceptual Model for the Kitsap Peninsula, Kitsap, Mason, and Pierce Counties, Washington Wendy Welch, USGS, Washington Water Science Center<br><br>*Enhancing Sustainability by Characterizing New Resources*<br>Abstracts11: Using Oil and Gas Data to Find Groundwater Supplies Patricia Billingsley and Madeline Dillner, Oklahoma Corporation Commission<br><br>Abstracts12: Characterization of Deep Groundwater, William M. Alley, NGWA<br><br>Abstracts12: Permian Basin Water Reuse and Surface Water Supplies - David Holt, Permian Basin Petroleum Association | 3:40-6:00 ROOM 615-616<br><br>Oil and Gas Environmental Workshop (cont.)<br><br>Abstracts13: The Use of Strontium Isotope and Element Geochemistry to Characterize Water from Fossil Fuel Sources - Liz Chapman, PhD., ECHELON Applied Geosciences<br><br>Abstracts14: A Review and Comparison of the Methods and Variables within the Methods Used for the Investigation of Dissolved Gas Concentrations - Charles J. Neslund, Eurofins Lancaster Laboratories Environmental, LLC. |

Tuesday, October 7

Morning Reception 7:30-10:00 West Lobby – upper level

8:00-9:40 State / Federal / Tribal Roundtable (governmental officials only) ROOM 618
Moderators: Mike Eggert, OH EPA; Leslie Savage, Railroad Commission of TX;
Ron Bergman, USEPA; & Kurt Hildebrandt, USEPA Region 7
NEW Groundwater Initiatives - State, Federal, Tribal
Groundwater sustainability
ASR as a management tool
State Water planning efforts
Groundwater policy/regulatory development
Reaction to proposed US Forest Service Groundwater Directive
Waters of the US and Groundwater
EPA's NEW Aquifer Exemption check list (EPA memo)
Induced Seismicity - National Technical Workgroup Update and State Initiatives
Injection pore space competition
Groundwater research needs
Nutrients
Stormwater management--groundwater contamination
Hydraulic Fracturing
Groundwater awareness
Aboveground Storage Tanks dealing with potential releases/SWP
Domestic water well education/monitoring

8:00-9:40 ROOM 615-616
Oil and Gas Environmental Workshop
*Stray Gas Migration* – Preparedness & Incident Response™
Fred Baldassare, Echelon Applied Geosciences & Debby Yost, Chesapeake Energy Abstracts14:
Recent Research, Regulatory & Policy Initiatives
Physical/chemical properties of methane & light gases
- Gas phase
- Dissolved phase

Sampling for dissolved and gas phase methane
- Establishing baseline
- Methane: natural variability vs. anthropogenic impact
- Protocol for dissolved phase & gas phase sampling
- Evaluation of field and laboratory methane data
- Isotope sampling protocol

9:40-10:00 Break

10:00-11:40 ROOM 619-620
*Groundwater Availability, Sustainability, & Water Planning*
Moderator – Kevin Frederick, WY

Abstracts15: Overview of National Climate Assessment Development Advisory Committee - Paul Fleming, Seattle Public Utilities' Climate Resiliency Program

Abstracts15: Sustainable Water Management in Massachusetts – Duane LeVangie, Water Management Program Chief, MA DEP

Abstracts16: Hydraulic Fracturing and Water Tracking – Thom Kerr

State Groundwater Resource Evaluation Status – Discussion Session… what do we know and what do we need to know regarding groundwater quality and planning for the future

10:00-11:40ROOM 615-616
*Stray Gas Migration* – Preparedness & Incident Response™ (cont.)
General Chemistry Parameters
- Pre-drill & post drill
- Potential impacts to groundwater geochemistry

Stray Gas Migration Response Protocol – Site Investigation/demonstration
- Methodology to determine threat level
- Geological setting
- Stray gas case studies

Measures to protect public health & safety
- Interim remedial measures
- Long-term remedial measures

Principles and design

Lunch on your own
11:40-1:00

Tuesday, October 7

1:00-2:20 ROOM 619-620

Water Quality and Quantity *Private Water Well*

Abstracts16: Communicating Water Well Stewardship to Elicit Effective Behaviors Kevin B. McCray, National Ground Water Association

Abstracts17: PrivateWellClass.org – An Online Technical Assistance Program for Private Well Owners Steven D. Wilson, Illinois State Water Survey

Abstracts17: Private Well Sampling Near Oil and Gas Operations - Bob Puls, Oklahoma Water Survey

Abstracts18: Texas Well Owner Network: Protecting Groundwater Resources and Human Health - Drew Gholson, Texas A&M AgriLife Extension Service

1:00-2:20 ROOM 615-616

Oil and Gas Environmental Workshop (cont.)

Well Integrity: Stray Gas Wellbore Intrusion Analysis Abstracts:

J. Daniel Arthur, P.E., SPEC & Tom Tomastik, P.G., ALL Consulting

Well Integrity & Gas Intrusion

Regulatory Considerations

- State-Specific Requirements
- Variations Among States
- Useful References
- Others Considerations
- Drilling Method issues

Air

Mud Rotary

Adequate vs. Failed Cement

2:20-2:40 Break

*2:40-5:20* ROOM 619-620 Water Quality

Groundwater Monitoring – Moderator Joe Lee, PA

Abstracts19: Development and Implementation of National Ground Water Monitoring Network - Mike Wireman, Sub-Committee on Groundwater, U.S. EPA, retired

Abstracts19: Wyoming Groundwater-Quality Monitoring Network Gregory K. Boughton, Wyoming-Montana Water Science Center of the USGS

Abstracts20: The Kentucky Interagency Groundwater Monitoring Network: Expanded Monitoring Programs Jessica Moore, Kentucky Division of Water

Abstracts20: Required Baseline and Ongoing Monitoring of Groundwater in CBM Areas of Colorado – Use in Case Studies of Possible Impacts to Groundwater. Peter Gintautas, Colorado Oil and Gas Conservation Commission

Groundwater Protection

Abstracts21: How do States Define "Usable Quality" Groundwater? - Steven P. Musick, Ground Water Protection Council

Abstracts21: Hunting Big Brine: How the Oklahoma Corporation Commission is using Historical Aerial Photographs to Protect Oklahoma Waters Madeline Dillner, Oklahoma Corporation Commission

*2:40-5:20* ROOM 615-616

Well Integrity: Stray Gas Wellbore Intrusion Analysis (cont.)

Well Integrity Analysis

- Using Holistic Analysis
- Well Records Analysis
- Timeline Analysis
- Well Site Safety
- Vent Rate Testing Methods
- Pressure Testing & Analysis
- Well Logging Method
- Other Methods

Wellbore Remediation

- Developing an Approach
- Remedial Design
- Remedial Considerations
- Remedial Methods
- Remedial Products

Case Study

Abstracts: Huerfano County Colorado Stray Gas Incident Response and Monitoring Peter Gintautas, Colorado Oil and Gas Conservation Commission

Summary and Conclusions

*2:40-4:40* ROOM 618

*Training Session*

Abstracts22: NETL's Variable Grid Method Tool for Simultaneous Visualization and Assessment of Spatial Trends and Uncertainty - Jennifer R. Bauer and Kelly Rose, National Energy Technology Laboratory

- Introductions etc
- Overview and introduction to the VGM approach
- Q&A
- Training for use of the VGM Tool

Wednesday, October 8

Morning Reception 7:00-10:20 West Lobby – upper level

8:00-10:00 ROOM 619-620

EPA Source Water Session Abstracts22:

Session Goal: Share new and forthcoming tools to help states and others use data and collaboration to protect drinking water sources and respond to critical opportunities to improve source water protection

- Overview of Tools for Source Water Protection - Holly Green, Acting Branch Chief, Prevention Branch, EPA OGWDW

New and Forthcoming Tools

- DWMAPS: EPA developing new GIS tool to update/improve source water assessments and plans - Sherri Comerford, Prevention Branch, and Rachel Carlson, ORISE Intern, Prevention Branch, EPA OGWDW
- Source Water Collaborative "How-to Collaborate Toolkit": Connect with key partners to implement priority source water protection actions - Rachel Carlson, ORISE Intern, Prevention Branch, EPA OGWDW
- Tools for emergency notification, mitigation, and resiliency measures- Rachel Carlson, ORISE Intern, Prevention Branch, EPA OGWDW
- Brief overview of resources developed by EPA's Water Security Division. Discussion may include tools for contaminant fate and transport, natural disaster preparation, and notifying nearby utilities of a potential source water contamination incident.

8:00-10:00 ROOM 615-616

Unconventional Oil and Gas Water Management – Moderator Tim Baker, OK

Abstracts26: Oil & Gas Industry's Impact on Rural Water Systems – Ken Royse, Bartlett and West Inc.

Abstracts26: Regulatory and Infrastructure Challenges – Heather Palmer, Bracewell & Giuliani.

Abstracts27: Water Use by Sector: An Analysis of FracFocus and USGS Water Use Data Mike Nickolaus, GWPC

Abstracts27: Shale Energy Produced Fluids Management and UIC Well Disposal Trends David Yoxtheimer, P.G. Associate with Penn State University

Panel Discussion: *Developing Water and Oil & Gas Sector Partnerships*

Abstracts: Panel discussion by state regulators, water system managers and oil and gas industry representatives Developing Water and Oil & Gas Sector Partnerships

10:00-10:20 Break

10:20-12:40 ROOM 619-620

*Source Water Protection* Moderator – Evan Cane, NC

Abstracts23: NGWA/ANSI Water Well Construction Standard, Kevin B. McCray, National Ground Water Association

Abstracts23: Collaborative Approaches to Source Water Protection Plan and Stormwater MS4 Implementation - Matt Genchur, Pennsylvania Rural Water Association (PRWA).

Abstracts24: Kentucky's Source Water Protection Assistance Program Jessica Moore, Kentucky Division of Water

Abstracts24: Trends in Permitting of Class V Wells in Alabama – Sonja Massey, ADEM

*Onsite and Decentralized Septic Systems – BMPs for Source Water Protection*

Abstracts25: Sustainability is the Name of the Game – EPA's Decentralized Wastewater Program Efforts' Maureen Tooke, Environmental Protection Specialist

10:20-12:40 ROOM 615-616

*Unconventional Oil and Gas Water Management* Moderator Stan Belieu, NE

Abstracts28: Disposal Wells and Shale Resource Development: A National Perspective J. Daniel Arthur, ALL Consulting

Abstracts28: An Evaluation of Fracture Growth and Gas/Fluid Migration as Horizontal Marcellus Shale Gas Wells are Hydraulically Fractured in Greene County, Pennsylvania - Richard Hammack, Office of Research and Development, NETL-DOE

Abstracts29: Comparative Databases for Water Quality and Quantity Regulations Pertaining to Oil and Gas Development Matt Samelson, University of Colorado

Abstract29: Virtual Hydraulic Fracturing Site Andra Wilcox, HARC

# Abstracts

## Basic Principles of Groundwater Occurrence and Flow and Transport and Fate of Contaminants in Groundwater

**Mike Wireman** – National Groundwater Expert

Michael Wireman is a hydrogeologist recently retired from the US Environmental Protection Agency in Denver, CO where he served as a National Ground-Water Expert. Currently he is a member of the ACWI Sub-Committee on Groundwater engaged in the development and implementation of a national groundwater monitoring network, a member of the Board of Directors of the Science and Engineering Division of the National Ground Water Association, serves as an advisor to the World Bank and is currently in the process of joining the roster of expert witnesses for the US Department of Justice. He has a Master's degree from Western Michigan University in Kalamazoo, Michigan, PhD level classes in hydrogeology at the Colorado School of Mines and 33 years of experience in ground-water investigations in the western USA, Eastern Europe, Republic of Georgia, the Middle East, Russia and China. Mike has managed applied research projects related to solvent contamination of groundwater, mine-site hydrology / geochemistry, ground-water sensitivity/vulnerability assessment, isotope hydrology, and aquifer characterization. He has significant experience in the legal, scientific and programmatic aspects of ground-water resource management. He has served as an adjunct professor at Metropolitan State College in Denver where he taught a class on Contaminant Hydrology. He is a member of the Colorado Ground- Water Association, the Geological Society of America, and is a past Chair of the North American Chapter of the International Association of Hydrogeologists.

## Comparing and Communicating the Relative Risks of Hydraulic Fracturing of Shale for Natural Gas

**William Rish** Ph.D., Hull Risk Analysis Center directs the Hull Risk Analysis Center, a team of experts that apply science and communication skills to support risk-based decisions. For over 30 years, Dr. Rish has prepared hundreds of risk assessments and has been active in the development of federal and state regulatory policy and guidance on risk assessment and risk-based cleanup standards. He is currently serving as chair of the Marcellus Shale Coalition work group on hydraulic fracturing risks and as a member of the American Petroleum Institute work group on induced seismicity. Bill earned his doctorate in Engineering and Public Policy and his Bachelor of Science in Metallurgy/Material Science and Public Affairs (jointly conferred) from Carnegie-Mellon University.

Rapid growth of the use of hydraulic fracturing along horizontal stages in shale formations for the extraction of natural gas has resulted in significant regulatory agency and public concern about the environmental risks that may be associated with this development. Publicity and media coverage have increased these concerns. All human activities to use natural resources and technology for the benefit of society have corresponding risks. As such, understanding the relative risks of hydraulic fracturing in shale is useful for making decisions about how to best regulate and communicate the risks. To be most useful, this understanding of relative risks is best developed by considering both technical risk factors and perceived risk factors.
This presentation explores comparing and communicating the technical and perceived risks of hydraulic fracturing for shale gas development relative to other technological activities, including extracting and using other natural resources. The relative nature and significance of technical risks are compared, and risk perception factors that can impact effective risk communication are also compared.

## NETL's Variable Grid Method Tool for Simultaneous Visualization and Assessment of Spatial Trends and Uncertainty –

Jennifer R. Bauer and Kelly Rose, NETL

Jennifer Bauer is a post-graduate research fellow for the National Energy Technology Laboratory's Office of Research & Development. Her current research leverages her risk and hazard, GIS, GIS programming, and spatial statistics background to analyze spatio-temporal trends, interpret spatial datasets, and assess risks and potential impacts associated with various forms of energy production and development.

Kelly Rose is a research geologist and Geology Team Lead with the National Energy Technology Laboratory's Office of Research & Development (NETL-ORD). Previously, she worked on the assessment of tight gas resources in the western United States, first as an exploration geologist and then as a research geologist with DOE/NETL. At present, she works with research teams spanning ORD's geologic and environmental sciences portfolio conducting geologic and geospatial research in support of energy and climate related programs. She also serves as the coordinator and systems integrator for NETL's Energy Data eXchange, a public and private online coordination/collaboration knowledge management tool.

The products of spatial analyses that leverage the interpolation of sparse, point data to represent continuous phenomena are often presented without clear explanations of the uncertainty associated with the interpolated values. As a result, there is frequently insufficient information provided to effectively support advanced computational analyses and individual research and policy decisions utilizing these results. This highlights the need for a reliable approach capable of quantitatively producing and communicating spatial data analyses and their inherent uncertainties for a broad range of uses. To address this need, NETL has developed the Variable Grid Method (VGM), a flexible approach designed to apply to a variety of analyses and use case scenarios where users need a method to effectively study, evaluate, and analyze spatial trends and patterns while communicating the uncertainty in the underlying spatial datasets. The VGM outputs a simultaneous visualization representative of the spatial data analyses and quantification of underlying uncertainties, which can be calculated using data related to sample density, sample variance, interpolation error, uncertainty calculated from multiple simulations, etc. We will present examples of our research utilizing the VGM to quantify key spatial trends and patterns for subsurface data interpolations and their uncertainties and leverage these results to evaluate storage estimates and potential impacts associated with underground injection for $CO_2$ storage and unconventional resource production and development. The insights provided by these examples identify how the VGM can provide critical information about the relationship between uncertainty and spatial data that is necessary to better support their use in advance computation analyses and informing research, management and policy decisions.

VGM Tool Training: Whenever utilizing spatial data to drive advanced computational analyses or inform management, research, and policy related decisions, it becomes critical that any underlying uncertainties are appropriately quantified and communicated. This course will explore how NETL's VGM approach can be apply to various spatial data analyses and interpretations to provide a single product that simultaneously communicates spatial data patterns and trends and any uncertainties underlying the data and/or analyses. Through discussion and demonstration this course will outline the VGM, familiarize users with the products that can be created using the VGM approach, introduce users to the Variable Grid Tool, a plug-in Python tool for ArcGIS that helps facilitate the VGM approach, and present examples utilizing various spatial datasets to create different variable grids that represent multiple forms of uncertainty quantification. Participants should have a familiarity with spatial datasets and software used to work with such data.

## Nitrogen Dynamics at a Manured Grass Field Overlying the Sumas-Blaine Aquifer in Northwest Washington

Barbara M. Carey, Washington State Department of Ecology and Joe H. Harrison, Washington State University and Extension Center

Barbara Carey is a licensed hydrogeologist with the Washington State Department of Ecology. She has an M.S. from the University of Washington, Seattle, in Environmental Engineering and Science. Much of her work has been studying non-point source impacts on groundwater and the vadose zone, including land application of nutrients and wastewater.
Joe Harrison is a professor at Washington State University and Extension Center (Puyallup). He leads the Livestock Nutrient Management Research and Outreach Program at WSU Puyallup. He has a PhD from Ohio State University with projects in whole-farm nutrient management involving integration of animal nutrition, agronomy-crops-soils, engineering, and economics.

The Washington State Department of Ecology, in cooperation with Washington State University, conducted a 4-1/2-year intensive monitoring study at a manured grass field overlying the Sumas-Blaine Aquifer in northwest Washington. The purpose of the study was to evaluate nitrogen dynamics in dairy manure, soil, crop, and groundwater at a field overlying the Sumas-Blaine Aquifer.

We quantified the mass of nitrogen added to the field in the form of manure, inorganic fertilizer, and irrigation water; the mass of nitrogen removed in the crop; the mass of nitrate in the soil during the post-harvest period; and the concentration of nitrate in groundwater beneath the field. Shallow depth to water enabled rapid responses to nitrate transport, especially during the high-rainfall period (October through March).

Average monthly nitrate concentrations in 6 shallow monitoring wells ranged from 5.5 to 30 mg/L-N with a maximum in one well of 45 mg/L-N. Early winter average nitrate concentrations in groundwater, representing newly recharged water carrying nitrate from the soil column, were (1) above 10 mg/L-N following growing seasons with nitrogen loading greater than the mass of nitrogen removed in the crop and (2) generally below 10 mg/L-N when nitrogen loading was similar to crop removal. Other factors that affected nitrate concentrations in groundwater included timing of manure applications, tillage shortly before the study began, and denitrification in the aquifer.

Model results based on measured field parameters indicated an average of 115 lb/acre of nitrate leached to groundwater from September through March. Two methods for estimating the nitrogen residual at the end of the growing season, mass balance analysis and post-harvest soil nitrate testing, were not reliable predictors of nitrate concentrations in groundwater. Direct monitoring of water quality at the water table was the only reliable method for tracking effects of manure management on groundwater nitrate.

## Nitrates in Nebraska Groundwater and a Small Town's Plight to Avoid Treatment

Ryan Chapman, Nebraska Department of Environmental Quality

Ryan Chapman is the Wellhead Protection program coordinator with the Nebraska Department of Environmental Quality since 2009. He also administers many of the groundwater related Section 319 Non-Point Source grants that the State awards annually. Ryan holds a Bachelor's degree in Agricultural Sciences and Natural Resources and from the University of Nebraska Lincoln, and Bachelor's and Master's degrees in Landscape Architecture from Iowa State University. His graduate work focused on urban groundwater, stream conditions, and landowner perceptions.

Nearly 500,000 analyses from 25,000 wells have been collected and compile since 1974 in the State's Quality-Assessed Agrichemical Database for Nebraska Groundwater. With approximately 172,000 active registered water wells, resources only allow samples from 1.9% to 2.6% of these annually. As a result, a selection of approximately 1,400 wells, mostly irrigation, were identified and targeted for annual sampling to support long-term trend analyses. Multi-level dedicated monitoring wells are currently being installed to supplement this network. Nitrate is Nebraska's number one groundwater contaminant requiring 66 of the 550 groundwater based community public water systems to perform quarterly sampling. An example of this is a small community of 250, first issued an administrative order for nitrate in 2005. Since that time they have conducted numerous studies and implemented on-the-ground best management practices to avoid treatment. They are currently working on ways to utilize and protect better quality water in bottom portions of the aquifer. Discrete annular seals are being retrofitted into existing irrigations wells and abandoned wells are being decommissioned using explosion techniques to plug annular spaces. Cutting edge on-the-ground best management practices are also being implemented utilizing the latest variable rate irrigation and fertilization technologies on crop ground in their wellhead protection area.

## The Washington Nitrate Prioritization Project

Laurie Morgan Washington State Dept. of Ecology

Laurie Morgan is a Hydrogeologist with the Washington State Dept. of Ecology, Water Quality Program. She was responsible for the Aquifer Vulnerability Project and rewrote and updated the Critical Aquifer Recharge Areas technical guidance to assist local government who must protect groundwater under the Growth Management Act. Currently, Laurie is working on the Washington Nitrate Prioritization project. She began her career working on Superfund sites in the San Fernando Valley, California in the Wellhead Investigation Program after graduating from California State University Fullerton with a B.S. in Geological Sciences, emphases in hydrogeology and engineering geology. Email: lmor461@ecy.wa.gov.
The Washington Nitrate Prioritization Project grew out of discussions held by agency directors in 2012 at the behest of then Governor Gregoire to address agricultural pollution of surface and ground water.

Public concern about nitrate contamination of drinking water has risen over the last few years as knowledge of these problems has grown. Many small water systems face high costs to supply clean water when nitrates rise above the health limit of 10 mg/L.

Residential wells in many areas of the state have been sampled and found to exceed the health limit for nitrate. Residential wells in areas with known nitrate exceedances that may not have been sampled are of concern.

Project goals are to:

- Identify areas statewide where nitrates in groundwater have exceeded or are at risk of exceeding drinking water standards.
- Rank and prioritize these areas based on such information as population and resources impacted.
- Explore how the groundwater quality data for this project could be housed and publicly shared.
- Prepare the data and GIS information collected during this project for a potential web application.

Information developed during this project can be used to help:

- Coordinate cross-agency nitrate management strategies and action plans.
- Target resources where they are most needed to protect public health.
- Prioritize the implementation of nitrate source loading reduction and controls.
- Plan monitoring strategies for current conditions /trends over time.
- Plan effectiveness monitoring strategies.
- Provide important information to well owners deciding whether to test their well water.
- Provide everyone, including those who control nitrate loading sources, information about what is known about nitrate contamination of groundwater in their area and how people and resources are impacted.
- Aid in evaluating potential loading sources and for supporting future loading estimates.

The project plan is online.

## Is It Working? Lysimeter Monitoring in the Southern Willamette Valley Groundwater Management Area

Susanna L. Pearlstein[1], Jana E. Compton[2], Audrey Eldridge[3], Alan Henning[4]
John Selker[5], J. Renée Brooks[6]
[1]PhD Candidate, Department of Soil, Water and Environmental Science, University of Arizona, Tucson, AZ;
[2]Ecologist, U.S. Environmental Protection Agency NHEERL Western Ecology Division, Corvallis, OR
[3]Coordinator for the Southern Willamette Valley Groundwater Management Area, Oregon Department of Environmental Quality
[4]Environmental Protection Specialist, U.S. Environmental Protection Agency Region 10 Office of Water and Watersheds, Eugene, Or

Groundwater nitrate contamination affects thousands of households in the southern Willamette Valley and many more across the Pacific Northwest. The southern Willamette Valley Groundwater Management Area (SWV GWMA) was established in 2004 due to nitrate levels in the groundwater exceeding the human health standard of 10 mg nitrate-N $L^{-1}$. In impacted rural areas, well water concentrations are often above this level but households may be unaware of this contamination, increasing the risk of health problems associated with nitrate consumption. Much of this nitrate comes from agricultural nitrogen use and Confined Animal Feeding Operations, CAFOs, and thus improvements in N management are needed to reduce the leaching to groundwater. Previous work in the Willamette Valley by researchers at Oregon State University determined the importance of cover crops and irrigation practices in reducing nitrogen (N) leaching. We are re-sampling many of the same fields studied by OSU to examine the influence of current crops and nutrient management on nitrate leaching below the rooting zone. This study represents crops currently grown in the GWMA and includes five grass fields, three vegetable fields, and one each of mint, hazelnuts, blueberries and wheat. New nutrient management practices include slow release fertilizers and precision agriculture approaches in some of the fields. This work will examine the nitrogen balances and rate of N leaching at the field level from the 1990's to the present. The goal of this project is to provide information and tools that will help farmers, managers and conservation groups quantify the water quality benefits of management practices they are conducting or funding. In addition, the data from this study will be incorporated into the USDA-APEX model to help inform the development of a nutrient water quality trading framework in the GWMA.

## Observations and Thoughts on Produced Water Management

John Veil – Veil Environmental, LLC

Very large volumes of produced water are brought to the surface during oil and gas production. Management of produced water is a challenge for the industry – produced water management represents a significant cost to producers and an important business opportunity for companies providing water technologies and services.

This presentation offers observations and thoughts that can help producers better understand produced water and choose appropriate water management approaches. There is no single option that is the best for all situations. Understanding the key drivers for option selection help companies evaluate a range of potential options and choose the option that is the best fit for their site.

The main themes covered during the presentation are:

- Background on produced water
- U.S. water volumes and management practices
- Different water issues for each type of oil and gas production
- Key concepts for water management
- How clean must water be/choosing technologies
- How regulations/standards play a role.

## Comparing and Communicating the Seismic Risks of Hydraulic Fracturing of Shale for Natural Gas

William Rish, Ph.D. - Hull Risk Analysis Center

William Rish directs the Hull Risk Analysis Center, a team of experts that apply science and communication skills to support risk-based decisions. For over 30 years, Dr. Rish has prepared hundreds of risk assessments and has been active in the development of federal and state regulatory policy and guidance on risk assessment and risk-based cleanup standards. He is currently serving as chair of the Marcellus Shale Coalition work group on hydraulic fracturing risks and as a member of the American Petroleum Institute work group on induced seismicity. Bill earned his doctorate in Engineering and Public Policy and his Bachelor of Science in Metallurgy/Material Science and Public Affairs (jointly conferred) from Carnegie-Mellon University.

Rapid growth of the use of hydraulic fracturing along horizontal stages in shale formations for the extraction of natural gas has resulted in significant regulatory agency and public concern about the environmental risks that may be associated with this development. Publicity and media coverage have increased these concerns. All human activities to use natural resources and technology for the benefit of society have corresponding risks. As such, understanding the relative risks of hydraulic fracturing in shale is useful for making decisions about how to best regulate and communicate the risks. To be most useful, this understanding of relative risks is best developed by considering both technical risk factors and perceived risk factors.

This presentation explores comparing and communicating the technical and perceived seismic risks of hydraulic fracturing for shale gas development relative to other technological activities, including extracting and using other natural resources. The relative nature and significance of technical risks are compared, and risk perception factors that can impact effective risk communication are also compared.

## Ground Movement and Induced Seismicity

Arthur Frankel, USGS

Arthur Frankel is a senior scientist with the U.S. Geological Survey, stationed in Seattle. He specializes in 3D simulations of earthquake ground motions and seismic hazard assessment. He is the task leader for urban seismic hazard mapping in the Pacific Northwest. He was project chief for the National Seismic Hazard Mapping Project of the USGS from 1993-2004, where he led the effort to completely update the methodology of the national seismic hazard maps, which are used in the International Building Code. He received his PhD. from Columbia University (Lamont-Doherty Earth Observatory) in 1982.

## Seismic Studies Program at the Alberta Geological Survey

**Dr. Todd Shipman**, Alberta Geological Survey, Alberta Energy Regulator

**Todd Shipman** is the manager for the Landscapes and Geological Hazards Section in the Alberta Geological Survey. This section is responsible for the regional seismic monitoring and forensic investigation of events for the province. He received his B.S. in Geoscience from the University of Arizona, M.S. in Geology from Northern Arizona University, and PhD. in Geoscience from University of Arizona.

The Alberta Geological Survey is the science arm of the Alberta Energy Regulator, as part of our responsibilities our group maintains/monitors the regional seismic network for Alberta, builds a seismic catalogue for the province, and provides forensic analysis of abnormal seismic activity. Monitoring consists of review of automated alerts and notifying significant seismic event clusters to upper management. Seismic network consists of AGS Regional Alberta Observation for Earthquake Studies Network (RAVEN) and shared arrays of Canadian National Seismograph Network (CNSN, Alberta Telemetered Seismograph Network (ATSN), Montana Regional Seismic Network (MRSN), and Canadian Rockies and Alberta Network (CRANE). RAVEN network is telemetered and shared through IRIS in near-real time, where the CRANE network data is collected twice a year by AGS through an agreement with the University of Alberta. If an abnormal seismic event takes place we are asked to understand potential sources of the event and to evaluate likely causes. AGS's roles in the seismic events are recognition, evaluation, and communication to upper management. We are regarded as subject matter experts and consulted in the development in possible regulations.

The Seismic Studies Program began in 2009 with modest resources and has developed into a three person staff with a near-real time network throughout the province. Initially we relied on collaborative relationships to collect data through the province; however in 2014 the RAVEN deployment gave AGS access to wide regional coverage of the province. In 2011 the program produced an automated email alert system to notify of seismic events $2M_L$ or greater within the province. Currently we monitor/catalogue events and produce special alerts on events greater than $3M_L$ to upper management.

## Seismicity and the SWD-C4A Well: An ongoing UIC Case Study in the Denver Basin, Colorado

**Chris Eisinger**, Stuart Ellsworth, and Bob Koehler, Colorado Oil and Gas Conservation Commission

At ~9:30PM on May 31st, the USGS recorded a magnitude 3.2 event about 5.6 miles northeast of Greeley, Colorado. The event was both heard and felt by residents in the Greely area. Reported shaking was weak to light with no notable damage. Subsequent to the May 31st event, a portable network of seismometers was installed by University of Colorado seismologists. Numerous smaller events, including M 2.6, M 2.3, and M 2.1 events, were recorded by this network throughout June, July, and August.

Coincidentally, these earthquakes were located at close proximity to a high volume (>10,000 barrels per day) produced wastewater injection well – NGL's SWD-C4A well – which began significant injection in the fall of 2013. After the second > M 2.5 event in mid-June and following discussions with the Colorado Oil and Gas Conservation Commission (COGCC), the operator voluntarily ceased injection activities for 20 days as a precaution.

With seismic activity not historically common in the vicinity, the potential for these events to be induced by high volume waste-water disposal is being carefully examined. To this end, the COGCC has been working closely with the well operator, University of Colorado researchers, and other experts, to better understand: (1) the subsurface geology; (2) seismicity risk, including baseline characterization and analysis of recent events; and (3) injection volumes, rates, and pressures at the C4A well.

The COGCC is cautiously allowing NGL to resume limited injections with step increases in injection rates dependent on the absence of any significant seismic events. Initially, resumed injection was allowed at a maximum rate of 5,000 barrels per day with a maximum pressure of 1,512 psi in mid-July. After 20 days, the maximum injection rate was increased to 7,500 barrels a day at the same pressure. A third increase to roughly 9,500 barrels per day is just now being implemented. A risk-based traffic-light system is being used that will halt injection activity if seismic events within a 2.5-mile radius of the well occur at or above a magnitude of 2.5 – the U.S. Geological Survey's default threshold for seismic event notification. Further, the Commission is asking that commercial injection well operators install seismometers for ongoing and future injection activities with the hope that a statewide network eventually be established for better monitoring. At this point, the COGCC views induced seismicity from UIC activities as a risk management discussion focused on location, monitoring, pressure, rate, and volume.

Peter Grevatt, Ph.D is the Director of the USEPA Office of Ground Water and Drinking Water (OGWDW). The Office of Ground Water and Drinking Water in collaboration with states, tribes and its many stakeholders, is responsible for safeguarding America's drinking water. Over 300 million Americans nationwide rely daily on public water systems to provide them with safe drinking water in the convenience of their home. He is responsible for the development and implementation of national drinking water standards, oversight and funding of state drinking water programs and the implementation of source water protection and underground injection control programs to protect public health nationwide.

Prior to joining the OGWDW in October of 2012, Peter Grevatt served as the Director of the Office of Children's Health Protection and served as the Senior Advisor to EPA's Administrator for Children's Environmental Health. Peter has held leadership roles in EPA's national hazardous waste and water quality programs. Peter received his M.S. and Ph.D degrees in Basic Medical Sciences from New York University Medical Center and earned his bachelor's degree in Biology from Earlham College.

Nancy Johnson - Director of Planning and Environmental Analysis. US Department of Energy. Office of Fossil Energy

Bill Cunningham is the Chief of the U.S. Geological Survey Office of Groundwater. This office oversees the technical and policy aspects of USGS groundwater investigations and data collection activities across the Nation, and develops groundwater tools and techniques. Prior to joining the Office of Groundwater, Bill worked on groundwater science investigations in the Ohio and North Carolina Water Science Centers. He also serves as Co-Chair of the Subcommittee on Groundwater for the Federal Advisory Committee on Water Information. Bill received undergraduate and graduate degrees from The Ohio State University.
Name: Clarita Lefthand-Begay, Ph.D. in Environmental and Occupational Health.

## Groundwater Sustainability: Indigenous Cultural Values, Uses and Sources

Clarita Lefthand-Begay, MS, Ph.D - Director of Hózhó Research and Consulting, Seattle, WA.

Clarita Lefthand-Begay, MS, Ph.D. recently received her doctoral degree in Environmental and Occupational Health Sciences from the University of Washington's School of Public Health. She is the Director and Principal Researcher of Hózhó Research & Consulting in Seattle, Washington. Her research aims to understand environmental health disparities, water security, climate change isks and adaptation barriers and indigenous environmental values. She has worked with tribal communities as a research scientist for 9 years.

Indigenous communities in the United States have resilient traditions that connect them to their homelands and culture. These traditions depend on water security. Groundwater is a vital natural resource to the future of ecosystem, human and economic health, and tribal nations have been fighting to preserve this resource for generations. Adequate access to quality groundwater continues to be very challenging to many land-based communities, which have occupied traditional lands for generations. For these land-based communities, in particular rural communities that depend solely on groundwater for all household and cultural uses, addressing water security problems is critical to the long-term health of future generations. These issues include declining water wells, contamination and environmental justice factors. In addition, data about groundwater in tribal lands is totally insufficient, which makes it difficult to meet community needs and aid future planning. In this talk, I will discuss the importance, cultural uses and sources of groundwater to many tribal communities. I'll highlight examples of how tribes are working to protect groundwater as nations and communities in the face of obstructions to their work. This presentation provides an indigenous perspective on water security, and proposes ways to support the efforts of communities that are working to preserve this natural resource. In addition, I'll discuss what sustainability means from an indigenous perspective, and how this has informed local decision-making for many indigenous peoples.

## Keeping the Pump Primed: Groundwater Sustainability

John Jansen, Cardno Entrix

How will groundwater resources fare in the future and how will that affect society? How can we ensure the sustainability of our aquifers through sound science? How should groundwater contractors and scientists confront economic and political challenges affecting the resource that is pivotal to the success of their businesses? How is "sustainability" defined and what tools and strategies can be used to protect groundwater systems as well as those who obtain and develop it? What information must be gathered and compiled to build consensus and present a compelling case to regulators and policymakers?

By attending the 2013 McEllhiney Lecture presentation, you will gain an understanding of:

- How several different definitions of "sustainability" apply to the management of an aquifer, and how these different definitions may affect your business
- States' varying approaches to aquifer management, reflecting their local conditions and history—with specific consideration of how the approach in your state affects you and your business
- How regulatory practices are evolving, and why they must balance local economic and political realities with environmental needs to be accepted and successful
- Meaningful ways that you provide information and build consensus, to help the regulatory evolution move in a positive direction
- Steps needed for successful management from all perspectives.

## The Forest Service Proposed Groundwater Directive: Status, Intent, and Path Forward

Christopher P. Carlson, USDA Forest Service

Chris Carlson has served as the National Groundwater Program Leader for the USDA Forest Service since June 2005 where his focus has been on developing the national program, fostering awareness of groundwater across the agency, and providing technical assistance and training on groundwater issues. Prior to joining federal service, Chris worked for nearly 15 years as a hydrogeologist for the Wisconsin Department of Natural Resources, where he was primarily involved in metallic mining and landfill permitting and clean up. Chris has a BA in physics from Carleton College in Minnesota and an MS in Environmental Science, an MS in Geology, and a PhD in Geological Sciences from Indiana University.

The U.S. Forest Service is responsible for managing 193 million acres of National Forests and Grasslands located in 42 states and Puerto Rico. These public lands are the source of about 14 percent of the Nation's overall fresh water supply and approximately one-fifth of the municipal supply. Groundwater plays a significant role in sustaining those supplies both on and off of these lands. In recent years, through comments on specific proposed Forest Service decisions and other avenues, including judicial remands, the public and the courts have increasingly indicated an expectation that the Forest Service will identify and address potential impacts to groundwater resources as part of its decision making.

To help meet this need, on May 7, 2014, the Forest Service published for public comment a proposed directive on Groundwater Resource Management (Forest Service Manual 2560). The original 90-day comment period was subsequently extended twice until October 3, 2014.

The proposed directive is designed to provide a consistent and credible approach to addressing groundwater resources on National Forests and Grasslands in the context of Forest Service decision making. The proposed directive requires cooperation with the states and tribes while clearly recognizing state responsibilities for water allocation and state and tribal responsibilities for water quality. The proposed directive would make Forest Service decision making more predictable and transparent and help the agency be a better partner with states, tribes, and others when decisions are being made about uses of national forests and grasslands that may affect groundwater.

The proposed directive emphasizes interconnectivity between groundwater and surface water, groundwater's support of ecosystems, and groundwater as an important source of water supply. It emphases the need to inventory and monitor groundwater and to pursue strategies to encourage sustainable practices. In addition, the proposed directive requires monitoring and mitigation when needed. Response to comments and final direction is anticipated in the first half of 2015.

## Groundwater Balancing Act: Using the Groundwater Requirements of Wetlands to set Limits to Groundwater Alteration

Allison Aldous, The Nature Conservancy; Joe Gurrieri, USDA Forest Service; Leslie Bach, The Nature Conservancy; Christopher Carlson, USDA Forest Service; Emilie Blevins, The Nature Conservancy

Groundwater discharge supports the species and ecosystem processes of many wetlands and other groundwater-dependent ecosystems (GDEs). Groundwater management activities that intercept groundwater flowpaths supplying these ecosystems, such as withdrawal for domestic, agricultural, or municipal needs, can be detrimental to obligate species and key ecological processes. Many GDEs are found on National Forest System (NFS) lands, and The USDA Forest Service recently released a groundwater directive which calls for establishing procedures for reviewing new proposals for groundwater withdrawals which might affect GDEs. In response to this, The Nature Conservancy and the Forest Service are developing an approach for identifying limits to groundwater withdrawals based on ecological thresholds, termed Environmental Flows and Levels. The method was developed in fen wetlands in central Oregon, and is being tested in prairie wetlands in North Dakota; springs in central Oregon; and coastal wetlands in Oregon. At each site, groundwater discharging to wetlands is also intercepted for agricultural or municipal uses. In this method, the hydrogeologic setting is characterized with a water budget and a model to compare the relative importance of groundwater discharge versus groundwater intercepted for management purposes. Simultaneous with the hydrogeologic analyses, groundwater-ecology relationships are quantified to determine ecological thresholds beyond which the wetlands may experience irreversible degradation. These data are used to establish limits to groundwater alteration in a way that supports wetland integrity and society's needs for groundwater resources. We illustrate the method with results from the four study sites.

## Alabama Groundwater Sustainability: A Strong Scientific Foundation for Water Resource Management and Policy to Secure Alabama's Water Future

Marlon R. Cook - Groundwater Assessment Program - Geological Survey of Alabama

Alabama is blessed with abundant groundwater resources from 25 major aquifers that provide public water supplies for more than 70% of the geographic area of the state. During the past 10 years, drought, periodic water shortages, and economic growth in Alabama have alerted water supply systems, agricultural interests, local governments, and state agencies to the need for plans to assure sustainability of future water supplies. Alabama Governor Robert Bentley and the Permanent Joint Legislative Committee for Water Policy and Management have joined to initiate the development of a water resource management plan and water policy legislation in Alabama. These state leaders understand that effective water management and policy must be based on sound scientific data. Therefore, the Groundwater Assessment Program at the Geological Survey of Alabama has been mandated to conduct a comprehensive statewide assessment of groundwater resources. This assessment includes 15 hydrogeologic elements that form a comprehensive evaluation of groundwater availability and sustainability that will guide future water management and policy legislation and development of groundwater resources in Alabama. The assessment includes methodologies modified from oil and gas exploration as well as traditional hydrogeologic and geochemical investigations. State-wide water management and policy, based on sound science is an essential part of securing Alabama's water future.

## NGWA Informational Resources: Defining Managed Aquifer Recharge and Best Suggested Practices for Aquifer Storage and Recovery

William M. Alley and Steven P. Musick

William M. Alley is Director of Science and Technology, National Ground Water Association (NGWA) and Steve Musick is an independent contractor with the Ground Water Protection Council
Water supply shortages are occurring now and are expected to occur more widely in the future. Managed aquifer recharge (MAR) will become an increasingly important tool for mitigating the economic, environmental, and public health impacts of these shortages. MAR captures available water (during wet periods, during periods of low demand, or water that would be lost otherwise) and moves this water under controlled conditions into underground reservoirs. MAR projects are occurring in every region of the country, although some states have more experience than others do. Properly sited, designed, constructed, operated, and maintained MAR projects are a key component for addressing the nation's water supply challenges.

Best Suggested Practices for Aquifer Storage and Recovery (ASR) are intended to foster the conceptualization, planning, and implementation of an aquifer storage and recovery project primarily using potable source water. ASR is one method to recharge aquifers with available water when there are surpluses and recover it when it is needed most, increasing water supply reliability. The BSP contains information for consideration from conception to maintenance of an ASR system. Design, installation, well development, maintenance, operation, monitoring, permitting, water rights, and community involvement are all components of an ASR system. The components require a multidisciplinary approach for success in achieving the goal(s) of the ASR system.

## Application of Aquifer Storage and Recovery to Agriculture

Tuck Russell , Freelance Journalist

Tuck Russell is a central Washington based freelance journalist covering water, environmental issues, the wine industry, and urban development. He serves on the Citizen's Committee of the Yakima Basin Fish and Wildlife Recovery Board. This committee helps prioritize salmonid recovery projects in the Yakima Basin. He has a B.A. in Finance from the University of Texas at Austin, where he minored in English.

Agricultural entities in dry areas face increasing scarcity of water during the irrigation season as climate changes and population grows. Aquifer Storage and Recovery (ASR) could help them address this scarcity, but technical and regulatory hurdles are usually more challenging for them than for municipalities. Agricultural entities generally lack the internal human resources for dealing with the technical issues and regulatory apparatus. More critically, they lack the ability to treat source water economically. For these reasons, successful agricultural applications of ASR are relatively rare.

With surface water already allocated, Madison Farms and other farmers in northern central Oregon had been using groundwater for newer irrigation needs. Collectively, this use depleted the aquifer to the point that the Oregon Water Resources Department designated their area as a Critical Groundwater Area in 1986. OWRD implemented restrictions and rationing based on seniority, and Madison Farms was unable to use their well.

Madison Farms implemented an ASR program using untreated source water from a seasonal creek and flood irrigation that filters through alluvial sediment into a collector well. OWRD's water quality standard for injection into aquifers is typically twice as stringent as the state and federal drinking water quality standard. The collected water achieves this standard with the exception of nitrates, which can stray up to the drinking water limit of 10mg/L. OWRD allowed a variance to 7mg/L, requiring Madison Farms to stop injection when those levels were exceeded. In the recovered water, nitrates go below the detection threshold within a few days.

The shallow alluvial source water level varies during the injection season, and can drop below the level of the collector well, so targeted injections volumes are not hit for the season. Nevertheless, ASR is a better alternative than connecting to the distant Columbia River.

## Can the Ogallala Aquifer Sustain Long Term Ground Water Production?

Jay Lazarus, Jim Riesterer, P.G., and Elke Naumburg, PhD Glorieta Geoscience, Inc.

Jay Lazarus is President and Sr. Geohydrologist of Glorieta Geoscience, Inc. and has been a consulting ground water geologist for 35 years. He specializes in water resource development, water rights environmental protection and abatements. His clients include municipalities, farmers and dairymen, Indian tribes, Los Alamos National Laboratory, Nye County Nuclear Waste Repository Office, Water and Sanitation Districts, industrial dischargers and individual water users. He has been qualified as an expert witness more than 30 times in geology, hydrology, geomorphology and structural geology. His current projects include securing and developing more than 75,000 acre-ft of water rights in Nevada, New Mexico, and Texas.

The High Plains/Ogallala Aquifer is the largest continuous aquifer in the United States. In the 7 states pumping from the High Plains aquifer, irrigated acreage increased from 2.1 million acres in 1949 to 13.7 million acres in 1980. The increased irrigation, dairy, municipal, and industrial demands have resulted in significant mining and depletion of the aquifer. From 1950-2012 water levels in eastern New Mexico and West Texas declined 100-150 feet or more, an unsustainable loss of more than 50% of available water column. For farming and dairies to remain competitive, the sustainable lifetime of the aquifer needs to be extended through proactive water conservation and reuse of ground water. Based on metered well production, conservation and conversion to drought tolerant crops are the most effective immediate ways to reduce water use. High efficiency, smaller diameter wells specifically designed to a declining Ogallala water table can reduce local drawdown and require less energy to pump ground water.

## Conceptual Model for the Kitsap Peninsula, Kitsap, Mason, and Pierce Counties, Washington

Wendy Welch and Lonna Frans work as hydrologists at the U.S. Geological Survey, Washington Water Science Center.

The Kitsap Peninsula covers approximately 787 square miles in the southern Puget Sound Lowland of Kitsap, Pierce, and Mason Counties in western Washington. The watershed is underlain by as much as 2,000 feet of unconsolidated sediments that are the result of multiple Pleistocene glacial and interglacial periods. Defining extents and thicknesses of the aquifers and confining units within these unconsolidated sediments is essential to understanding groundwater flow and interaction with surface-water features.

In October 2010, the U.S. Geological Survey (USGS) Washington Water Science Center in partnership with the Water Purveyors Association of Kitsap County began a project to characterize the water resources and create a numerical groundwater flow model of the Kitsap Peninsula. As part of that project, a more detailed conceptual model and hydrogeologic framework of the area was needed.

Four major elements were completed to construct the hydrogeologic framework. A digital surficial hydrogeologic map was compiled by merging existing 1:100,000 and 1:24,000 geologic maps. A dataset of more than 2,000 wells was assembled from the USGS National Water Information System database and hydrogeologic unit assignments were made incorporating surficial geology, drillers' logs, and previous investigations. Cross-sections were created to illustrate the likely correlations between hydrogeologic units across the entire study area. Finally, maps were created to show the extents of the hydrogeologic units and the interpolated elevations of the unit tops.

Hydraulic parameters were estimated for hydrogeologic units using available data from aquifer tests, drillers' reports and published values. Water-level maps were prepared for principal aquifers within the basin in order to better understand groundwater flow directions, and horizontal and vertical water-level gradients.

All available data were then used to construct a numerical flow model of the Kitsap Peninsula to assist water resources managers in managing the groundwater system.

## Using Oil and Gas Data to Find Groundwater Supplies

Patricia Billingsley and Madeline Dillner Oklahoma Corporation Commission

Due to our prolonged drought, Rural Water Districts (RWDs) in Oklahoma are looking to drill new Public Water Supply wells as sources for their rural and small town customers. However, RWDs do not have either hydrogeologists on staff or a sufficient budget to hire consultants. At the request of the Oklahoma Rural Water Association, the Oklahoma Corporation Commission has helped out by using some of our oil and gas well data, and easily accessible (to us, but not to RWDs who may have no internet connection) water data, to recommend which of a RWD's possible new well locations might be better bets. We:

- Make maps showing the locations of current and past oil and gas wells, to help them avoid possible historically polluted drilling locations;
- Utilize oil and gas well data such as electric logs that were drawn up through possible aquifer zones to predict if a good aquifer zone (e.g. a sandstone) might be present;
- Tell RWDs, based on our data, where the base or fresh water probably is. This will help to decide where the thickest fresh water zones likely are;
- Use our current and past aerial photos to look at land features, current and back to the 1940's; and
- Download and map data from the Oklahoma Water Resources Board on all water wells known in the area, with reported depths, water bearing zones, and yields; also OWRB aquifer data.

Obviously, we cannot make ANY guarantees – but we can serve as a resource for them, assisting them to choose the best available new water well test locations. We are also working with a Hydrogeology class of university students, teaching them to do this work; the students are assisting on one RWD study.

## Characterization of Deep Groundwater

William M. Alley, Michael Wireman, Mary Musick
William M. Alley is Director of Science and Technology, National Ground Water Association, Michael Wireman is a hydrogeologist, recently retired from the U.S. Environmental Protection Agency, and Mary Musick is a geologist and consultant for the Ground Water Research and Education Foundation.

In May 2014, the National Ground Water Association (NGWA) held a conference on deep groundwater in association with the Ground Water Research and Education Foundation (GWREF). The purpose of the conference was to bring together investigators from different segments of the hydrogeological community and the oil, gas, mineral, and water supply industries that have an interest in characterizing deep groundwater resources, particularly areas underlain by sedimentary basins. The event provided a forum to share ideas on what we know today, how to characterize and develop deep groundwater, and what research should be conducted in the future. Discussions took place under two broad areas: (1) analysis of data and information to characterize hydrogeologic settings, water quality and flow in deep groundwater systems, and (2) tools and methods for collecting samples and in-situ hydrologic data for deep groundwater systems. This paper presents a summary of these discussions.

## Permian Basin Water Reuse and Surface Water Supplies

David Holt, Permian Basin Petroleum Association
David Holt is the manager of governmental affairs in Austin, Texas, for the Permian Basin Petroleum Association. In addition to his duties with PBPA, David also serves as Board President of the Colorado River Municipal Water District. The CRMWD provides water to over 500,000 West Texas residents.

The Permian Basin Petroleum Association was formed in 1961. PBPA has grown from twenty members to almost a thousand. The Permian Basin covers a large area of West Texas and Southeastern New Mexico. The Permian produces over 1.6 million barrels of oil per day. The daily rig count exceeds 530 rigs. Its membership consists of some of the largest producers to some of the smallest.
One of the challenges facing the Permian Basin as well as the other unconventional shale plays is finding enough water. Producers are using brackish groundwater, produced water and treated municipal effluent. Because fresh water amounts are limited, producers are using as little fresh ground and surface water as possible.

## EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil & Gas on Drinking Water Resources

E. Ramona Trovato, USEPA Office of Research and Development
Ramona Trovato is the Acting Principal Deputy Assistant Administrator for EPA's Office of Research and Development. She provides executive leadership on EPA's hydraulic fracturing research. During her distinguished 33 year career at EPA, Trovato has served in numerous leadership positions in the Office of the Administrator, Office of Water, Office of Enforcement and Compliance Assurance, Office of Air and Radiation, Office of Environmental Information and Office of Solid Waste and Emergency Response, as well as her present leadership position in ORD. She has successfully led many implementation initiatives focused on improving operational performance, and building efficiency into environmental protection efforts. Some notable examples include her work in protecting and promoting children's health; developing and implementing the Comprehensive State Ground Water Protection Program; working with the private sector and states to make the best and highest use of properties cleaned up under the Superfund program; and, developing and implementing the National Environmental Laboratory Accreditation Program. Among the many awards received during government service, she was recognized with the Distinguished Career Award in recognition of extraordinary leadership and exceptional dedication in serving the American people, and the President's Meritorious Executive Rank Award for building strong coalitions and partnerships to achieve environmental and public health goals. She has a BS degree in Zoology from the University of Maryland at College Park and has undertaken additional studies in chemistry, facilitation, negotiation, information technology management, management and leadership throughout her career.

At the request of Congress, EPA is conducting a study to assess the potential impacts of hydraulic fracturing for oil and gas on drinking water resources and to identify the driving factors that may affect the severity and frequency of such potential impacts. EPA has designed the scope of the research around five stages of the hydraulic fracturing water cycle: water acquisition, chemical mixing, well construction and formation stimulation, produced water and flowback, and wastewater treatment and disposal. EPA's state of the science assessment will be supported by an extensive review of the literature, results from recently completed EPA research projects, and input from states, industry, non-government organizations, the public and other stakeholders. The progress report and detailed information about the study can be found on the study's website at www.epa.gov/hfstudy.

## Baseline Water Quality Testing for Oil and Gas Operations

Robert W. Puls, Ph.D. Oklahoma Water Survey

Dr. Robert Puls is Director of the Oklahoma Water Survey and Associate Professor at the University of Oklahoma. Dr. Puls was employed by the U.S. Environmental Protection Agency (USEPA) in Ada, Oklahoma for almost 25 years. He was the Technical Lead for the ongoing National USEPA Study on Hydraulic Fracturing and Drinking Water Resources prior to his retirement in early 2012. He has authored more than 150 publications on ground-water sampling, ground water remediation and hydraulic fracturing and drinking water resources. He has a Ph.D. from the University of Arizona.

Several states have recently made baseline water quality testing of domestic wells mandatory in their oil and gas regulations and guidance (CO, WY, IL, OH, CA, MI). Other groups have also recently put forward guidelines for sampling private water wells where oil and gas operations are occurring as pubic service information (e.g. Penn State Agricultural Extension; Oklahoma State Agricultural Extension; NGWA/GWPC; Louisiana Department of Health and Hospitals). While these are steps in the right direction, there continues to be many states that have not adopted this approach. Some state use presumption of liability to coerce operators to sample domestic wells, while others are using groups such as the USGS to do a better job of understanding baseline water quality in oil and gas operating areas in their states. While leading the field technical portion of the USEPA Hydraulic Fracturing Study in 2010 and 2011, the single most glaring deficiency in all state programs for oil and gas operations was the absence of any rules or guides for baseline water sampling. Baseline programs vary substantially from one state to another in terms of distance between domestic wells and production wells, number of pre drill sampling events and number of post drill sampling events. However, are these programs sufficient to determine if impacts to local ground-water quality are happening? It is proposed that additional site characterization studies be undertaken in collaboration with all stakeholders to demonstrate that oil and gas operations can be conducted in a manner that protects ground water resources in both the short and long term.

## State and Local Regulations for Pre and Post Drill Monitoring

Kate Konschnik, Harvard Law

Kate Konschnik is Director of Harvard Law School's Environmental Policy Initiative. EPI provides real time, real world legal analysis on today's most pressing energy and environmental challenges. Kate has presented her research to a number of state and national organizations including the National Research Council, the National Governors' Association, the Midwestern Power Sector Collaborative, and the United States Secretary of Energy's Advisory Board. Prior to joining Harvard, Kate served as Chief Environmental Counsel to Senator Sheldon Whitehouse (D-RI), directing the Senator's subcommittee on the Senate Environment and Public Works Committee for three years. Kate also spent seven years as a Trial Attorney at the United States Department of Justice. Kate was a member of the Clean Air Act New Source Review Power Plants litigation team, and represented the Environmental Enforcement Section in drafting Clean Air Act policy proposals for the incoming Obama Administration.

## The Use of Strontium Isotope and Element Geochemistry to Characterize Water from Fossil Fuel Sources

Liz Chapman, PhD., ECHELON Applied Geosciences

The synthesis of strontium (Sr) isotopic data with major and trace element geochemistry provides a powerful geochemical approach to characterize groundwater, surface water, and produced water from various fossil fuel sources. Natural Sr isotope composition can be a sensitive tool in the understanding of complex groundwater interactions and can be used to distinguish between inputs from deep and shallow contamination sources, as well as between mineralogically similar but stratigraphically distinct rock units. The application and value of Sr isotopes to identify natural and anthropogenic sources of major elements and to quantify the effects of mixing water from different sources will be presented.

## A Review and Comparison of the Methods and Variables within the Methods Used for the Investigation of Dissolved Gas Concentrations

Charles J. Neslund, Eurofins Lancaster Laboratories Environmental, LLC

Mr. Neslund is Technical Director for the Eurofins Lancaster Laboratories Environmental, LLC. He has direct responsibilty for the HRGC/HRMS, LC and GC/MS/MS sections and the Method Development group. He also manages the Volatiles in Air group. Mr. Neslund also serves as lead technical contact for evaluation of RSK175 applications, implementation of discrete analyzer chemistries, tracer compound applications and applications of alternative sample preparation/digestion technologies. His responsibilities also include the development and validation of methods that are required to comply with ISO 17025, GLP, EPA and FIFRA data submission requirements.
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The analysis for dissolved gases in Pre- and Post-Drill samplings of water wells in and around active drill sites has become an important and controversial topic. The results of such sampling and analysis can have a significant impact on water quality for the affected homeowner and a significant impact on costs of operation for the natural gas generator. With such high stakes for quality of life and reputations at hand, it would seem imperative that a very standardized and consistent method and analytical approach be utilized. Unfortunately, this is not the current practice. Various applications of RSK-175, a proposed ASTM method and methods developed by several manufacturers are all used for pre-drill assessments and more significantly for stray gas investigations. Often times the method, or variation of a given method, used by the enforcement agency's lab will not return results consistent with the laboratory used by the generators lab. Yet each reporting lab is a certified lab for the application of dissolved gas analysis.

This paper will discuss several of the differences between the different methodologies and the variables within a given methodology that can impact the results generated from the analysis of a given sample location. Impact of sampling methodology will also be discussed along with some initiatives of the MSC around this issue.

## Stray Gas Migration – Preparedness & Incident Response™

Fred Baldassare has more than 25 years of experience as a geologist, and 20 years of experience investigating more than 200 reported incidents of stray gas migration. He is an experienced investigator, and researcher who has helped pioneer the application and advancement of isotope geochemistry to identify and distinguish the origin of different microbial and thermogenic gases in the Appalachian Basin. Fred was the lead author for the Pennsylvania's Oil & Gas regulations (25 PA. CODE CH. 78, §78,89) for stray gas incident response, the Marcellus Shale Coalition's technical guidance manual for stray gas investigations, and co-author of the first comprehensive manual for investigating and characterizing incidents of stray gas migration: Technical Measures For The Investigation And Mitigation Of Fugitive Methane Hazards In Areas of Coal Mining. Fred has authored and co-authored professional papers for peer reviewed journals on the application of isotope geochemistry, taught and lectured nationally, and at his alma maters, Penn State University and The University of Pittsburgh.

Debby L. Yost serves as a Senior Environmental Specialist with Chesapeake Energy Corporation and works at Chesapeake's corporate headquarters in Oklahoma City. Yost has been part of the Environmental Health and Safety and Regulatory Affairs Department since 2007. Yost has worked on a variety of projects involving both regulatory affairs and compliance issues associated with oil and gas exploration and production. Yost has a Bachelor of Science in Microbiology and a Master of Science in Agronomy (emphasis on soil chemistry and fertility) from Oklahoma State University. Prior to joining Chesapeake she worked as the Quality Control/Quality Assurance Manager for The Benham Group (now SAIC) offices in Oklahoma, Texas, Arkansas and Missouri for almost 18 years. Before that Yost worked at Oklahoma State University running the Cooperative Extension Services Soil, Water and Forage Analytical Laboratory and overseeing soil fertility research projects for over 13 years. During her time at OSU she authored and co-authored a number of publications.

Yost has also been an active participant in the Marcellus Shale Coalition (MSC) and has been part of Environmental Stewardship Subcommittee since 2010. She has served as chair or co-chair of this subcommittee and has overseen the development and roll-out of Recommended Practices on pre-drill water surveys and stray gas investigations as well as development of a Sampling and Analysis Plan for pre-drill sample collection and related fact sheets. Debby also participated in a work group tasked with developing a database for housing pre-drill water test data for MSC operator members.

## Overview of National Climate Assessment Development Advisory Committee

**Paul Fleming**, Climate Resiliency Group, Seattle Public Utilities

Paul Fleming is the lead for Seattle Public Utilities' (SPU) Climate Resiliency Program where he is responsible for leading SPU's climate research initiatives, assessing climate risks, mainstreaming adaptation strategies and establishing collaborative partnerships. He is a member of the National Climate Assessment Development Advisory Committee, which led the development of the 2014 U.S. National Climate Assessment (NCA). He was a Convening Lead Author of the Water Resources chapter, the Sustained Assessment Special Report and a Lead Author of the Adaptation chapter of the NCA. He is a Past Chair of the Water Utility Climate Alliance (WUCA), an alliance of ten U.S. water suppliers focused on providing leadership in assessing and adapting to the potential effects of climate change through collaborative action.

The 3rd National Climate Assessment (NCA), which was released in May 2014, is the most comprehensive documentation of the observed and projected impacts of climate change in the U.S. released to date. The NCA, which is statutorily required by the Global Change Research Act of 1990, includes nearly 30 chapters that focus on climate impacts in every region and several sectors of the U.S., cross cutting topics and response strategies. This presentation will focus on the water resources chapter and specifically the groundwater elements of this chapter and what is known about the climate impacts on groundwater, the sectoral demand patterns on groundwater and the management implications going forward.

## Sustainable Water Management in Massachusetts

**Duane LeVangie**, Massachusetts Department of Environmental Protection

Duane LeVangie is an environmental analyst with the Massachusetts Department of Environmental Protection. Mr. LeVangie has over twenty-three years of experience with the Department, with the last 13+ years as Program Chief of the Water Management Program. He has also served as the Department's staff lead on the Massachusetts Executive Office of Energy and Environmental Affairs' Sustainable Water Management Initiative (SWMI). Mr. LeVangie has a B.S. in Geography from Salem State College in MA.

In 1985, the Massachusetts Water Management Act (WMA) (M.G.L. c. 21G) was passed in order to comprehensively manage water withdrawals throughout the Commonwealth to ensure an appropriate balance among competing water needs and preservation of the water resource. The WMA establishes two mechanisms for authorizing water withdrawals in excess of the threshold volume of 100,000 gallons per day: registrations and permits. Those making withdrawals from 1981 through 1985, prior to passage of the WMA, were given the opportunity to "register" the volume and location (withdrawal point) of their withdrawals. Increased withdrawals of more than the threshold, withdrawals that were not registered in a timely manner, and new withdrawals above the threshold require a permit.

SWMI was initiated in 2010 to incorporate the best available science into the management of the Commonwealth's water resources in order to ensure there is enough water for the many, and sometimes competing, long-term water needs of our communities, businesses, industry, agriculture, recreation and our aquatic ecosystems. SWMI involved a wide range of public and private stakeholders and included support from multiple state agencies within Massachusetts. The final SWMI results are intended to reduce the controversy surrounding WMA permitting decisions by establishing a more transparent, predictable, flexible, and science-based water allocation system.

The following elements, based on the SWMI deliberations, have been developed for incorporation into WMA permitting decisions:

- Safe yield – A methodology for calculating the amount of water that can be withdrawn from a river basin.
- Streamflow Criteria – Categorize subbasins according to the level of flow and biological alteration.
- Permit Review Categories - Define the requirements of a WMA permit based on size of the withdrawal and any changes to streamflow criteria that result from the withdrawal.
- Minimization - Permittees in the most groundwater-depleted areas must minimize their impacts.
- Mitigation - Permittees must mitigate the impact of any increased withdrawals.
- Coldwater Fish Resources - Permittees avoid impacts to waters that support coldwater aquatic life.

Proposed regulatory revisions have gone through the public comment process and are undergoing final review and approval now with an expected promulgation date in the Fall of 2014. To date the response has been mixed with the municipal/public water supply community raising concerns about overly restrictive conditions and the cost of implementation, and the environmental community expressing concern that the changes do not provide enough protection nor improve riverine conditions. The proposed changes are a compromise and balance between these two divergent positions.

### WaterTracker: Accounting for Water Use in Hydraulic Fracturing Operations

**Thom Kerr**, Stan Belieu (NOGCC) and Paul Jehn (GWPC)

Thom Kerr has worked with the oil and gas industry for thirty-eight years. He currently is an independent contractor working with a focus on computer applications used in regulatory systems. He left the Colorado Oil and Gas Conservation Commission after twenty-three years, leaving as the Deputy Director of Field Operations. Prior to that he spent time working with a contractor to the Minerals Management Service on the conversion production reporting systems from the Bureau of Land Management. He spent four years working with an independent oil and gas exploration company. Through these assignments he has worked extensively with computer information systems used for tracking permitting, construction and ongoing activity of producing and support wells. Before that he spent nine years conducting and managing onshore seismic acquisition for Western Geophysical.

The Ground Water Protection Council frequently receives requests concerning the amount of water used in hydraulic fracturing operations. The GWPC is currently developing an RBDMS module to track water usage which will be compatible with state and federal oil and gas databases, FracFocus and the National Oil and Gas Gateway. Obtaining measurements on the amount of water used hydraulic fracturing is complicated by the co-mingling of sources of water, multiple wells using the water and multiple disposal options available for flowback and produced water. In addition water withdrawal permits (if they are even required) is handled by multiple agencies at the state and local levels. The presentation will discuss the GWPC's research on tracking water in the oil and gas industry and discussed proposed next steps for the WaterTracker module.

### Communicating Water Well Stewardship to Elicit Effective Behaviors

**Kevin B. McCray, CAE** National Ground Water Association

Kevin McCray, CAE, is the executive director of the 11,000 member National Ground Water Association headquartered at Westerville, Ohio. McCray has been executive director since 1995, after serving in several other capacities on the Association's management staff. McCray has served on a number of ground water-related advisory groups. In addition to dozens of articles, he has authored or compiled six books for the ground water industry, including the Ground Water Industry Market Backgrounder. McCray is also the chief executive of the National Ground Water Research and Educational Foundation.

Private water well systems, regulated at the local and state level, are sometimes portrayed as providing an inferior means of potable water supply. This presentation will examine measured consumer attitudes, the role of private water well systems in supplying drinking water to more than 13 million American households, how federal data sources measure the actual scope of private water well safety, and will conclude with an examination of the public and private sector initiatives to further protect the health of consumers utilizing private water well systems, including the role of personal stewardship.

The audience will be: exposed to new ideas about the health risks from private water well systems; given an opportunity to increase their knowledge in at least one area related to private water well systems; and introduced to ideas as to how to integrate some knowledge gained from the presentation into their daily work.

A review of the performance of a recent U.S. EPA grant for private well owner communication will also be examined, including the various tools created to facilitate public awareness.

This presentation will cast a vision for the audience to become regularly involved in educating water well owners on water well and groundwater stewardship.

## PrivateWellClass.org – An Online Technical Assistance Program for Private Well Owners

Steven D. Wilson, Jennifer S. Wilson, & Cassia R. Smith

Bio: Steve Wilson is a groundwater hydrologist who has been at the Illinois State Water Survey since 1983. Most of his research has been related to groundwater quantity and quality issues in the sand and gravel aquifers of Illinois. He has worked on numerous projects related to the Mahomet Aquifer, arsenic, private wells, and those involving small water and wastewater systems. He manages SmallWaterSupply.org, which provides free resources and support for small water and wastewater system operators; and PrivateWellClass.org, a free online class for private well owners and very small water systems.

An innovative, email-based class that helps private well owners better understand the geology, hydrology, and construction features of their wells has been developed at the University of Illinois at Urbana-Champaign. A series of ten lessons, delivered via email using a staggered, self-paced approach, provide guidance on dealing with common well maintenance issues and problems. Other topics include source water protection, sampling, interpreting results, home treatment, and emergency situations.

The lessons were developed to be a basic, but comprehensive, class that well owners could use to become better stewards of their wells and nearby groundwater. One lesson is sent to the participant's email address each week for 10 weeks. Pre- and post-tests, as well as an evaluation, allow participants to provide feedback for improving the class.

The program has been marketed through state agencies responsible for well construction and driller registration, cooperative extension, and public health agencies, all of which were contacted by phone and/or email. The Rural Community Assistance Partnership has marketed the program throughout their network of technical assistance providers and trainers. Social media provide additional marketing and a more personal approach to participants who have questions. The website includes an email address for participants to ask specific questions.

In the first year of the project, over 2600 people nationwide participated. Participants include private well owners, sanitarians from local health departments, operators of small water systems, and other interested stakeholders. We will describe the class material and provide results from the evaluations, which describe what they liked/ didn't like, would change, and suggestions for improving the class. We will also describe new efforts underway to expand outreach as it moves through an additional year of funding (videos, Q & A webinars, podcasts, comprehensive contact list).

## Private Well Sampling Near Oil & Gas Operations

Robert W. Puls, Ph.D. , Oklahoma Water Survey

Dr. Robert Puls is Director of the Oklahoma Water Survey and Associate Professor at the University of Oklahoma. Dr. Puls was employed by the U.S. Environmental Protection Agency (USEPA) in Ada, Oklahoma for almost 25 years. He was the Technical Lead for the ongoing National USEPA Study on Hydraulic Fracturing and Drinking Water Resources prior to his retirement in early 2012. He has authored more than 150 publications on ground-water sampling, ground water remediation and hydraulic fracturing and drinking water resources. He has a Ph.D. from the University of Arizona

With the rapid expansion of high volume horizontal well drilling with hydraulic fracturing for oil and gas extraction, the public has become increasing concerned about potential risks to domestic drinking water wells near these operations. Millions of people in the U.S. obtain their drinking water from ground water. It is essential to know the quality of the water we are drinking. Unlike municipal supply wells, domestic wells are not regulated. Recent studies indicate that a quarter of all domestic wells have at least one contaminant at a level that poses a risk to human health. This presentation identifies the risks to these water supplies in the context of oil and gas extraction and provides guidance on what, where, how and when to sample. It briefly summarizes current state programs for baseline water quality monitoring and provides key references regarding the sampling of domestic wells.

## Texas Well Owner Network: Protecting Groundwater Resources and Human Health.

Drew M. Gholson[1], Diane E. Boellstorff[2], Ryan A. Gerlich[3], John W. Smith[4] and Mark L. Mcfarland[4], (1)Soil and Crop Sciences, Texas A&M AgriLife Extension Service, College Station, TX (2)Soil & Crop Sciences, Texas A&M AgriLife Extension Service, College Station, TX (3)Biological and Agricultural Engineering, Texas A&M AgriLife Extension Service, College Station, TX (4)Soil & Crop Sciences, Texas A&M AgriLife Extension Service, College Station, TX

Drew Gholson is an Extension Program Specialist-water resources in the Soil and Crop Sciences Department for the Texas A&M AgriLife Extension Service. He coordinates the Texas Well Owner Network, an extension program that aims to improve the water quality and health of Texans reliant on water wells. Gholson has been involved in numerous groundwater assessment projects dealing with both groundwater quantity and quality issues. Drew's primary area of focus is groundwater, private water wells and water quality and has worked with private well owners since 2007.

Over 1 million private water wells in Texas provide water to citizens in rural areas and increasingly to those living in small acreages at the growing rural-urban interface. Private well owners are independently responsible for all aspects of their water well system including monitoring the water quality, maintenance, and responding to water quality or water quantity problems. To support this need to educate private well owners, the Texas Well Owner Network (TWON) was initiated as a partnership between Texas A&M AgriLife Extension Service and the Texas State Soil and Water Conservation Board. Primary goals of the program are changes in knowledge, awareness, attitudes and actions of private water well managers and improvement of private well management to safeguard homeowner health and protect aquifer integrity.

The TWON is offered state-wide for Texas residents to become familiar with groundwater resources, septic system maintenance, well maintenance, water quality and water treatment. The program also offers the opportunity for participants to bring water samples from their own water well to be screened for nitrate-nitrogen, TDS, and fecal coliform bacteria. Participants with water samples exceeding the maximum containment levels are provided recommendations to improve water quality. Training is delivered through educational presentations and easy to understand publications. The TWON program aims to help private well owners understand their role in protecting their water supply and groundwater resources.

## Well Integrity: Stray Gas Wellbore Intrusion Analysis

J. Daniel Arthur is a registered professional petroleum engineer specializing in fossil energy, planning/engineering analysis, and environmental issues. He has over 25 years of diverse experience that includes work in industry, government, and consulting. Mr. Arthur served as the primary expert for the largest well integrity evaluation program in the United States related to wellbore methane intrusion. As part of the program, several innovations related to well integrity analysis were developed. Mr. Arthur is a founding member of ALL Consulting and has served as the company's President since its inception in 1999.

Tom Tomastik received his BS and MS degrees in geology from Ohio University in 1979 and 1981. From 1982 to 1988, Mr. Tomastik was employed as a consulting geologist involved in oil and gas exploration and development in southeastern Ohio. From December of 1988 until August of 2014, Tom was employed by the Ohio Department of Natural Resources, Division of Oil and Gas Resources Management, UIC Section. Tom retired from the Division in August of 2014. He was responsible for all of the Underground Injection Control (UIC) duties, which include performing independent reviews of applications for Class II saltwater injection, secondary and enhanced recovery projects, and Class III salt-solution mining wells in Ohio. Tom also planned and implemented highly complex groundwater conflict investigations involving oil and gas investigations. He provided technical expertise to the general public, oil and gas industry, governmental agencies and officials regarding Federal and State regulations, oil and gas and injection well construction, well operations, and groundwater contamination and stray gas investigations. He has authored or co-authored articles on various aspects of Ohio's oil and gas industry, groundwater investigations, injection wells, solution mining, and geology. Tom is currently employed as a Senior Geologist and Regulatory Specialist with ALL Consulting of Tulsa, Oklahoma and is involved in injection well evaluation, permitting, and oversight, stray gas investigations, groundwater complaint investigations, water sourcing, induced seismicity and seismicity monitoring.

## Development and Implementation of National Ground Water Monitoring Network

Mike Wireman , Sub-Committee on Groundwater, U.S. EPA, retired
Robert P. Schreiber, PE, BCEE, D.WRE , Water Resources Division, CDM Smith - Vice President, Cambridge, MA
William L. Cunningham, Office of Groundwater, U.S. Geological Survey, Reston, VA

The Subcommittee on Ground Water (SOGW) of the federal Advisory Committee on Water Information has guided a collaborative effort to develop a framework for design and implementation of a long-term nation-wide groundwater quantity and quality monitoring network (NGWMN). The network, focused on major aquifers in the USA, is intended to provide data and information necessary for sustainable management of groundwater. Groundwater professionals from more than 50 organizations including, government, professional organizations, private sector firms, and academic institutions have participated in the SOGW. The NGWMN is envisioned as a voluntary, cooperative, integrated system of data collection, management and reporting. In 2009 the SOGW released A National Framework for Ground-Water Monitoring in the United States and in 2010 -2011 conducted pilot studies in partnership with six states aimed at testing the concepts and feasibility of developing and implementing a NGWMN. In September 2011 the SOGW released National Ground-Water Monitoring Network –Results of Pilot Studies. Lessons learned during the pilot studies were used to make necessary revisions to the 2009 Framework document and in 2013 the SOGW released an updated version. A critical element of the NGWMN is the development of a web-based portal through which groundwater data can be viewed or downloaded by the public. The SOGW is currently focused on implementation of the network. A number of states are currently participating and more are expected to become data providers in the next few years. On July 15.2014, The U.S. House of Representatives Appropriations Committee approved the fiscal year 2015 Interior and Environment Appropriations bill, which includes funding to begin implementation of a NGWMN.

## Wyoming Groundwater-Quality Monitoring Network

Gregory K. Boughton

The author earned his Bachelor of Sciences degree in Watershed Sciences from Colorado State University in 1989. He began his career with the USGS Illinois Water Science Center upon graduation and transferred to the USGS Wyoming-Montana Water Science Center in 1990. He has worked on a variety of surface water, groundwater, and ecology projects and is currently a hydrologist in the groundwater and surface water section of the Wyoming-Montana Water Science Center of the U.S. Geological Survey.

The Wyoming Groundwater-Quality Monitoring Network is a cooperative program with the Wyoming Department of Environmental Quality begun in 2009 to establish baseline groundwater conditions in the state. Representatives from U.S. Geological Survey, Wyoming Department of Environmental Quality, U.S. Environmental Protection Agency, Wyoming Water Development Office, Wyoming Geological Survey, and Wyoming State Engineer's Office formed a steering committee, which meets periodically to evaluate progress and consider modifications to strengthen program objectives.

Ambient or baseline monitoring is being conducted in "priority" areas where groundwater has been identified as an important source of drinking water to public and private water supplies; is susceptible to contamination, and is overlain by one or multiple land-use activities that could negatively impact groundwater resources.

Groundwater samples were collected from 146 existing shallow (less than or equal to 500 feet deep) wells from November 2009 through September 2012. These randomly selected wells were a mix of domestic, stock, municipal, and monitoring wells. Samples were analyzed for a broad suite of inorganic and organic constituents. Several different laboratories capable of varying reporting levels and using dissimilar data formats performed the analyses.
Values of physical characteristics, major ions, trace elements, nutrients, radionuclides, volatile organic compounds, and coliform bacteria were compared to Federal and State regulatory water standards. Major-ion chemistry was characterized for different hydrogeologic units. Stable isotopes of hydrogen and oxygen were compared to the Global Meteoric Water Line and Local Meteoric Water Lines.

Water-quality data are stored in the USGS National Water-Information system data base. Data are publically available and are used by interested stakeholders to establish baseline groundwater-quality conditions to serve as a reference to which future groundwater-quality data can be compared. Well owners were notified of results exceeding Federal or State regulatory water standards.

## The Kentucky Interagency Groundwater Monitoring Network: Expanded Monitoring Programs

Jessica Moore[1], Robert J. Blair[1] and Bart Davidson[2]

Jessica Moore is a geologist in the Kentucky Division of Water, Watershed Management Branch. She coordinates the Wellhead Protection Program, including the Source Water Protection Assistance Program. She received a B.S. in Geology from the University of Kentucky and an M.S. in Geology from the University of North Carolina at Chapel Hill. She has been with the Division of Water for three years.

Rob Blair is a professional geologist with the Watershed Management Branch of the Kentucky Division of Water. He manages the Kentucky Groundwater Monitoring Network and is the principle investigator for multiple groundwater monitoring projects throughout the state. He has been with the Division of Water 14 years and received a B.S. in Geology from the University of Kentucky.

Bart Davidson is a hydrogeologist in the Water Resources Section with the Kentucky Geological Survey. He has been with the survey for 28 years and specializes in working with GIS applications for water data. He is also the manager of the Kentucky Groundwater Data Repository. Bart received a B.A. in Psychology from Berea College and an M.S. in Geology from Eastern Kentucky University.

Systematic groundwater monitoring in Kentucky was initiated through a consortium of academic and government agencies in the mid 1990s. This body eventually became the Interagency Technical Advisory Committee (ITAC) on Groundwater and established the Interagency Groundwater Monitoring Network ("the Network").

ITAC made several recommendations for the Network's design, including representation of aquifer types and physiographic regions, spatial distribution of sites and parameters to be analyzed. The Network was established with the Kentucky Division of Water (KDOW) collecting samples at approximately 60 sites on a quarterly basis. Although the parameters, aquifer types and physiographic regions have been represented as designed, the spatial distribution and site density are only a fraction of what was proposed. To fill these data gaps, one-time sampling sites were selected based on proximity to permanent sites and requests by groundwater users. Additionally, after several years the sampling frequency at some sites was decreased so that new sites could be added to the Network. Finally, expanded monitoring has been conducted through various programs and grants, which have allowed for regional and watershed-based groundwater projects led by KDOW and the Kentucky Geological Survey (KGS).

Expanded groundwater monitoring projects by KDOW and KGS were initially conducted within the individual boundaries of major river basins, or Basin Management Units (BMUs). These studies covered large areas and focused on characterizing ambient groundwater quality throughout the BMU. Follow up studies then focused on smaller watersheds within various BMUs where surface streams had been assessed and deemed impaired. The goal with these projects was to determine the influence of groundwater on surface water quality. Additionally, some follow up studies focused on regions previously not assessed or under represented. Recent monitoring projects in karst regions have utilized an approach to integrate surface water assessment protocols to better define the relationship of these conjunctive systems.

## Required Baseline and Ongoing Monitoring of Groundwater in CBM Areas of Colorado – Use in Case Studies of Possible Impacts to Groundwater.

Peter Gintautas[1], Karen L. Spray[2] [1]Colorado Oil and Gas Conservation Commission [2]Southern Ute Indian Tribe – Growth Fund

Peter Gintautas is an environmental protection specialist with the COGCC. Karen Spray is currently the exploration and production manager with the Growth Fund and previously was an environmental specialist with the COGCC. Peter has more than 30 years of experience in geochemistry as well as a Ph.D. in geochemistry. Karen has more than 25 years of experience in hydrogeology and a Ms. in hydrology. Karen is a principal author of the Groundwater Atlas of Colorado.

Baseline and continuing groundwater monitoring in areas of coal bed methane (CBM) development has been required for more than 10 years in parts of Colorado. These requirements have resulted in hundreds of data sets that can be evaluated on a well-by-well or on a regional basis to assess potential impacts from nearby drilling, completion and production of CBM wells. Statistical analysis have been used to assess potential regional impacts in the San Juan Basin and gas composition, gas and water isotopes, overall inorganic chemistry and analysis of specific chemicals used in drilling and completion are routinely utilized in investigations of potential impacts to individual water wells. This paper summarizes results of both a statistical regional assessment of water quality changes in the San Juan Basin and a situation in the Raton Basin where an unintended chemical tracer from hydraulic fracture stimulation was successfully used to investigate a complaint alleging impacts to groundwater accessed by a domestic water well. Baseline and continued sampling is now required for all oil and gas wells in the State of Colorado. Data from required baseline and continued sampling of water wells has proven to be the most effective tool available for investigations of potential impacts to groundwater from oil and gas operations.

The analytical requirements for the water well samples are summarized in Table 1.

| Monitoring Period | Analytical Requirements |
|---|---|
| Baseline (pre-drilling) | Major cations (Ca++, Mg++, K+, Na+), major anions (CO3-,HCO3-, Cl-, SO4--), total dissolved solids, iron, manganese, nutrients (nitrates, nitrites, selenium),dissolved methane, pH, presence of bacteria, specific conductance, and field hydrogen sulfide.<br><br>Methane ≥ 2ppm triggers compositional analysis for:<br>δD (methane) and δ13C (methane). |
| One year post well completion | |
| Three years post well completion | |
| Six years post well completion | |

How do States Define "Usable Quality" Groundwater?

Steven P. Musick, P.G.

The presentation will provide an overview of current regulatory programs relative to groundwater protection for 26 oil and gas producing states. The review included regulations of both Oil and Gas and Water Quality/Environmental state agencies. Our work describes generally the definitions of usable and fresh groundwater, protection depths, environmental policy statements and states' protection requirements. The scope of state groundwater classifications and the application of water quality standards are discussed, as are relationships to permitting and corrective action.
Steve Musick received his Bachelors Degree in Geological Sciences from the University of Texas at Austin in 1976. He worked with the Texas Commission on Environmental Quality and its predecessor agencies for 26 years. He has consulted with and represented the Ground Water Protection Council on technical and policy issues since 2008. He is licensed in the State of Texas as a Professional Geologist.

Hunting Big Brine: How the Oklahoma Corporation Commission is using Historical Aerial Photographs to Protect Oklahoma Waters

Madeline Dillner Oklahoma Corporation Commission

Madeline Dillner graduated from the University of Oklahoma in May 2013 with a B.S. in Environmental Sustainability. She started at the Oklahoma Corporation Commission in June of 2012 as an intern, georectifying the OCC's collection of historical aerial photos. In August of 2013, she earned a position as a GIS analyst for the OCC's Brownfields Program. In addition to making maps for environmental protection projects, she assists with Brownfields site assessment and cleanup, and helps manage the OCC's Historical Aerial Digitization Project. Outside of work, she enjoys researching natural building methods and environmentally sustainable living.

Since 2007, the OCC has been digitizing all hard copy aerial photos from the 1930s onward in Oklahoma. We are sharing our extensive collection of digital photographs via OKMaps, a free, public online data viewer, so they can benefit others as much as they have benefitted us. By hosting all of our photographs online we hope to crowdsource these photographs' georectification, so university GIS classes and others can help us create historical aerial mosaics faster than we ever could by ourselves. This is OHADP—the Oklahoma Historical Aerial Digitization Project.

As the historical aerial coverages expand, the OCC will be able to better protect Oklahoma's groundwater and surface water from the most common bane of old oilfields: brine plumes. The most noticeable effect of a surface brine spill is an area void of vegetation; these areas show up as bright white patches in aerial photographs. However, a saline groundwater plume caused by a surface brine spill that has migrated down a gravel-packed water well into the aquifer below does *not* show up on an aerial photograph. The Corporation Commission hopes that by using GIS to delineate bright white patches on the surface ground in aerial photographs, we can push for regulations for water well drillers in those high-pollution-risk areas areas and stop creating pathways for surface brine to reach aquifers. And, by advocating for remediation and revegetation of the salt-killed areas, we can stop both brine and topsoil's migration to streams, rivers, and lakes.

Training Session: NETL's Variable Grid Method Tool for Simultaneous Visualization and Assessment of Spatial Trends and Uncertainty – Jennifer R. Bauer and Kelly Rose

The products of spatial analyses that leverage the interpolation of sparse, point data to represent continuous phenomena are often presented without clear explanations of the uncertainty associated with the interpolated values. As a result, there is frequently insufficient information provided to effectively support advanced computational analyses and individual research and policy decisions utilizing these results. This highlights the need for a reliable approach capable of quantitatively producing and communicating spatial data analyses and their inherent uncertainties for a broad range of uses. To address this need, NETL has developed the Variable Grid Method (VGM), a flexible approach designed to apply to a variety of analyses and use case scenarios where users need a method to effectively study, evaluate, and analyze spatial trends and patterns while communicating the uncertainty in the underlying spatial datasets. The VGM outputs a simultaneous visualization representative of the spatial data analyses and quantification of underlying uncertainties, which can be calculated using data related to sample density, sample variance, interpolation error, uncertainty calculated from multiple simulations, etc. We will present examples of our research utilizing the VGM to quantify key spatial trends and patterns for subsurface data interpolations and their uncertainties and leverage these results to evaluate storage estimates and potential impacts associated with underground injection for $CO_2$ storage and unconventional resource production and development. The insights provided by these examples identify how the VGM can provide critical information about the relationship between uncertainty and spatial data that is necessary to better support their use in advance computation analyses and informing research, management and policy decisions.

VGM Tool Training: Whenever utilizing spatial data to drive advanced computational analyses or inform management, research, and policy related decisions, it becomes critical that any underlying uncertainties are appropriately quantified and communicated. This course will explore how NETL's VGM approach can be apply to various spatial data analyses and interpretations to provide a single product that simultaneously communicates spatial data patterns and trends and any uncertainties underlying the data and/or analyses. Through discussion and demonstration this course will outline the VGM, familiarize users with the products that can be created using the VGM approach, introduce users to the Variable Grid Tool, a plug-in Python tool for ArcGIS that helps facilitate the VGM approach, and present examples utilizing various spatial datasets to create different variable grids that represent multiple forms of uncertainty quantification. Participants should have a familiarity with spatial datasets and software used to work with such data.

Jennifer Bauer is a post-graduate research fellow for the National Energy Technology Laboratory's Office of Research & Development. Her current research leverages her risk and hazard, GIS, GIS programming, and spatial statistics background to analyze spatio-temporal trends, interpret spatial datasets, and assess risks and potential impacts associated with various forms of energy production and development.
Kelly Rose is a research geologist and Geology Team Lead with the National Energy Technology Laboratory's Office of Research & Development (NETL-ORD). Previously, she worked on the assessment of tight gas resources in the western United States, first as an exploration geologist and then as a research geologist with DOE/NETL. At present, she works with research teams spanning ORD's geologic and environmental sciences portfolio conducting geologic and geospatial research in support of energy and climate related programs. She also serves as the coordinator and systems integrator for NETL's Energy Data eXchange, a public and private online coordination/collaboration knowledge management tool.

EPA Source Water Session

Holly Green currently serves as the Acting Branch Chief for the Prevention Branch in the US Environmental Protection Agency's Drinking Water Protection Division, Office of Ground Water and Drinking Water. In that role she manages the national Source Water Protection Program and works closely with the Underground Injection Control Program. Previously, Holly held leadership positions in EPA's national Water Quality Standards Program, focusing on water quality criteria implementation in Clean Water Act programs and national nutrients policy. She also spent three years with the EPA Office of Inspector General. Prior to EPA, Holly served as a Peace Corps Volunteer in Honduras working with communities to build, sustain and protect rural drinking water systems. Holly received a B.A. in Environmental Planning from Binghamton University (State University of New York) and a Master of Environmental Management degree from the Yale School of Forestry and Environmental Studies.

Rachel Carlson is an Oak Ridge Institute of Science and Education intern with the Office of Ground Water and Drinking Water (OGWDW), US EPA. At OGWDW, Rachel assists with GIS and outreach in projects such as the Drinking Water Mapping Application to Protect Source Waters (DWMAPS); the Source Water Collaborative; and the Clean Water Act/Safe Drinking Water Act Collaboration Initiative. Rachel earned a Master's in Environmental Engineering from Rice University, where she researched drinking water treatment and urban storm surge issues. She has provided technical support for numerous watershed rehabilitation and sanitation initiatives in India, Senegal, and Guinea, and the United States.

Sherri Comerford has spent more than a decade working on various programs within EPA's Office of Ground Water and Drinking Water. Last spring, she joined the source water protection team after spending three years focused on hydraulic fracturing in the Underground Injection Control program. Previously, she worked on a variety of outreach projects related to national drinking water standards. She has a Master of Arts in Science Writing from Johns Hopkins University and a bachelor's degree from Miami University's School of Interdisciplinary Studies, with a focus on environmental studies. Prior to joining EPA, she worked in journalism and served as a Peace Corps volunteer.

## National Ground Water Association's ANSI/NGWA 01-14 Water Well Construction Standard

Kevin McCray, CAE, National Ground Water Association

Kevin McCray, CAE, is the executive director of the 13,000 member National Ground Water Association headquartered at Westerville, Ohio. McCray has served on a number of water-related advisory groups, including the U.S. Water Resources Export Council; Water Systems Council; U.S. EPA/AWWA Comprehensive Integrated Resource Cooperative Blue Ribbon Panel; Kellogg Foundation Ground Water Education Consortium; Great Lakes Commission Ground Water Education Roundtable; and the Ground Water Remediation Technology Analysis Center Advisory Board.

By having an American National Standards Institute (ANSI) approved water well construction standard the National Ground Water Association (NGWA) continues to advance the protection of public health and the safety of the groundwater resource. ANSI, founded in 1918, promotes and facilitates voluntary consensus standards and conformity assessment systems, and safeguards their integrity.

Two major factors for NGWA's selection of ANSI were: (1) ANSI standards are recognized worldwide and (2) the ANSI process is inclusive. The ANSI process demands the standard setter actively seeks comment from all parties and responds to all comments. An important aspect is that ANSI approves the process, but does not approve the actual standards. NGWA approves the standards and ANSI verifies that its process has been completed.

There will be at least three significant and immediate benefits of NGWA standards: (1) certified standards further strengthen NGWA's voluntary certification program, which is also relied upon by 17 states and one county for contractor licensing purposes; (2) certified standards enhance the utilization of water well systems as a safe and reliable source of drinking water; and (3) when a local regulatory agency's existing or proposed rules are not consistent with the reasonable application of scientific principles and real world experiences, certified standards are a feasible argument for change.

The NGWA starting point for the standard – but not the finishing point – was the 1997 edition of the Association's *Manual of Water Well Construction Practices,* a manual first developed in 1975 by a team of water well contractors from around the nation.

NGWA is an international not-for-profit professional society and trade association representing the ground water industry. Its members include many of the world's leading public and private sector ground water scientists, engineers, water well contractors, as well as manufacturers and suppliers of ground water related products and services.

## Collaborative Approaches to Source Water Protection Plan and Stormwater MS4 Implementation

Matt Genchur is the manager of the Source Water Protection program for the Pennsylvania Rural Water Association (PRWA). He has been employed there since 2004 and has served in his current capacity since 2010. During this time, Matt has assisted several hundred public water systems in efforts to protect their sources of drinking water. Assistance includes on-site visits and conversations to drafting and implementing full source water protection plans. Matt is also involved in many statewide and regional water resource planning efforts in Pennsylvania, including the State Water Plan, and more recent initiatives in stormwater and MS4 implementation.

In Pennsylvania, the implementation of source water protection and stormwater programs faces many similarly layered challenges.

First, over 60% of the public water systems in the Commonwealth serve a population of less than 1,000. Subsequently, many of these systems are managed and operated with limited staff and resources. These limitations create challenges when finding the adequate and appropriate time to not only develop plans, but eventually implement them.

Second, the federal, state, and related partnering organizations like PRWA are working with ever dwindling funds and staff resources. Their roles have historically been rooted in assisting or directly developing protection plans, many needing an average of two years to create a quality product that the system can use effectively moving forward. Now, with fewer staff and those personnel being stretched into other regulatory roles and responsibilities, less time is available to manage quality projects.

Lastly, a paradigm shift has occurred over the past few years due to increasing federal pressure to obtain federal program benchmarks. Now more systems are being reached, which is a positive for the program, but the quality of work and attention that the system needs for success has suffered.

Over the past few years, the formation of county-wide source water protection and stormwater/MS4 coalitions has quickly changed the way these programs are being effectively implemented. Partnerships between state, regional, and local groups have proven to be the proper mix for water systems and municipalities to be involved, see meaningful progress, adequately balance the strengths and functions of the groups involved, and justifiably feel successful in their efforts. Individually, many systems and local governments struggle to implement their plans and permits; strength in numbers and peer-to-peer interaction has proven to bear greater results across the board. A number of different approaches will be covered in this session.

### Kentucky's Source Water Protection Assistance Program

Jessica Moore and Chris Yeary Kentucky Division of Water

Jessica Moore is a geologist in the Kentucky Division of Water, Watershed Management Branch. She coordinates the Wellhead Protection Program, including the Source Water Protection Assistance Program. She received her B.S. in Geology from the University of Kentucky and an M.S. in Geology from the University of North Carolina at Chapel Hill.

Chris Yeary is the environmental control supervisor for the Water Quantity Management Section in the Kentucky Division of Water, Watershed Management Branch. He oversees the Wellhead Protection Program and water withdrawal permitting and reporting. He has a B.S. in Forestry from the University of Kentucky.

The Kentucky Division of Water's Wellhead Protection Program developed the Source Water Protection Assistance Program to help communities and water systems implement source water protection strategies. As part of the source water and wellhead protection planning processes, water systems must formulate management strategies that will prevent potential contaminant sources from impacting their water supply. This program is one option water systems and local governments can utilize to research and implement source water protection measures specific to their protection area(s). These projects may require Public Water Systems (PWSs) or government entities to work with local landowners, local media, watershed groups, and many others to achieve their source water protection goals.

Multi-faceted source water protection implementation plans that include both physical management strategies and public involvement are the most successful. Outreach events including meetings, workshops, public service announcements, and many others are the best way to engage the citizens and local governments in source water protection activities. Education also helps dispel the common misconception that clean drinking water is solely the responsibility of the water system. PWSs must produce finished water that meets regulatory requirements but usually the system or municipality has little, if any, regulatory control over activities occurring within their protection areas. With this in mind, applicants were encouraged to include public education and outreach strategies in their project goals.

The response from water systems and local communities has been very positive and has raised interest in source water protection activities across the state. The Source Water Protection Assistance Program was able to support four projects with the first funding cycle. Approved projects include several different protection activities such as plugging unused drinking water wells within wellhead protection areas, developing public service announcements about drinking water, and monitoring contamination near a PWS well field.

### Trends in Permitting of Class V Wells in Alabama

Sonja S. Massey, Chief Groundwater Branch, Land Division, Alabama Department of Environmental Management

Sonja Massey is the Chief of the Groundwater Branch in the Land Division of ADEM. The Groundwater Branch directly administers the Underground Storage Tank Regulatory and Corrective Action programs, as well as the Underground Injection Control program for the State of Alabama. The Groundwater Branch also provides groundwater technical support where needed for other ADEM programs. Ms. Massey is a registered Professional Engineer in Alabama. She graduated from Auburn University in 1979 with a Bachelor's Degree in Chemical Engineering and spent three years as an environmental engineer in the paper industry. Following that, she began work with the Alabama Water Improvement Commission (a predecessor agency to ADEM) in 1982, as an environmental engineer in the Industrial NPDES permitting program, where she worked for five years. In 1987 she was appointed as Chief of the ADEM Groundwater Branch of ADEM.

The State of Alabama received primacy from EPA for the Underground Injection Control (UIC) program in 1982. This primacy is shared between the Alabama Department of Environmental Management (ADEM) for the Class III and V well categories and the Alabama Oil and Gas Board for Class II wells. Alabama has one Class III well field which involves the solution mining of sodium chloride as a raw material for the production of chlorine and sodium hydroxide. Alabama does not permit Class I wells, so the remainder of the ADEM UIC inventory consists of 351 active Class V wells.

Of these wells, approximately 25% dispose of wastewater from sanitary sewer wastewater treatment plants, 25% are related to the injection of nutrients, oxidants, etc., for the remediation of contaminated groundwater, and the remaining 50% of the Class V wells are associated with various commercial or industrial facilities.
One of the most challenging areas of permitting growth within the last decade has been the increase in the number of sanitary wastewater treatment plants discharging to groundwater. A minimum of secondary treatment is required. These disposal systems utilize either shallow, low pressure distribution systems or the more common, slightly deeper disposal systems usually associated with septic tanks.

Of concern to Alabama's program is the investment in resources needed to adequately regulate the sanitary sewer Class V permittees. These Class V permits require regular effluent monitoring for BOD and TKN, and nitrates in groundwater. It has become evident that without these monitoring requirements, and regulatory oversight, these treatment systems, because of the increasing trend in higher volumetric loading, could become very potent sources of nitrate to the environment.
Other subjects of this presentation include a discussion of program funding, and Financial Responsibility legislation enacted in Alabama for Decentralized Wastewater Treatment Systems which discharge to groundwater.

Sustainability is the Name of the Game – EPA's Decentralized Wastewater Program Efforts

Maureen Tooke, USEPA

Ms. Tooke currently works in EPA's Office of Wastewater Management out of the Idaho Operations Office in Boise, ID. Ms. Tooke has 18 years' experience in the environmental field. Her work is currently focused on activities within EPA's Decentralized Wastewater Management Program—leading the MOU Partnership for Decentralized Wastewater Management, homeowner awareness and education efforts through the SepticSmart program, the development/implementation of a model program for onsite system management for the states within the Chesapeake Bay watershed, as well as Sustainable Utility Management for Small Systems.

'Sustainability is the Name of the Game – EPA's Decentralized Wastewater Program Efforts' – Small and rural underserved communities across the U.S. are struggling to create sustainability within their communities regarding water and wastewater infrastructure. EPA has developed joint efforts and programs to assist these communities with tools and self-guided workshops to empower them to create and maintain sustainability to meet their current and future needs.
Small and rural underserved communities across the U.S. are struggling to create and maintain sustainability within their communities regarding water and wastewater infrastructure. EPA has developed and expanded joint efforts and programs to assist these communities to empower them to create and maintain sustainability regarding their water infrastructure to meet their current and future needs. EPA has joined forces with and continued long standing relationships with many organizations and other federal agencies with like missions such as USDA, Veterans Affairs, HUD, IHS, Mexico, Tribes, and U.S. Territories in order to assist these communities with their wastewater infrastructure needs. Projects of note include SepticSmart, data sharing on advanced treatment onsite wastewater technologies, effective/sustainable utility management, and U.S./Mexico border needs assessment. Creative thinking and partnering to serve the needs of those most in need for first time and adequate access to water and wastewater is the answer to dwindling budgets in the midst of growing needs.

## Oil Impact on Rural Water Systems

Ken Royse, Bartlett and West, Inc.

Ken Royse is a native of Mandan, ND and a graduate of Montana State University. He is a registered professional engineer in 14 states of the Midwest and has worked in water development projects throughout this area for over 30 years. Ken serves as a Vice President, Division Director, and member of the Board of Directors for the engineering firm of Bartlett and West, Inc. which has 11 offices in the Midwest. In such capacities, Ken directs policy, marketing, and technical service of a professional staff of approximately 100. Ken's division is responsible for an extensive listing of water development projects throughout a 10 state area of the central United States. Additionally Ken serves on the Board of Directors and is a Vice President in the West Dakota Water LLC company which is a large privately owned and operated regional water supply company which brings water to the oil and energy industry in western North Dakota.

In many of areas of the country there is a resurgence of oil and energy development activities due to new discoveries of recoverable oil and new technologies to recover such oil. Nowhere more than in western North Dakota has that occurred in more dramatic fashion, with nearly 2,000 new wells per year being drilled and developed and an estimate of approximately 40,000 wells to be installed. While the oil industry brings economic opportunity and wealth to the State of North Dakota and to the areas being developed, it also brings challenges and demands upon local municipal and rural water system because of the very large need, and very short supply, of water needed to support the industry.

A typical well in the Bakken formation of western North Dakota requires approximately between 2,000,000 to 5,000,000 gallons per well for use in a process called hydraulic fracking. Hydraulic fracking is the introduction of slurry of sand, chemicals, and water under high pressure and in high volumes to affect a 'frac' of the formation wherein lies the recoverable oil. The water in the solution is the key ingredient; it must be of sufficient quantity and of quality to achieve an optimum reaction with the added chemical to achieve the frac. Oil and energy companies have nearly exhausted the ground water resources limited incidental surface water resources (ponds, sloughs) of the area. Hug e demands are now being placed on the area communities and area rural water districts for the water; that demand is often presented with an offer of a large payment making it difficult for a municipality or district to not become involved. It is this demand, and challenges of providing water also then to the municipal and household users of the system, which the local districts have to resolve.

In addition to the very large demands for water by the oil industry, there is a corresponding increase in demand for domestic water for the many new homes which now must be built and served to accommodate the industry. This presentation discusses those needs also and how rural water and municipal systems of the area formulate policy and construction infrastructure to accommodate those needs in addition other oil industry needs.

## Regulatory and Infrastructure Challenges to Shale Play Development

Heather Palmer – Bracewell Environmental Group

As a partner in Bracewell's environmental strategies group, Heather Palmer offers clients in-depth environmental regulatory knowledge and experience in energy-related environmental issues. She plays a major role in advising oil and gas clients on the environmental issues surrounding shale play development, hydraulic fracturing and the permitting, construction and operation of LNG and LPG export facilities in the U.S. She is a frequent author and presenter on hydraulic fracturing issues, including disclosure of hydraulic fracturing chemicals under state and federal laws.

Shale plays have revolutionized the U.S. oil and gas industry. While hydraulic fracturing techniques have been used safely for over 50 years, the pace of shale play development and the corresponding publicity have resulted in a heighted level of regulatory scrutiny. This session will summarize the regulatory and infrastructure challenges to shale play development in the U.S. and provide insight into the unique challenges faced in each of the major shale plays, including the Bakken, Eagle Ford, Marcellus, and Monterey shales.

## Water Use by Sector: An Analysis of FracFocus and USGS Water Use Data

Mike Nickolaus, PG, Ground Water Protection Council, Oklahoma City, OK

It has often been said that hydraulic fracturing uses a relatively small amount of water when compared to other uses. Clearly, high volume horizontal well hydraulic fracturing is a relatively minor user of water at the national level, accounting for less than 0.1% of water use when compared to other consumptive water uses such as irrigation and public water supply. However, the question remains as to whether or not this ratio of usage between sectors remains consistent down to the local level. In this presentation we will discuss the findings of a comparative analysis of water use in the sectors of irrigation, public water supply, and hydraulic fracturing at decreasing geographic scales in three oil and gas producing states (Texas, Pennsylvania, North Dakota) to determine whether or not the relationship between water usage in these sectors remains relatively static from national to county levels. To analyze water usage across the three sectors, data from USGS water use publications and the FracFocus chemical registry were utilized. Where unique state or regional conditions might apply, additional information from state regulatory agencies was utilized to ensure that water usage was consistent with agency figures.

Mike is the Special Projects Director for the Ground Water Protection Council. He is the former director of the Indiana Department of Natural Resources, Division of Oil and Gas. Mike has worked in the field of geology for nearly 30 years. He is a Professional Geologist and Member of the Society of Petroleum Engineers.

## Shale Energy Produced Fluids Management and UIC Well Disposal Trends

Author: David Yoxtheimer, P.G.

David Yoxtheimer, P.G. is a hydrogeologist and extension associate with Penn State University's *Marcellus Center for Outreach and Research* and serves as a liaison to advise stakeholders on key environmental issues. He earned his B.S. in Earth Science from Penn State, where he is currently completing his Ph.D. in Geosciences. Previous to joining MCOR he spent 18 years as a consulting hydrogeologist with expertise in water supply development, karst hydrogeology, geophysical surveying, environmental permitting, shale energy geology, and integrated water resource management.

Shale energy production in the United States has been increasing significantly over the last decade, especially from the Bakken (North Dakota), Marcellus (Pennsylvania/West Virginia), Utica (Ohio), Eagleford (Texas) and Niobrara Formations (Colorado). Although shale energy holds promise as an abundant energy source, environmental challenges exist with its development, including adequate treatment and disposal of flowback and produced fluids. Large volumes of produced fluids are generated after a well has been hydraulically fractured, typically ranging from 5 to 10 barrels of produced fluids per million cubic feet of gas or for each barrel of oil. Total dissolved solids (TDS) concentrations of produced fluid from unconventional wells often exceed 100,000 mg/L, with elevated levels of strontium (Sr), bromide (Br), sodium (Na), calcium (Ca), barium (Ba), chloride (Cl), and radionuclides originating from the shale formation, as well as fracturing additives. Managing these produced fluids requires environmentally-sound approaches for treatment, reuse or disposal. Recent data from Pennsylvania suggest approximately 87% of Marcellus Shale produced fluids were treated and reused for hydraulic fracturing operations using a variety of in-field and centralized facility treatment and management techniques, with the remainder disposed of primarily through use of Class II-D underground injection control (UIC) wells. Data indicate that produced fluids from many other shale plays are primarily disposed of via UIC wells rather than recycled, mostly due to the relatively low cost of UIC well disposal. This presentation will explore the volumes of produced fluids generated from major shale energy plays and examine treatment and disposal practices including UIC well use and implications for future disposal reservoir capacity as shale energy production increases.

## Disposal Wells and Shale Resource Development: A National Perspective

J. Daniel Arthur, P.E., SPEC, Greg Casey, P.E., Doug Louis, P.G., Fernando DeLeon, P.E., (ALL Consulting) and Tom Tomastik, P.G (Ohio DNR)

There are approximately 190,000 Class II injection wells that have been permitted, drilled, and utilized throughout the United States. Historically, the bulk of these wells have been utilized for purposes of Enhanced Oil Recovery or Waterflooding. With the onset of the Shale Revolution, the vast majority of new Class II wells serve a different purpose. In an overwhelming sense, new Class II wells are being permitted and drilled for purposes of disposing of water produced during fracture flowback and production operations following high volume hydraulic fracturing operations of long-horizontal wells completed in shales.

Historically, the Underground Injection Control (UIC) Program had a flurry of activity for several years following initial program promulgation. Many wells were registered and permitted by rule under the federal program, many new permits were completed, and an entire new federal program was developed. This included research on various aspects of the program, from casing & cementing requirements, mechanical integrity, area of review, confinement, and so on.

Today, a new wave of activity in this program has developed. New Class II Disposal Wells are being permitted, drilled, and utilized at a frantic pace in virtually every region where shale resources are being developed. The permitting backlog in some states can be 6 months or more to get one Class II well permitted by a State Agency and longer in a State where U.S. EPA is the primary permitting authority. Furthermore, many new issues have arisen. Furthermore, an array of issues has arisen that blanket the program and involve concerns outside of the UIC program itself, such as assuring compliance, induced seismicity, underground trespass, traffic, road use maintenance, taking of skim oil, traffic accidents, receiving zone over-pressurization, area-of-review issues, and more.

This paper will discuss and compare current issues in each shale play region with respect to disposal wells. This will include items such as geologic and hydrogeologic challenges, permitting, induced seismicity, area of review, NORM/TENORM, incoming water quality issues, co-location of reuse/recycling, facility design, public opposition, economic & environmental risks, and more.

## An Evaluation of Fracture Growth and Gas/Fluid Migration as Horizontal Marcellus Shale Gas Wells are Hydraulically Fractured in Greene County, Pennsylvania

Richard Hammack National Energy Technology Laboratory

Richard Hammack is a geochemist and leader of a research team that is conducting field investigations of unconventional oil and gas development. The team's research looks at air and water quality changes that are coincident with different stages of unconventional oil and gas development. He received a B.S. in Geology and an M.S in Geochemistry from West Virginia University in Morgantown, WV.

This field study monitored the induced fracturing of six horizontal Marcellus Shale gas wells in Greene County, Pennsylvania. The study had two research objectives: 1) to determine the maximum height of fractures created by hydraulic fracturing at this location; and 2) to determine if natural gas or fluids from the hydraulically fractured Marcellus Shale had migrated 3,800 ft upward to an overlying Upper Devonian/Lower Mississippian gas field during or after hydraulic fracturing.

The Tully Limestone occurs about 280 ft above the Marcellus Shale at this location and is considered to be a barrier to upward fracture growth when intact. Microseismic monitoring using vertical geophone arrays located 10,288 microseismic events during hydraulic fracturing; about 40% of the events were above the Tully Limestone, but all events were at least 2,000 ft below producing zones in the overlying Upper Devonian/Lower Mississippian gas field, and more than 5,000 ft below drinking water aquifers.

Monitoring for evidence of fluid and gas migration was performed before, during, and after the hydraulic fracturing of six horizontal Marcellus Shale gas wells. This monitoring program included: 1) gas pressure and production histories of three Upper Devonian/Lower Mississippian wells; 2) chemical and isotopic analysis of the gas produced from seven Upper Devonian/Lower Mississippian wells; 3) chemical and isotopic analysis of water produced from five Upper Devonian/Lower Mississippian wells; and 4) monitoring for perfluorocarbon tracers in gas produced from two Upper Devonian/Lower Mississippian wells.

Conclusions of this study are: 1) the impact of hydraulic fracturing on the rock mass did not extend to the Upper Devonian/Lower Mississippian gas field; and 2) there has been no detectable migration of gas or aqueous fluids to the Upper Devonian/Lower Mississippian gas field during the monitored period after hydraulic fracturing.

### Comparative Databases for Water Quality and Quantity Regulations pertaining to Oil and Gas Development

Matt Samelson - Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, University of Colorado Law

Matt Samelson is an attorney working with the Getches-Wilkinson Center for the Natural Resources, Energy, and the Environment (GWC) at the University of Colorado. Matt is currently conducting a comparative law research project of state regulations for major shale oil and gas plays nationwide. The project is part of a federal grant administered by the Environmentally Friendly Drilling System Technology Integration Program by the Houston Advanced Research Center. Matt also works on K-12 education policy and severance tax issues. He is a graduate of the University of Colorado Law School and the University of Colorado School of Public Affairs.

Advances in extractive technologies (hydraulic fracturing and horizontal drilling) have enabled a rapid expansion in oil and natural gas production through development of tight shale formations in rural, suburban, and urban areas. While research on the health impacts of oil and gas development is expanding, public concern has prompted regulatory review at all levels of government. There is tremendous value for state and local governments in jurisdictions experiencing new or increased oil and gas development in examining regulatory regimes already in effect in order to guide their conversations about best regulatory practices.
In response, researchers from the University of Colorado-Boulder's Intermountain Oil and Gas Best Management Practices Project, part of the Getches Wilkinson Center for Natural Resources, Energy and the Environment, are developing a comparative database examining water quality, water quantity, and air quality regulations pertaining to oil and gas development. The datasets for water quality, completed December 2013, and water quantity, anticipated completion June 2014, (www.lawatlas.org/oilandgas) include statutes and regulations from Colorado, Louisiana, Montana, New Mexico, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming. These states overlay major shale formations such as the Bakken, Eagle Ford, Greater Green River, Haynesville, Mancos, Marcellus, Niobrara, Permian, Piceance, Powder River, San Juan, Uinta, and Woodford.
The comparative database project provides policymakers, local governments, concerned citizens, environmental and public health advocates, and researchers with law resources to further explore the impact of oil and gas law on public health as it relates to water quality, water quantity, and air quality.
This presentation will provide an informative overview of how the water quality and water quantity datasets can be deployed to examine oil and gas regulatory questions. It could fit well under either the water quality or water/energy track.

### Virtual Hydraulic Fracturing Site

Andra Wilcox

Andra Wilcox: Research Associate, Energy Production at HARC-EFD has a master of science in strategic leadership and Graduate Certificate in Environmental Science from Texas A&M. She has conducted on site evaluations of drilling operations in diverse ecosystems. Andra coordinates the development of the EFD 'Virtual Rig" sites.
Dr. Richard Haut: Senior Research Scientist, Program Manager for Energy and Environmental Projects, HARC. He serves as Principal Investigator (P.I.) for the Environmentally Friendly Drilling (EFD) program in partnership with various universities, industry and environmental organizations with the objective of integrating advanced technologies into systems that address environmental issues associated with O&G production.

The Environmentally Friendly Drilling Systems (EFD) program, managed by the Houston Advanced Research Center (HARC), provides unbiased science related to reducing the footprint of petroleum drilling and production. Selected for funding from the U.S. Department of Interior by the Texas Coastal Land Advisory Board (TCEQ, GLO, RRC), the EFD Coastal Impacts Technology Program (CITP) is a research and demonstration program for implementing environmentally friendly technologies along the Gulf Coast, measuring effectiveness of technologies, and educating the workforce. The objective of the workforce development program is to create a workforce skilled in environmental mitigation of exploration/production impacts in coastal regions.
In late 2013, HARC began to expand the Environmentally Friendly Drilling Systems (EFD) Virtual Site (www.efdvirtualsite.org) to include a Virtual Hydraulic Fracturing Site. This innovative tool offers a groundbreaking resource for those working within industry as well as the general public to learn more about groundwater protection and conservation practices within hydraulic fracturing operations. Towards the goal of providing education and outreach to all stakeholders, this free learning tool presents the sense of 'hands-on' experience through 'hotspots' on the virtual site that reveal 3D images, 360 degree views, animations and videos, as well as literature and web resources which discuss the technologies available that address the environmental issues associated with oil and gas production. Direct links to The Ground Water Protection Council and FracFocus are included on the virtual site within the interactive hotspots.
Through this valuable, interactive tool, current and new employees, administrative assistants, and other stakeholders including the general public can become more knowledgeable of hydraulic fracturing operations without having to undergo the training and certifications required in order to visit actual hydraulic fracturing sites. Visitors can learn how industry is taking measures to protect groundwater and the environment through new technologies and best management practices.

# List of Attendees

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|---|---|---|---|---|
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