July 24-26, 2012
Cleveland, Ohio

# STRAY GAS

Incidence & Response Forum

Preliminary Agenda DRAFT – June 011, 2012 – ***Subject to final changes***

| Tuesday – July 24 | |
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| 8:00-9:50 | ***Welcome*** - ***Rick Simmers***, *OH Oil & Gas Director*<br>***Panel: Federal Agency Perspectives Regarding Stray Gas***<br>With the recent Executive Order that led to the establishment of an EPA, DOE, & DOI memorandum of understanding to coordinate research on natural gas development, we will have a panel of agency representatives to discuss individual agency and coordination of initiatives related to stray gas issues. *Invited Panelists include:*<br>*Chris Smith, US Department of Energy;*<br>*David Russ, Northeast Region U.S. Geological Survey ;*<br>*George Guthrie, National Energy Technology Laboratory; and*<br>*Bob Sussman, US Environmental Protection Agency ; and*<br>*Kevin Teichman, US Environmental Protection Agency.* |
| 20 min. | BREAK |
| 10:10-11:30 | ***Introduction to Stray Gas***<br>• What is stray gas?<br>• Properties and potential hazards of methane<br>***Stray Gas Incident Response***<br>• Interviews, Reconnaissance surveys and Determination of threat level<br>• Establishing a Timeline and Defining the preliminary area of investigation<br>• Stray Gas forensics & secondary effects<br>• Combustible gas field screening-gas and monitoring protocols<br>• Protocol for active soil gas surveys<br>• Mitigation Strategies<br>Abstract 1: *Presenter* – ***Fred Baldassare***, *ECHELON Applied Geosciences Consulting* |
| 11:30-12:30 | ***Response Framework & Action Levels for Methane Concentrations***<br>Development of State Regulations to Include Emergency Response Procedures<br>Abstract 2: *Presenter* – ***Joe Lee***, *Pennsylvania DEP Bureau of Oil & Gas Management*<br><br>***Working Toward Rational, Consistent, Science-based, Risk-assessment Protocols***<br>• Gas in confined inhabited spaces<br>• Gas in confined, non-inhabited spaces<br>• Gas emitted from water well head space<br>• Dissolved gas in groundwater<br>• Soil gas<br>Abstract 3: *Presenter* – ***Scott Kell*** – *OH Oil & Gas* |
| 60 min. | LUNCH BREAK |
| 1:30-2:00 | ***Measures to Protect Public Health and Safety***<br>• Identifying and ventilating confined gas<br>• Temporary and permanent collection and vent systems<br>• Continuous indoor air monitoring systems<br>• Responder safety protocols<br>Abstract 4: Best Suggested Practices to Reduce and Mitigate Problematic Concentrations of Stray Gases in Water Well Systems – ***Kevin McCray***, *National Ground Water Association* |
| 2:00-2:30 | ***Tools for Preliminary Communications with the Public***<br>Abstract 5: *Presenter* – ***Rebecca Fugitt***, *Program Manager, Bureau of Environmental Health, Ohio Department of Health* |
| 2:30-4:30 | ***Pre-Drill Sampling and Variability***<br>• Abstract 6: Baseline Water Quality Sampling in Shale Gas Exploration and Production Areas – ***Debby McElreath***, *Chesapeake*<br>• Abstract 7: Real-Time Monitoring System for Evaluating Long-Term Variability in Methane in Domestic Water Wells in |


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| | Northeast Pennsylvania - ***Denise Good***, *Groundwater and Environmental Services, Inc.*<br>• Abstract 8: Short-Term Intra-well Variations in Methane Concentrations in Groundwater from Domestic Water Wells in Northeastern Pennsylvania – ***Nancy Coleman***, *Chesapeake*<br>• Abstract 9: The Occurrence of Methane in Shallow Groundwater from Extensive Pre-Drill Sampling – ***Elizabeth Perry***, *AECOM*<br>• Abstract 10: Evaluation Water Well Analytical Data Associated with EPA's Hydraulic Fracturing Retrospective Case Study - ***Deborah Watkins***, *Weston Solutions, Inc.*<br>• Abstract 11: Tools for Assessing Stray Gas Migration: A Case Study in Pennsylvania - ***Seth Pelepko***, *Pennsylvania Department of Environmental Protection's Bureau of Oil & Gas Planning and Program Management* |
| 20 min. | BREAK |
| 4:50<br>5:30 | ***Characterizing Gas Composition: Stray Gas Forensics***<br>Abstract 12: A Geochemical Context for Stray Gas Investigations in the Northern Appalachian Basin: Implications of Analyses of Natural Gases from Quaternary-through-Devonian-Age Strata – ***Fred Baldassare***, *ECHELON Applied Geosciences Consulting* |
| 6:15-<br>7:30 | RECEPTION |
| Wednesday – July 25 | |
| 8:00-<br>9:20 | ***Subsurface Gas Migration: Defining Migration Pathways***<br>Importance of understanding the three-dimensional geologic framework<br>Factors affecting subsurface gas migration<br>• Dissolved gas<br>• Free gas<br>Identifying migration pathways<br>Identifying driving mechanisms<br>Distribution of gas in aquifer systems<br>Down-hole videography<br>Evaluating potential contributing factors<br>• Drought<br>• Seasonal water table fluctuation<br>• De-watering<br>• Seismic activity<br>• Barometric pressure changes<br>Abstract 13: *Presenter* – ***Dr. Scott Bair***, *Ohio State University* |
| 9:20-<br>10:00 | ***Physical and Inorganic Water Quality Changes in Groundwater Associated with Stray Gas***<br>Abstract 14: Water Quality Changes Associated with Stray Gas Incidents - ***Anthony Gorody,*** *Universal Geoscience Consulting* |
| 20 min. | BREAK |
| 10:20-<br>11:00 | ***Long-Term Monitoring and Mitigation***<br>• Abstract 15: The Application & Case Studies of Geophysical, Remote Sensing & Earth Fracture Analysis Techniques to Identify Methane Gas Migration Pathways in the Subsurface - ***Tim Eriksen***, *Moody & Associates*<br>• Abstract 16: Engineering Design of Methane Mitigation Systems - ***John Sepich***, *P.E., Brownfield Subslab* |
| 11:00-<br>11:30 | ***Stray Gas Information Management***<br>Abstract 17: *Presenter* – ***Paul Jehn***, *Ground Water Protection Council* |
| 60 min. | LUNCH BREAK |
| 12:30-<br>2:30 | ***Oil and Gas Well Integrity Evaluations When Oilfield Activities are considered a Possible Source of Stray Gas***<br>Oil and gas drilling operations<br>• Shallow System Gas Intrusion<br>• Subsurface blowouts<br>Completed oil and gas wells<br>• Assessing Annular Pressure and Pressure Trends<br>• Assessing Annular Gas Vent Rates<br>• Cement Evaluation Relevant to Stray Gas<br>• Planning and Evaluating Cement Adequacy<br>• Surface Casing Adequacy and Testing<br>• Intermediate and Production Casing Considerations |

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| | • Testing and evaluating Internal & External mechanical integrity<br>• Designing for Remedial Action<br>• Products Used in Remedial Stray Gas Operations<br>• Considerations for Effectively Sealing Perforations<br>• Holistic Well Evaluation Process<br>Abstract 18: *Presenter – **Dan Arthur**, ALL Consulting*<br><br>***State-of-the-art Industry Tools for Diagnostics and Evaluations***<br>Abstract 19: *Presenters – Industry Representatives – TBA* |
| 20 min. | BREAK |
| 2:50-5:30 | ***Stray Gas Incidence Case Histories and Related Studies*** (lessons learned)<br>Abstract 20: Tools for Assessing Stray Gas Migration: A Case Study in Pennsylvania - ***Seth Pelepko**, Pennsylvania Department of Environmental Protection's Bureau of Oil & Gas Planning and Program Management*<br>Abstract 21: Carbon and Hydrogen Isotopic Evidence for the Origin of Combustible Gases in Water-Supply Wells in North-Central Pennsylvania – Implications for Hydraulic Fracturing – ***Kinga Revesz**, USGS*<br>Abstract 22: Geologic and Baseline Groundwater Evidence for Naturally Occurring, Shallow Source, Thermogenic Methane Gas in Northeastern Pennsylvania - ***Brent Wilson**, Chesapeake*<br>Abstract 23: Isotopic Forensic Techniques for Methane Source Discrimination – ***Julie Sueker**, ARCADIS*<br>Abstract 24: Integrated Assessment Model for Predicting Potential Risks Associated with Shale Gas Development - ***Grant Bromhal**, National Energy Technology Laboratory*<br>Abstract 25: Field Test of an Alternative Hypothesis for Stray Gas Migration from Shale Gas Development - ***Daniel J. Soeder**, National Energy Technology Laboratory* |

| Thursday – July 26 | |
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| 8:00-9:00 | ***Potential Legal Implications of Stray Gas Migration***<br>Regulations and legal interpretation:<br>Abstract 26: Can You Trespass with Gas? The Law as it Pertains to Alleged Gas Migration Incidents - ***David Overstreet**, K&L Gates*<br>Where do the liabilities lie?:<br>Abstract 27: *Presenter – **Jean Mosites**, Babst Calland* |
| 9:00-9:30 | ***Industry Stray Gas Incident Prevention Initiatives***<br>Abstract 28: *IPAA Presenter – TBA* |
| 20 min. | BREAK |
| 10:00-12:00 | ***Industry Stray Gas Incident Prevention Initiatives** (continued)*<br>Latest API developments on measurement, monitoring, risk assessment and mitigation of sustained annular pressures (API 65 Part 3)<br>Abstract 29: *API Presenter – TBA* |
| 60 min. | LUNCH BREAK |
| 1:00-2:00 | ***Industry Stray Gas Incident Prevention Initiatives** (continued)*<br>Abstract 30: *Presenters– TBA* |
| 2:00-3:00 | ***State Regulatory Responses***<br>Abstract 31: *Presenters – TBA* |

For more information about the Stray Gas Forum including: registration, event hotel, sponsorship opportunities, etc, please visit... www.gwpc.org or contact Ben Grunewald at 405 516 4972 or ben@gwpc.org.

***THANK YOU for caring about Groundwater!***

Abstract 4:

# Best Suggested Practices to Reduce and Mitigate Problematic Concentrations of Stray Gases in Water Well Systems

**Kevin McCray**, CAE
National Ground Water Association
Westerville, Ohio

As a benefit to members of the National Ground Water Association and others, the Association developed, by means of a consensus process, a document to provide water well system professionals (WWSP) with basic knowledge for gases that may be encountered during well drilling/construction and suggested practices to reduce and mitigate elevated stray (or fugitive) gas levels. Because of varying geologic conditions and other factors, it is not practical to develop a totally prescriptive guideline.

Subsurface gases may occur dissolved in groundwater or as a gas in the head space of a water supply. Sometimes the concentrations of select gases will prove to be unacceptably high even after careful site selection and well construction, or after cleaning an existing well. The WWSP can recommend cost-effective options to mitigate such problems. For instance, it may be less expensive for the consumer to install an appropriate watertight vented well cap to lower concentrations of a gas than to replace or deepen an existing well or to use a more expensive drilling technology to emplace a new well. Such decisions are site-specific and, thus, based on careful analysis by the WWSP.

For the purposes of the best suggested practices document it is not essential for the WWSP to understand groundwater chemistry or how stray gases form, although there are extensive studies and related publications that document these processes. However, the WWSP will benefit from knowing the geologic settings, as well as the human-related activities that may contribute to gas presence in water well systems.

- Section 1 offers background on the health and safety issues related to stray gases commonly encountered by water well system professionals.
- Section 2 is guidance about how geologic conditions and land-use settings may affect the concentrations of gases in groundwater.
- Section 3 provides a description of well location and construction methodologies to minimize the buildup of gases.
- Section 4 examines well function and stray gases.
- Section 5 deals with post-drilling operations.
- Section 6 describes groundwater sampling methods and treatment options.

Kevin McCray, CAE, is the executive director of the National Ground Water Association (NGWA). In addition to executive director of NGWA, McCray is the chief executive of the National Ground Water Research and Educational Foundation.

McCray has served on a number of water-related advisory groups, including the U.S. Water Resources Export Council, Water Systems Council, U.S. Department of Commerce mission to Australia and New Zealand, U.S. EPA/AWWA Comprehensive Integrated Resource Cooperative Blue Ribbon Panel, Kellogg Foundation Ground Water Education Consortium, the Great Lakes Commission Ground Water Education Roundtable, The American Ground Water Trust and the Ground Water Remediation Technology Analysis Center Advisory Board.

At the National Ground Water Association he has led initiatives to develop industry standards, best suggested practices, and significant upgrades to the voluntary certification program. He led an award-winning effort to develop computer-based business management tools for water well drilling and pump installation contractors.

Abstract 6:

# Baseline Water Quality Sampling Programs in Shale Gas Exploration and Production Areas

**Debby McElreath and Mark Hollingsworth**

***Debby McElreath*** is a Senior Environmental Specialist in the Environmental Compliance Group for Chesapeake Energy Corporation, Oklahoma City, OK. She was the quality assurance manager for a full-service environmental consulting firm prior to joining the staff of Chesapeake. She has B.S. and M.S. degrees from Oklahoma State University. Debby.McElreath@chk.com; 405-935-4179

***Mark Hollingsworth*** is the Environmental Manager of the Baseline Sampling Program for Chesapeake Energy Corporation, Oklahoma City, OK. Prior to joining Chesapeake, he was a Program Manager for Test America, Inc. in Nashville, Tennessee. Mr. Hollingsworth has a B.S. degree in Chemistry from David Lipscomb University. Mark.Hollingsworth@chk.com; 405-935-2417.

Over 20,000 baseline or "pre-drill" samples of groundwater from privately-owned domestic water wells and surface water resources have been collected in seven shale plays within the United States where active exploration for natural gas and natural gas liquids is being conducted. There are a number of challenges associated with the volume of sampling and analyses involved in baseline sampling programs. The experience gained from a large baseline sampling program will be presented. The major challenge is that the future need for any specific piece of baseline data is rarely known at time that the baseline sample is collected and analyzed. Recognition of the purpose and limitations of single-sample baseline sampling regimens is critical to operation of a baseline sampling program. This is particularly challenging when using the baseline sampling data to interpret findings in "post-completion", that is samples taken after drilling has been conducted. Issues related to analytical parameter selection and criteria for isotopic analysis of light gases as well as electronic data delivery and management will be discussed. Challenges related to light gas sampling methods and sampling personnel training issues will also be presented. Baseline sampling programs must have in place a procedure for rapid notification of the client regarding exceedences of standards or benchmark values for analytical parameters, especially for dissolved light gases.

Abstract 7:

# Real-Time Monitoring System for Evaluating Long-Term Variability in Methane in Domestic Water Wells in Northeast Pennsylvania

**Charles B. Whisman, P.E.[1], Debby McElreath[2], Charles Olmsted, P.G., CPG[2], Denise Good, P.E.[1], and Richard Wardrop, P.G.[1]**

Charles Whisman is GES' Chief Technical Officer and has over 17 years of industry experience. He leads GES' business strategy, engineering, and technology initiatives. He holds a BS in civil engineering and a certificate in environmental engineering from the University of Pittsburgh.

Debby McElreath is a Senior Corporate Environmental Specialist at Chesapeake Energy Corporation.

Charles Olmsted is the Supervisor of Regulatory Compliance at Chesapeake Energy Corporation.

Denise Good is a Principal Engineer at GES with 14 years of experience in groundwater remediation system design and management.

Richard Wardrop is a Principal Hydrogeologist with over 25 years of experience in subsurface fate and transport of contaminants and in groundwater resource evaluations.

Naturally-occurring methane is present in many domestic water wells in northeast Pennsylvania. A significant amount of data is currently being collected by the oil and gas industry as a result of sampling efforts and investigations, much of which is from pre-drilling ("baseline") sampling conducted prior to any drilling activity. However, gaps remain in understanding and quantifying the natural temporal variation in methane concentrations in these wells. This is of significant importance in assessing claims of gas migration when there is nearby anthropogenic activity. This presentation will discuss a research project developed and implemented to gain an understanding of the long-term variability of methane in domestic water wells.

Real-time remote monitoring and data trend analyses are being utilized to understand natural dissolved methane fluctuations in groundwater and correlations between methane headspace concentration in the well annulus and other physical and chemical parameters which could correlate to changes in headspace concentration. Significant efforts were made to select, evaluate, and prepare the wells for the study including borehole geophysics, well equipment upgrades, and installation of water-treatment systems. Descriptions of the customized real-time remote monitoring equipment, array of well headspace and water-quality sensors utilized, and equipment setup will be presented, as well as the associated challenges and logistics. Barometric pressure, water use, water quality, well recharge, water-level fluctuations, and pump cycling are examples of the variables monitored.

Interim results from the on-going study will be presented, including discussion of well construction, geologic settings, water quality, initial trends and findings, and real-time display of data. The usefulness of the data and the accuracy/precision of sensors will be discussed. The long-term study will provide further information to better understand the occurrence and potential causes of methane fluctuations in groundwater and associated water well quality issues in northeast Pennsylvania.

[1]Groundwater & Environmental Services, Inc.
[2]Chesapeake Energy Corporation

Abstract 8:

# Short-Term Intra-well Variations in Methane Concentrations in Groundwater from Domestic Water Wells in Northeastern Pennsylvania

**Nancy Pees Coleman and Debby McElreath**

***Nancy Pees Coleman*** is an environmental toxicologist and owner of Environmental Consultants in Oklahoma City, Oklahoma. She has over 30 years experience in evaluation of environmental data and risk assessment. Prior to entering consulting, she was toxicologist/epidemiologist for the Oklahoma Department of Environmental Quality. She has a B.S. degree from Old Dominion University and M.P.H. and Ph.D. degrees from the University of Oklahoma Health Sciences Center (r-n-coleman@sbcglobal.net).

***Debby McElreath*** is a Senior Environmental Specialist in the Environmental Compliance Group for Chesapeake Energy Corporation, Oklahoma City, OK. She was the quality assurance manager for a full-service environmental consulting firm prior to joining the staff of Chesapeake. She has B.S. and M.S. degrees from Oklahoma State University (Debby.McElreath@chk.com).

Domestic water wells in Northeastern Pennsylvania have been found to contain varying concentration of dissolved light gases, such as methane. Baseline sampling by a major natural gas production company in this region has shown that over 24% of samples contain detectible concentrations of dissolved methane. Short-term variation in dissolved methane concentrations within domestic water wells is not well understood. Daily monitoring of seven domestic water wells located near a natural gas wellhead was conducted for a period of 24 days following a well control event. An additional 23 water wells located near the same wellhead were sampled on a weekly basis for two to six weeks. Additional weekly data is available from eleven domestic wells located within the same county. Analytical data from these sampling events were statistically compared and evaluated for short-term temporal intra-well variability.

A comprehensive review of the analytical data indicates that there can be significant differences is water quality in northeastern Pennsylvania domestic water wells that are a result of natural temporal changes in water quality, or changes due to differences in sampling methodologies between sampling events and domestic water use. Proper recognition of these differences is important in evaluating this type of groundwater data in order to accurately determine if groundwater impact has actually occurred. Review of these data show the importance of obtaining representative samples of area water wells during baseline sampling and understanding the nature of potential natural temporal variability in water well groundwater quality when evaluating the results of subsequent samples from the same well. Data from this study can be used to better design baseline sampling programs and used to better understand the natural temporal differences in water quality that occurs in domestic water wells in northeastern Pennsylvania.

Abstract 9:

# The Occurrence of Methane in Shallow Groundwater from Extensive Pre-Drill Sampling

**A. Elizabeth Perry, PG**
**Rikka Bothun**
**Bert Smith, PG**
**Mark Hollingsworth**

Authors' Bios: Ms. Perry is a hydrogeologist at AECOM with over 26 years experience. She is a registered professional geologist in Pennsylvania and Indiana and holds a MS in Engineering Geology from Drexel University and a BA in Mathematics/Geology from Hamilton College. Ms. Bothun is a senior data analysis specialist and geologist with AECOM with over 13 years experience. She holds a BS in Geology from Colorado State University and is a MEng Civil Engineering/GIS candidate at the University of Colorado at Denver. Mr. Smith is a Senior Hydrogeologist with Chesapeake Energy. Mr. Hollingsworth is an Environmental Manager at Chesapeake Energy with over 15 years of environmental experience. He holds a BS in Chemistry from David Lipscomb University in Nashville, TN.

Abstract: On behalf of a major shale-gas operator, sampling of over 14,000 water wells has been conducted from 2009 to the present, from shale-gas development areas across Pennsylvania, Ohio, and West Virginia. Sampling was conducted prior to Marcellus/Utica Shale-related exploration, drilling, and production activities in the vicinity of these water wells. The pre-drill samples have been analyzed for methane, ethane, and propane as well as many inorganic parameters.

This presentation will explore the occurrence and distribution of methane in groundwater prior to unconventional gas development. GIS-based mapping and statistics will be used to evaluate the geographic distribution and relationship to bedrock geology. The relationships between methane and other parameters can also help explain methane occurrence, including parameters such as ethane and propane, alkalinity, TDS and major ions, barium, etc.

Better understanding of methane in shallow groundwater will lead to better decision-making when evaluating potential impacts of shale-gas development on water supplies and stray gas occurrence.

Abstract 10:

# Evaluation Water Well Analytical Data Associated with EPA's Hydraulic Fracturing Retrospective Case Study Bradford County, Pennsylvania

**Deborah M. Watkins, P.E. and Thomas S. Cornuet, P.G.; Weston Solutions, Inc.**

Ms. Deborah M. Watkins, P.E. earned a B.S. in Chemical Engineering from Bucknell University and a M.S. in Environmental Engineering and Water Resources from Villanova University. She holds professional engineering licenses in the Commonwealths of Pennsylvania and Virginia, and in the States of New Jersey, Maryland, and Delaware.
Mr. Thomas S. Cornuet, P.G. earned a B.S. degree in Geology from Indiana University of Pennsylvania and a M.S. in Engineering Geology from Drexel University. He holds a professional geology license in the Commonwealth of Pennsylvania.

The Environmental Protection Agency (EPA) is conducting a retrospective study to evaluate the relationship, if any, between hydraulic fracturing and drinking water resources as described in EPA's "Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources" dated November, 2011 (EPA Study). An evaluation of analytical data (split samples), collected by Chesapeake Energy contractors and analyzed by commercial laboratories from 14 water wells and 1 spring (EPA Study Wells) that were included in EPA's October and November 2011 Bradford County, Pennsylvania sampling events, was conducted. The drinking water resources were located within the vicinity of Chesapeake Energy's operating area. The EPA Study Well split-sampling water-quality data provided by Chesapeake Energy were assessed to meet the following objectives:

- To determine whether any of the water-quality parameters had experienced significant changes following Chesapeake Energy baseline sampling;
- To compare the EPA Study Wells water quality with historic water-quality data (USGS NURE and NWIS databases) obtained prior to the commencement of Marcellus Shale activities in Bradford County, PA (pre-2007);
- To identify any EPA Study Well exceedances of various screening criteria derived from EPA MCLs and SMCLs, PADEP Act 2 Medium-Specific Concentrations (MSCs), and EPA Regional Screening Levels (RSLs) and contrast any EPA Study Well exceedances with historic water quality exceedances; and
- To provide general observations regarding the EPA Study Well water-quality data contrasted with historic water quality in Bradford County, and Chesapeake Energy's baseline data for nearby water wells.

Based upon review of the water-quality data for each of the 14 water wells and one spring and subsequent comparison of these results with regional historical and baseline water-quality databases, it was concluded that these fifteen water sources do not appear to be impacted by natural gas drilling or production activities, including hydraulic fracturing.

Abstract 11:

# Tools for Assessing Stray Gas Migration: A Case Study in Pennsylvania

**Seth Pelepko and Stewart Beattie**

Mr. Pelepko works as a geologist for the Pennsylvania Department of Environmental Protection's Bureau of Oil & Gas Planning and Program Management. His areas of interest include stray gas migration case work and gas well integrity. Prior to accepting his most recent position, he was employed as a petrographer by the Pennsylvania Department of Transportation. He has also worked as a consulting hydrogeologist. He received a B.S. in Earth Sciences in 1998 from the Pennsylvania State University and is currently pursuing his M.S. in Geological Sciences at the University of Delaware. He earned his Professional Geologist's license in 2004.

Mr. Beattie is the GIS/Information Specialist for the Pennsylvania Department of Environmental Protection's Bureau of Oil & Gas Planning and Program Management. He has worked for the Department for almost a year and recently finished his M.S. in Geo-Environmental Studies at Shippensburg University. He also holds a B.S. in Secondary Education with a concentration in Historical Geography from Millersville University. Prior to accepting his current position, he was employed by various agencies and organizations including the Pennsylvania Department of Transportation, the National Museum of Bermuda and the Army Heritage Education Foundation where he helped implement GIS and mapping related projects.

A case study in Pennsylvania is presented in order to acquaint state regulators with tools that are readily accessible and may be useful in certain stray gas investigations. The tools may also be valuable for oil and gas operators and consultants unaccustomed to conducting such investigations. Multivariate statistical analyses, including multiple regression and R-mode factor analysis, are discussed in the context of defining background methane concentrations when no pre-drill data are available and correlating gas-well workover activities to water-well response data, respectively. Simple geochemical modeling is introduced to explore the utility of testing for geochemical indicator parameters that may potentially serve as metrics for assessing the return of an impacted aquifer to baseline conditions. The process of transitioning from a simple, one-dimensional time-series analysis of methane in water supplies to a 3D geologic conceptual model that considers stray gas migration pathways is also discussed. Finally, a brief tutorial showing applications within ESRI's ArcGIS environment utilized to complete the investigation is reviewed.

Abstract 12:

# A Geochemical Context for Stray Gas Investigations in the Northern Appalachian Basin: Implications of Analyses of Natural Gases from Quaternary-through-Devonian-Age Strata

**Fred J. Baldassare[1], Mark A. McCaffrey, PhD[2], John A. Harper, PhD[3]**

Fred J. Baldassare is a Sr. Geoscientist and the owner of Echelon Applied Geochemistry Consulting. He has 19 years of experience investigating incidents of stray gas migration. Fred previously worked for the Pennsylvania Department of Environmental Protection where he developed the agency's stray gas investigation protocol and served as the statewide consultant for characterizing source(s) of stray gases. Fred has helped to pioneer the application and advancement of isotope geochemistry to identify the origin of natural gases in the Appalachian Basin. He has authored and co-authored numerous technical papers for peer reviewed journals on the application of isotope geochemistry.

Mark A. McCaffrey is a Senior Technical Advisor at Weatherford Laboratories. He has 22 years of petroleum geochemistry experience, including 11 as founder and President of OilTracers LLC, a firm which Weatherford acquired in 2010. Mark has a BA in Geology (1985) from Harvard University and a Ph.D. (1990) in Chemical Oceanography from the Massachusetts Institute of Technology / Woods Hole Oceanographic Institution Join Program. As an Expert Witness in gas fingerprinting, he has testified (i) in Mississippi State Court, (ii) in Ohio Federal Court, (iii) before the Oklahoma Corporation Commission, and (iv) before the Railroad Commission of Texas.

John A. Harper received an M.S. degree in geology from the University of Florida 1n 1972 and a Ph.D. in paleontology from the University of Pittsburgh in 1977. He joined the Pennsylvania Geologic Survey in the Pittsburgh office in 1977 where he has been involved primarily in data collection and dissemination, and studies of the subsurface geology and reservoir characteristics of Pennsylvania's oil and gas fields. He currently serves as Chief of the Geologic Resources Division, overseeing programs responsible for research, data collection, and evaluation of petroleum geology and engineering, industrial minerals, coal, and both organic and inorganic geochemistry.

**ABSTRACT**

As the pace of drilling activity to the Marcellus Formation in the northern Appalachian Basin has increased, so has the number of alleged incidents of stray natural gas migration to shallow aquifer systems.

Prior to the present study, the occurrence and origin of natural gas in the strata above the Marcellus Formation has not been well defined. More than 1,900 gas and water samples were analyzed in the present study for (1) molecular composition, (2) stable carbon and hydrogen isotope compositions of methane and (3) stable carbon isotope composition of ethane. The samples are from Quaternary to Middle Devonian-age strata in a five-county study area in northeastern Pennsylvania. Gas and water samples were collected from (1) 181 gas wells during Mudgas Logging (MGL) programs for wells being drilled to the Marcellus Shale Formation, and (2) 67 private water supply wells during baseline groundwater water-quality testing programs. Regional and local geologic conditions were evaluated from core analyses and published studies.

Evaluation of this geochemical database reveals that microbial, mixed microbial/thermogenic, and thermogenic gases occur in some shallow aquifer systems, and that the gas occurrences pre-date Marcellus Formation drilling activity. The isotope data reveal that thermogenic gases in the Quaternary and Upper Devonian strata are typically distinct from gases from deeper Middle Devonian strata (including the Marcellus Fm).

Significantly, however, a more detailed review of the geochemistry at the site-specific level also reveals a complex thermal and migration history with gas mixtures indicated by partial isotope reversals ($\delta^{13}C_1 > \delta^{13}C_2$) in deeper formations and throughout the stratigraphic section above the Marcellus Formation in some areas of the basin.

[1] ECHELON Applied Geochemistry Consulting, 1229 Twelve Oaks Ct., Murrysville, PA 15668
[2] Weatherford Laboratories, 3500 Oak Lawn Ave., Suite 205, Dallas, TX 75215
[3] Pennsylvania Geological Survey, 400 Waterfront Dr., Pittsburgh, PA 15222

Abstract 14:

# Water Quality Changes Associated with Stray Gas Incidents

**Anthony W. Gorody, Ph. D., P. G.**

BIO

Dr. Anthony W. Gorody is a geoscientist with more than 30 years of diverse international and domestic oil and gas industry experience. His technical specialty relates to state-of-the-art forensic geochemical fingerprinting and hydrogeologic characterization techniques. These are applied to evaluate natural gas resources, groundwater and surface water resources, produced water, and pollution in the near-surface hydrogeologic environment. An industry leader in baseline environmental measurement and monitoring programs, Dr. Gorody provides both consulting and training services. He is licensed to practice geology in Pennsylvania, Texas, and Wyoming.

ABSTRACT

Invasion of stray gas into shallow groundwater aquifers can affect water quality in domestic water wells. The degree to which such impacts will be observed depends on well bore construction and pump design parameters, the vertical distribution and relative confinement of aquifers tapped by a water well, and the dominant transport mode of stray gas in the dissolved and/or free gas phase. Interpreting how environmental variables interact to change baseline conditions at a water well is conditional on having good quality baseline groundwater data from wells in and around the impacted area and on data from multiple samples collected after a complaint is registered.

Commonly observed water quality changes associated with free gas invasion are increased turbidity, changing fluid color, and the sudden onset of hydrogen sulfide odors and associated elevated dissolved sulfide concentrations. Such changes can also be accompanied by significant increases in dissolved iron and manganese concentrations and the detection of other redox sensitive elements such as arsenic and selenium. These effects result from changing oxidation-reduction conditions in a well that are associated with stray gases and not necessarily to invasion of drilling and completion fluids. The most reliable water quality data useful for addressing impacts from oil and gas operation and the subsequent effects of natural attenuation are those that provide indices which adequately reflect the following: hydrochemical facies (charge-balanced major ion analyses), baseline redox conditions (calibrated field parameters, selected nutrients, dissolved iron and manganese and RCRA metals), salt origins (bromide), and bacterially-mediated reactions (BART™).

Abstract 16:

# Engineering Design of Methane Mitigation Systems

**John Sepich, P.E.**

**Bio:** John Sepich is a professional engineer with nearly 40 years of experience in design and installation of methane control systems. His experience began in the early 1970's with landfill gas control systems, and he became involved in gas control above oilfields in the 1980's in California. Mr. Sepich holds several U.S. patents related to gas control, and has helped numerous agencies write methane codes. He is president of a consulting firm, Brownfield Subslab, specializing in soil gas control. And is currently chair of an ASTM E-50 committee to develop a methane soil gas standard.

**Abstract:** The art of methane gas mitigation became a necessity in the post World War II decades, when burning dumps were outlawed and landfill gas became a problem. At about the same time, extensive urban sprawl in areas such as Los Angeles occurred extensively over old oilfields. Today, continued oilfield development including fracking is a concern. The art of mitigation is becoming a science. The paper will discuss:

Briefly:
-- at-risk areas, by testing or by chance observation
-- site evaluation methodology using probes, surface sweeps, building sweeps
-- determining methane hazard – using concentrations, volumes, pressures, and

In Detail:
-- design options: active (fans, detectors), passive (barriers, venting)
-- oil wells, vent hoods, setbacks vs. modern platforms
-- intrinsically safe construction, including raised floors and podium structures
-- new construction, engineering drawings and details
-- selection of venting methods, trenches, flat pipes, geodomes, design guidelines
-- selection of membrane materials / membrane placement
- pvc, cpe, ldpe, visquene, hdpe, spray-on (cma), composite
- mat and post-tensioned slabs

-- gas detectors, types, use with ventilation
-- electrical classifications, electrical conduits and service
-- pathway plugging, trench dams
-- use of subslab monitoring probes
-- elevator pits and pistons
-- hydrostatic design
-- construction methods -- what can go wrong, seams, cuts, tiebacks, bathtub design, waterproofing, foundation wraps
-- construction inspections, testing, certifications
-- monitoring and reporting
-- future modifications to systems (tenant improvements)
-- existing construction retrofit, venting, barriers, detectors

Methane Politics:
Pro-active mitigation vs. Agency mandates/action levels
ASTM proposed standard

Abstract 18:

# Oil and Gas Well Integrity Evaluations Related to Stray Gas

**J. Daniel Arthur, P.E. (ALL Consulting), Dave Cornue, P.G. (ALL Consulting), Brian Bohm, P.G. (ALL Consulting), Jeff Kennedy (ALL Consulting), and Preston Wilson (ALL Consulting)**

**Lead Author Bio**: Mr. Arthur is a Registered Professional Petroleum Engineer and SPEC. He is the president of ALL Consulting and has been involved in well integrity issues since the mid-1980s. He is a former member of the EPA's National Mechanical Integrity Test Workgroup, he has written various documents and papers on the subject of well integrity analysis methods, he has conducted MIT training with GWPC, and is currently engaged in numerous well integrity evaluations. Mr. Arthur and his team at ALL Consulting have designed and conducted more than 500 noise and temperature logs, many hundreds of internal pressure tests, along with radioactive tracer surveys, various cement evaluation logs, and designed and implemented well remediation on wells to address methane intrusion.

**Abstract**: The presentation will cover a range of issues including shallow system gas intrusion, assessing annular pressure and pressure trends, analyzing annular gas vent rates (including measurements methods), review and analysis of cement evaluation logs, internal and external well integrity testing methods with a focus on noise, temperature, and cement logging, applicability of well histories, remedial methods and challenges, and the use of a holistic well evaluation process.

Abstract 21:

# Carbon and Hydrogen Isotopic Evidence for the Origin of Combustible Gases in Water-Supply Wells in North-Central Pennsylvania – Implications for Hydraulic Fracturing

**Kinga M. Révész,[1] Kevin J. Breen,[2] Alfred J. Baldassare,[3] and Robert C. Burruss[4]**

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## 1. Introduction

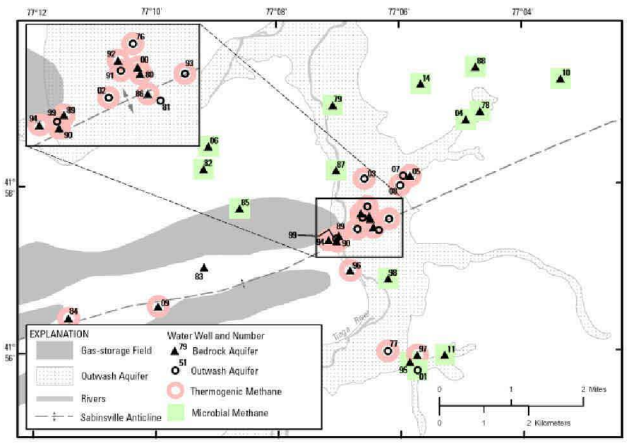
The origin of natural gas in water-supply wells at Tioga Junction, Tioga County, Pennsylvania was investigated using compositional and isotopic characteristics of methane and ethane in gas and water wells. There are four plausible origins for natural gas in the water wells at Tioga Junction: (1) deep native gas in the Oriskany Sandstone (thermogenic), (2) shallow native gas in Devonian shale bedrock (thermogenic), (3) microbial gas from organic debris (drift gas) in unconsolidated sediments and (4) non-native gas from a gas-storage field (thermogenic). Gases from the Oriskany Sandstone and the gas-storage field were similar in chemical composition, with methane ($CH_4$) and ethane ($C_2H_6$) being predominant; however, the gases had different stable isotopic compositions.

## 2. Origins of $CH_4$ in Groundwater

Groundwater for rural-domestic supply and other uses is from two aquifer systems in and adjacent to the Tioga River valley. An unconsolidated aquifer of outwash sand and gravel of Quaternary age underlies the main river valley and extends into the valleys of tributaries. Outwash-aquifer wells are seldom deeper than 30 m. The river-valley sediments and uplands adjacent to the valley are underlain by a fractured-bedrock aquifer in sandstones and shales of Devonian age, primarily the Lock Haven Formation. Most bedrock-aquifer wells produce water from the Lock Haven Formation at depths of 76 m or less.

The $\delta^{13}C$ values of methane in groundwater were measurable in 35 out of 91 sampled waters. The isotopic composition of methane in water samples from 14 wells reflected a microbial origin, while the composition of the other 21 wells were representative of a thermogenic origin.

The $\delta^{13}C$ values of methane and ethane in thermogenic gases from water wells either matched or were intermediate between the samples of non-native storage-field gas from injection wells and the samples of gas from storage-field observation



Abstract 22:

# Geologic and Baseline Groundwater Evidence for Naturally Occurring, Shallow Source, Thermogenic Methane Gas in Northeastern Pennsylvania

**Brent Wilson**[1]

[1]Chesapeake Energy; Oklahoma City, Oklahoma, brent.wilson@chk.com

## AUTHOR BIO

Recently promoted to manage Chesapeake's Hydrogeology department, which is focused on aquifer characterization and groundwater protection. Spent the last year researching Upper Devonian fractured bedrock aquifers and thin-bedded coal seems found throughout the Catskill and Lock Haven formations in northeastern Pennsylvania. Previous experience includes exploration geology (Chesapeake), environmental geology (consulting firm) and hydrogeology (Oklahoma Water Resources Board).

## ABSTRACT

The study documents the presence and the sources of naturally occurring thermogenic methane that predates natural gas drilling activity in Bradford, Sullivan, Susquehanna, Tioga and Wyoming counties of northeastern Pennsylvania. Pre-drill baseline groundwater and surface water samples collected from nearly 17,000 locations in the study area, with more than 13,400 representing water wells. Methane was detected in 26.4% (1 in 4) of the water wells tested, 6.4% (1 in 15) exhibited methane concentrations greater than 3 mg/L, 2.6% (1 in 40) above 10 mg/L, and 0.5% (1 in 200) above 28 mg/L – the average saturation limit of methane in groundwater at atmospheric pressure. A comprehensive geologic investigation was undertaken by Chesapeake Energy to better characterize natural, shallow subsurface conditions in northeastern Pennsylvania in order to establish a coherent baseline to distinguish alleged incidents and impacts from natural regional conditions.

The origin of thermogenic natural gas in the shallow subsurface is associated with numerous organic-rich beds composed of carbonaceous, woody plant material, deposited during the Late Devonian. Widespread, thinly-bedded coal seams were observed throughout the stratigraphic section of the Catskill and Lock Haven formations at nearly 50 surface locations across a 2,600 square mile study area, which included bedrock outcrops, road cuts, quarries and excavation sites. Samples collected exhibit considerable gas source potential with total organic carbon as high as 44.4% by weight and thermally mature with calculated vitrinite reflectance ranging from 1.8% to 3.3%. Methane source potential is further supported by mud gas shows observed while drilling through shallow organic beds. Results of Chesapeake's comprehensive geologic investigation confirm thermogenic methane occurrence in water wells and other groundwater sources to be naturally occurring and common in the region.

Abstract 23:

# Isotopic Forensic Techniques for Methane Source Discrimination

**Julie K. Sueker, Ph.D., P.H., P.E., ARCADIS, Lakewood, CO**
**Boyce L. Clark, Ph.D., P.Hg., ARCADIS, Baton Rouge, LA**
**George H. Cramer, P.G., ARCADIS, Baton Rouge, LA**

**Author Bio:** Dr. Sueker is a hydrologist with 21 years of professional experience in geochemistry, environmental forensics, physical hydrology, isotope hydrology, isotope geochemistry, and hydrogeology. She has considerable experience in designing, managing, and conducting environmental forensic investigations and is skilled in applying physical, chemical, isotopic, and statistical approaches to evaluate sources and fate of constituents of interest in soil, surface water, and groundwater. Dr. Sueker leads the Applied Isotope Geochemistry technical team for ARCADIS and is authoring a book on isotope applications in environmental investigations.

**Abstract** Combustible gases, such as methane, in soil and shallow groundwater present a safety concern due to potential offgassing and accumulation in water well and plumbing systems that could lead to an explosion. Elevated concentrations of methane in enclosed spaces also pose an asphyxiation hazard. Methane observed in shallow subsurface environments can be derived from many potential sources including swamps, landfills, coal beds, and natural gas production and storage operations. Understanding methane provenance may be important for sites where methane hazards are present and multiple unrelated methane sources exist. Generation of methane and other light hydrocarbon gas occurs via three principal mechanisms; 1) biogenesis – microbial decomposition of organic matter (e.g., carbon dioxide reduction and acetate fermentation); 2) thermogenesis – thermal decomposition of deeply buried organic matter (associated with coal, oil, and gas formation); and 3) abiogenesis – formation of methane within Earth's mantle. These different methane generation mechanisms result in differing compositions of light hydrocarbon gases as well as in differing stable carbon and hydrogen isotope ratios which can be used to assess methane provenance. Carbon-14 ($^{14}C$) age dating can further discriminate methane sources, as thermogenic gases are "fossil" carbon sources and do not contain measureable quantities of $^{14}C$, whereas biogenic gases are typically "modern" and contain measurable quantities of $^{14}C$. Methane forensic techniques were utilized to distinguish a single source of natural gas released from a Gulf Coast region salt dome cavern storage facility from other sources of methane known to occur naturally in the region. The natural gas release was caused by a breach of a storage well casing at an elevation above the storage cavern. Natural gas escaped through the well casing breach into overlying formations and migrated to the surface. Application of methane forensic techniques resulted in delineation of a significantly smaller affected footprint than originally interpreted.

Abstract 24:

# Integrated Assessment Model for Predicting Potential Risks Associated with Shale Gas Development

**Robert Dilmore[1], Grant Bromhal[2], Dan Soeder[2], Alexandra Hakala[1]**

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[2]National Energy Technology Laboratory, Morgantown, WV 26507-0880

Speaker Bio: (Dr. Grant S. Bromhal is the Technical Coordinator of the National Energy Technology Laboratory's (NETL's) National Risk Assessment Partnership (NRAP) and a Team Lead in NETL's Geosciences Division, focused on modeling, experiments, and field research related to carbon storage, enhanced oil recovery, and environmental impacts of gas shale production. Dr. Bromhal received his PhD in Civil and Environmental Engineering from Carnegie-Mellon University and his BS/BA in Civil Engineering and Math from West Virginia University. He is the recipient of the 2007 Hugh Guthrie Award for Innovation at NETL, the 2010 USGS Director's Award for Exemplary Service to the Nation, and the 2011 DOE Secretary's Achievement Honor Award. )

NETL researchers are developing integrated assessment models (IAMs) to quantitatively characterize risks associated with unconventional resource development. Potential risks of particular interest are those associated with impacts to groundwater resources as a result of possible unintended fluid migration, and induced seismicity as a result of hydraulic fracturing and brine disposal. To develop these IAMs, researchers are drawing on data from field investigations, laboratory analyses, and secondary public and proprietary sources that help characterize salient features of coupled geologic and engineered systems. These data are being used to inform development of numerical models that characterize the disposition and behavior of key system elements of this system, including: distribution and extent of natural and engineered fractures, migration of *in situ* and injected fluids, extent of fluid saturation and pressure fronts in fractured hydrocarbon-bearing formations, geomechanical behavior of fractured geologic media, potential migration of fluids through overlying geologic strata and wellbores, and hydrologic models of overlying groundwater aquifers' response to these perturbations. These manageable models of individual system elements will be used to help develop reduced order models for each system component that can be integrated into a systems-level model and that model exercised to quantitatively assess risk of potential physical/chemical impacts to the local environment, including characterization of uncertainties associated with those assessed risks. Such assessments will provide information useful for policymakers and stakeholders so risk considerations and related uncertainties can be incorporated into decisions about how to develop these important energy resources safely and with minimal environmental impact. This approach will also help researchers to identify parameters and system attributes that contribute most to uncertainty in quantified risks, allowing them to direct subsequent research to resolve those key uncertainties.

Abstract 25:

# Field Test of an Alternative Hypothesis for Stray Gas Migration from Shale Gas Development

**Daniel J. Soeder**

USDOE National Energy Technology Laboratory, Morgantown, WV 26507

**Speaker Bio:** Dan Soeder is a geologist with the U.S. Department of Energy at the National Energy Technology Laboratory in Morgantown, West Virginia investigating energy and environmental issues related to unconventional fossil energy resources. Prior to joining DOE in 2009, Mr. Soeder was a hydrologist with the U.S. Geological Survey in the mid-Atlantic region, after spending eight years on the Yucca Mountain Project in Nevada. His career before joining the USGS in 1991 included a decade of research at the Institute of Gas Technology in Chicago on unconventional natural gas resources, including shale, and several years characterizing drill cores on the DOE Eastern Gas Shales Project. Mr. Soeder received a BS degree in geology from Cleveland State University in 1976, and an MS in geology from Bowling Green State University (Ohio) in 1978.

**Abstract:** Much ado has been made in the media concerning the presence of methane gas in groundwater, and the possible link between this gas and drilling activities. The news stories often draw the conclusion that the presence of flammable methane gas in a water supply must be related to nearby Marcellus Shale gas drilling activities. The small Pennsylvania town of Dimock became a poster child for stray gas when a domestic water well vault exploded in 2010. A study by Duke University reported a seventeen-fold increase in methane in groundwater near active gas wells in the Dimock area, and isotope analyses identified the gas as thermogenic methane of geological origin. The Duke study found no evidence of drilling fluids, frac fluids or formation brines in any of the groundwater samples analyzed that could positively link the gas to the Marcellus Shale, and industry background data indicate that methane is ubiquitous in the shallow groundwater of northeastern Pennsylvania. If the shale gas wells are not the source of the groundwater methane, perhaps they are affecting the transport. Standard practice is to use high-pressure air while drilling the vertical portion of Marcellus Shale gas wells, including operations that penetrate the freshwater aquifers. Some of this drilling air, which can be at pressures of up to 350 psi, might enter the aquifer and cause the groundwater to surge radially in all directions away from the well bore at a much higher than normal velocity. The fast-moving water may transport pre-existing methane gas to nearby domestic wells, along with sediment and minerals, which have also been reported near shale gas drilling operations. The National Energy Technology Laboratory intends to test this hypothesis by monitoring groundwater heads and methane levels in observation wells located near drill sites. Results should help define effects on aquifers during the drilling of gas wells.

Abstract 26:

# Can You Trespass with Gas?
# The Law as it Pertains to Alleged Gas Migration Incidents

**By David R. Overstreet and Anthony R. Holtzman**

Biographies

David Overstreet has been with K&L Gates since 1993 and has an administrative law and litigation practice spanning several substantive disciplines with an emphasis on energy and environmental matters. He is actively involved on behalf of a number of different clients in permitting, enforcement and litigation matters associated with the development of shale gas facilities in the Marcellus and Utica shale regions.

In the fall, Mr. Overstreet will serve as an Adjunct Professor at the University of Pittsburgh School of Law teaching a class in water law and shale gas development.

Anthony Holtzman, with K&L Gates since 2005, has a practice focused on appellate, constitutional, and governmental litigation and environmental and energy law. Mr. Holtzman has extensive experience in litigating cases before Pennsylvania's Supreme Court and Commonwealth Court and the Pennsylvania Environmental Hearing Board. On the federal side, he often litigates cases before the Third Circuit Court of Appeals and the U.S. District Court for the Middle District of Pennsylvania.

Currently, Mr. Holtzman is serving as counsel to industry members in a number of cases premised on allegations that their gas well operations caused contamination of residential water supplies.

Abstract

This presentation will focus on certain legal implications of alleged gas migration incidents. The speakers will discuss civil lawsuits in which landowners, advancing primarily common law theories of recovery, contend that they have sustained property damage and personal injuries due to the migration of gas and that, as a result, gas well operators are liable. The speakers, in this regard, will provide an overview of the common law theories of recovery that are commonly advanced in the suits. They will likewise discuss key evidentiary issues and the remedies that the landowners seek.

The speakers, additionally, will touch upon statutory and regulatory schemes that relate to gas migration incidents. They will describe, generally, how the statutes and regulations function and explain how they bear upon the gas migration lawsuits.

Finally, the speakers will discuss potential future developments in the legal landscape that surrounds gas migration incidents.

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For more information about the Stray Gas Forum including: registration, event hotel, sponsorship opportunities, etc, please visit... www.gwpc.org or contact Ben Grunewald at 405 516 4972 or ben@gwpc.org.

***THANK YOU for caring about Groundwater!***