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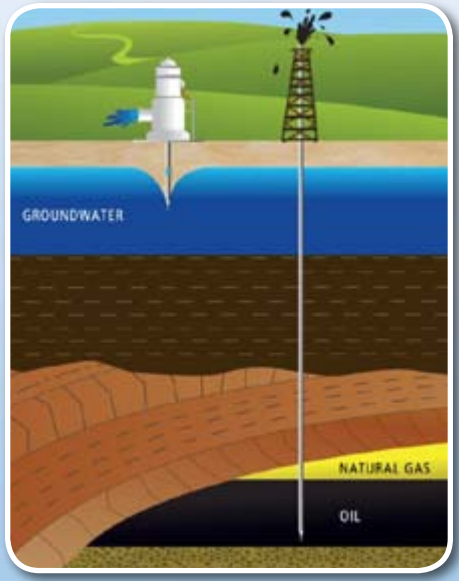
Summary of GRA's California Oil, Gas, and Groundwater Symposium

By Ted Johnson, Rob Gailey, Brent Miyazaki, Ghina Yamout, Lynn Edlund, Jean Kulla, and Tim Parker

Production of oil, natural gas and groundwater from California's reservoirs and aquifers spans over a century. In recent years, significant advances in geo-steering technologies have allowed precision horizontal drilling and enhanced formation stimulation to occur, creating a boom (and glut) in the hydrocarbon production industry. Today, oil extraction in the United States is at a 25-year high and rising, and natural gas production is at an all-time high. The U.S. is currently the largest single-country producer of oil and natural gas in the world.

With this increased activity comes questions from public and private groups regarding potential impacts to the environment resulting from increased oil and gas activities. In 2013, California passed Senate Bill SB-4 (Pavley), which outlined new regulations on well and reservoir stimulation practices, including acidizing and hydraulic fracturing. The bill requires, among other things, that the State Water Resources Control Board develop model criteria for groundwater monitoring by July 1, 2015, to ensure protection of groundwater from well stimulation activities.

GRA and the Los Angeles Basins Geological Society (LABGS) held the *California Oil, Gas, and Groundwater Symposium* on February 18–19, 2015,



in Long Beach, CA to bring together groundwater and petroleum specialists to openly discuss the current state of knowledge, separate fact from fiction, and provide the latest information on current petroleum industry knowledge and practices related to California groundwater. An optional field trip was held on February 20th to the offshore THUMS Oil Islands, a land subsidence area, and to the top of Signal Hill to see firsthand the current oil operations, monitoring and protection measures being employed. Attendees heard 22 invited experts in their respective fields communicate the latest information on how to successfully produce both hydrocarbons and groundwater, while simultaneously minimizing the risk of negative impacts to both resources.

Below is a summary of the information provided at the Symposium and field trip.

Setting the Stage: Questions and Issues Related to Exploration, Production and Protection of Hydrocarbon and Groundwater Resources in California

*Moderated by **Ted Johnson**, Chief Hydrogeologist at the Water Replenishment District of Southern California, and facilitated by **Rob Gailey**, R.M. Gailey Consulting Hydrogeologist*

Dr. Donald Paul, Executive Director at the University of Southern California Energy Institute, presented *Developing Technologies for Solutions*. He first summarized pertinent aspects of activities and operating environments of the petroleum and groundwater industries. Dr. Paul then outlined opportunities and challenges to be addressed by technology development in the future, including managing water derived from petroleum production, developing substitutes for freshwater use, monitoring groundwater

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The Groundwater Resources Association of California is dedicated to resource management that protects and improves groundwater supply and quality through education and technical leadership.

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The Drought Goes On

By Ted Johnson

Hey, where did all the rain go? What happened to the snow? I mean really? Are we going to have a fourth year of drought? Really?

Those are the thoughts going through my head as I sit in the Long Beach Airport, writing this article in a location where cold beverages are graciously served (hey, it's the only place with an available electrical outlet), and on the TV is a news report stating that despite the terrific December rains, January will end up as one of the driest on record, if not THE driest. What's going on here? Is it a continuation of that "Ridiculously Resilient Ridge," a term coined by Stanford climate scientist Daniel Swain who tells of the high-pressure ridge that is parked offshore Washington State and western Canada that won't break down, blocking the winter jet stream and its storms from moving down into California (see my fall 2014 report for more information on the Ridge)? Or is it a less ominous ridge that only blocks weak storms, but will allow the stronger ones to pass? Time will tell, but for now all we know is that January was dry.

A quick look at the National Oceanic and Atmospheric Administration's (NOAA) California Climate Station Precipitation Summary tells me that as of today, January 30, 2015, the total precipitation in CA is about average for this time of year, with some areas a bit up, and others a bit down. So the December rains were offset by the January nada, and we are now at about average. But an average year just won't cut it for sustaining the state's water supply. The drought won't be over and normal precipitation will not make up for the past three years of deficit that caused our reservoirs, both surface and groundwater, to drain. We need significantly above average precipitation to replenish our water supplies. I hope that by writing this article in January that I am jinxing the dry weather pattern and that by the time you read this in March there will have been exceptional February storms that delivered copious amounts of water to the state's snowpack, rivers, and aquifers. If not, I am afraid 2015 will be another drought year and will pose a real challenge for the water suppliers to meet the needs of water users. Conservation and cutbacks, and in some cases panic, will surely follow.

How this year turns out climatically pales in importance to managing California's groundwater basins sustainably and "living within our means" in order to survive future droughts. GRA is proud to be taking the lead in providing information related to the Sustainable Groundwater Management Act that was passed in 2014. So far in 2015, we have presented two free web casts ("GRACasts") on the topic and had over 1,000 telephone lines (likely over 3,000 people) listening in. GRA also will be presenting several one-day events on the topic in various CA locations later this year, and at least 10 more GRACasts. Clearly, this is an important issue with associated timelines in place and requirements that must be met, and involves science (accurate information), consensus, political will, legal certainty, education, boundary issues, agency creation, and funding needs to form these Groundwater Sustainability Agencies. We hope you will call into and attend future events to learn more about this important topic and find out how you can be involved with helping California reach its goal of having every medium- and high-priority basin achieve sustainability.

With all the recent attention focused on groundwater management, GRA has not lost sight of other equally important groundwater issues, such as contaminant hydrogeology. As water resources become more scarce, impaired water bodies are being targeted for treatment and reuse—for direct consumption, or for pump, treat, and re-injection programs. Site investigations and cleanup have been important for decades, but perhaps never as important as they are today. California will need to conserve, protect, replenish, and remediate its groundwater as part of a sustainable water portfolio, which is why GRA will be hosting future GRACasts and events on these groundwater contamination topics, including the latest remediation technologies, development of investigative tools and techniques, and emerging contaminants of concern.

Other aspects of groundwater hydrology will also be covered by GRA this year. Groundwater monitoring related to petroleum operations under SB4 and Underground Injection Control has been the focus of GRACasts and a major two-day event in Long Beach in February, and will be revisited in future events. Managed

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Groundwater Sustainability – A Common Goal – *Continued*

aquifer recharge and land subsidence will continue to be addressed. A GRACast on simulating flow and transport using the Unstructured-Grid version of MODFLOW will be on April 1 (no kidding!). Our annual Legislative Symposium will be on April 29 in Sacramento, where we'll hear from numerous legislators regarding new bills being introduced in 2015 related to CA groundwater. GRA's quarterly journal, *HydroVisions*, also provides outstanding, timely and relevant groundwater information to our members. Keep checking our website at http://grac.org/ to find out about the latest events being offered and registration/sponsorship opportunities, along with back-issues of *HydroVisions*.

GRA recently passed the 1,500 member mark, which is an all-time record. Our Association continues to grow with the increasing recognition of the importance of groundwater in the state. The Association is run by a host of energetic, passionate, and experienced water resource professionals who volunteer as much time as they can to make GRA as good as it can be. It is led by 15 dedicated members of the Board of Directors, plus ex-Board members, a treasurer, committee participants, and Branch officers that all help to strategically develop programs that best meet the needs of our membership. In addition, we use the services of the professional association management firm Smith Moore & Associates to administer all of the day-to-day needs and details of our non-profit organization. All of these efforts are hopefully fulfilling your needs as a member of GRA. If not, and if you would like to offer advice, please send me an email at tjohnson@grac.org.

At the end of December, we saw the retirement of GRA founding Board members Vicki Kretsinger Grabert and Brian Lewis, two individuals who since 1992 led the way with vision and dedication to start and grow this Association to the premiere organization that it is today. We also saw the retirement of Board members Sarah Raker and David Von Aspern, who also volunteered so much of their time to the success of GRA. These individuals offered to retire to make room for new members on the Board, including Murray Einarson, John McHugh, Lisa O'Boyle, and Brett Wyckoff, who will offer new insights and points of view based on their years of service to the groundwater industry. I thank Vicki, Brian, Sarah, and David for their hard work and efforts on the Board—it was a real pleasure serving with you—and welcome Murray, John, Lisa, and Brett. I look forward to meeting the challenges ahead with you on GRA's continuing efforts to be the most relevant, current, diverse, and outstanding groundwater association in the state and the nation.

Rock on!

TJ

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systems and ensuring long-term well integrity. A key issue, he explained, is what to do with the produced water and associated contaminants. Technical solutions exist, and more are being developed to handle this challenge. He emphasized that new technologies should possess the characteristics of robustness, reliability, flexibility, cost effectiveness and scalability/modularity.

Jon Parker. Photo by Ted Johnson.

Jon Parker, General Manager of the Kern Water Bank Authority, presented *The Kern Water Bank and Oil*. He first summarized the facilities and operations of the Kern Water Bank Authority, then discussed petroleum production activities within and adjacent to the Bank's area of operations. Examples of soil and groundwater contamination resulting from legacy petroleum production operations indicated the need to guard against quality impacts to the freshwater resource. His main concern is over increased total dissolved solids (TDS) from petroleum operations, including disposal of produced water in unlined pits, and associated impacts on fresh groundwater. Jon discussed the need for improvements in groundwater monitoring planning under the new SB-4 regulations and the Underground Injection Control Program, emphasizing that (1) more information is needed to understand the relationship between oil-bearing formations and groundwater, and (2) the groundwater community must be included in discussions of UIC aquifer exemptions and SB-4 monitoring.

Kevin Buchan, Senior Coordinator at the Western States Petroleum Association, presented *Exploration, Production and Protection of Hydrocarbon and Groundwater Resources in California*. He summarized well stimulation treatment operations and the current regulatory landscape in California. Kevin then discussed potential sources of groundwater contamination from petroleum operations, the potential migration pathways for contamination to occur, and the associated risk of contamination events. He made the case that monitoring under SB-4 should only be required where potentially complete migration pathways exist.

How Are Other States Tackling the Hydrocarbon/Groundwater Compatibility Issue?

*Moderated by **Brent Miyazaki**, Associate Vice President, AECOM.*

Dr. Ken Carlson is an associate professor of Civil and Environmental Engineering at Colorado State University, and co-director of the Colorado Energy Water Consortium. His presentation, *Colorado – Successful Government/Industry Collaboration*, described the collaboration between Colorado politicians, government regulators, academia, and oil industry in developing an approach to assess and monitor potential risks to groundwater. Their program, called "Colorado Water Watch," is a real-time groundwater monitoring pilot program developed by the Center for Energy Water Sustainability at CSU. The monitoring system comprises a network of water-quality sensors capable of detecting changes in groundwater quality due to natural or operational processes using anomaly detection algorithms. One strong finding is that Oxidation Reduction Potential (ORP) can be a good surrogate for real-time monitoring of methane. The monitoring data are analyzed, and reported on the web site waterwatch.colostate.edu.

Ryan Leatherbury, a Client Service Manager at Weston Solutions, presented *Baseline Groundwater Sampling and California SB-4*. He explained the im-

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SYMPOSIUM AT A GLANCE

What: Oil, Gas and Groundwater: Wise Production and Protection of Our Valuable Natural Resources

When: February 18, 19, 20, 2015

Where: Long Beach, CA

Committee: GRA & LABGS. Ted Johnson, Jean Kulla, Brent Miyazaki, Ghina Yamout, Rob Gailey, Tim Parker, Lynn Edlund, Brian Lewis, Smith Moore and Associates

Attendees: 152

Speakers: 21, all invited, plus final panel and 3 Posters

Sponsors: California Water Foundation, AECOM, Weston Solutions, Trihydro, National Exploration-Wells-Pumps

Exhibitors: Accutest Labs, ASC Tech Services, Blaine Tech Services, Confluence Environmental Field Services, Enviro-Chem In-Situ, Layne Christensen, National Exploration-Wells-Pumps, OTT Hydromet, Snap Sampler/ProHydro, Test America, Wayne Perry

Keynote: Don Clarke – AAPG 2014-15 Distinguished Ethics Lecturer

Field Trip: John Jepson – Long Beach Gas and Oil Department to Offshore Oil Islands, Land Subsidence, and Top of Signal Hill

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portance of baseline groundwater sampling, which he defines as the process of collecting water samples from sources surrounding a well pad, to document groundwater conditions prior to drilling. The states with baseline sampling regulations include Pennsylvania, Ohio, Colorado, Maryland, West Virginia, Wyoming, Illinois, Alaska, and now California. He described getting permissions to sample, what to sample, where to sample, analyses to perform, and how California's regulations differ from the other states—particularly in defining the base of freshwater at 10,000 parts per million TDS, which is a more strict requirement than in any other state he reviewed.

Dr. Kelly Sanders. Photo by Ted Johnson.

Dr. Kelly T. Sanders, an assistant professor at USC, in the Sonny Astani Department of Civil and Environmental Engineering, presented *The Energy-Water Nexus within the Marcellus Shale Region*. She discussed water use and reuse challenges for the oil and gas industry, especially in the northeastern part of the U.S. She reported that the modern era of Marcellus Shale production in the Appalachian Basin, the largest known shale-gas resource in the country, began in 2004. Deep well injection is the preferred method of disposal there; however, injection does not occur in Pennsylvania (about 8 injection wells compared to over 50,000 in Texas), so wastes from the Marcellus exploration are trucked to Ohio for injection, which adds significant cost and risk. She presented the four documented risks to water from hydraulic fracturing, including contamination of shallow aquifers with fugitive hydrocarbon gases; contamination of surface water and shallow groundwater from spills, leaks, or other inadequate management of shale gas wastewater; the accumulation of toxic and radioactive elements in soil or stream sediments near disposal or spill sites; and the over-extraction of water resources for high-volume fracturing that could induce water shortages.

Mike Nickolaus is from the Groundwater Protection Council (GPC), where he is Special Projects Director. His presentation, *National Trends on State Regulations*, compared and contrasted existing regulations from several states for protecting groundwater from oil and gas activities. The GPC's 2014 report, *Regulations Designed to Protect State Oil & Gas Water Resources*, identifies the oil and gas regulations in 27 states that protect water, and describes the associated regulatory language. These 27 states represent 98% of all oil and gas production within the U.S. He also outlined the emerging issues as the GPC saw them, including water sampling and analysis (with varying state requirements), and the presence of naturally occurring radioactive materials (NORMs) that have been documented in formation waters brought to the surface during oil and gas operations in many sedimentary basins. He concluded with a discussion of future directions for the GPC, which in 2015 will be planning for the next report update (publication in 2017), and for the 2016 regulatory evaluation.

Lunch Keynote

Don Clarke, AAPG's 2014–2015 Distinguished Ethics Lecturer, presented *Induced Earthquake Potential from Energy Technologies – Ethically, How Do We Move Forward and Do the Right Thing?* In 2010, Senator Bingaman of New Mexico requested that Department of Energy Secretary Steven Chu engage the National Research Council

Keynote Speaker, Don Clarke. Photo by Ted Johnson.

(NRC) to form an ad hoc committee to examine the topic of "Induced Seismicity Potential in Energy Technologies." Don Clarke, consulting geologist from Long Beach, California, was one of eleven people selected to be on the committee. During the course of a year, the committee convened five public information-gathering meetings and produced a consensus report on induced seismicity in the United States with respect to various energy technologies; the report addresses hazards, risks, government roles and responsibilities, proposed research needs and suggestions on how to move forward. The findings of the committee dispelled some myths about hydraulic fracturing and revealed that deep wastewater injection was responsible for much of the induced seismicity, particularly the more significant seismicity. The committee also interviewed some of the people shown in the movie, Gas Lands, which has been influential with the public. Don recounted that the interviews he held revealed different facts and accounts than were presented in the movie, such as hydraulic fracturing activities in the area did not actually cause cows to die nor water to ignite.

The committee was formed from a large set of nominees sent to the NRC staff from a spectrum of professionals in academia, government and industry, and

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was approved by the chair of the NRC. The committee members, each of whom served pro bono for the duration of the project, brought a wide range of expertise to the study, including oil and gas exploration and production, geothermal energy, drilling engineering, fluid injection, seismic monitoring and modeling, seismic hazard assessment, geomechanics, mining engineering, fluid-rock interaction, and regulatory oversight, with professional experience derived from academic research, private industry, and government service. The report stands as an example of how a group of objective professionals with varying viewpoints can come to a consensus and produce a useful, scientifically-grounded document to help guide developments with emerging energy technologies. The lunchtime presentation from Don was both informative and entertaining.

Petroleum and Groundwater Activities in California

Moderated by ***Ghina Yamout****, Principal Scientist at Weston Solutions Inc.*

Dr. Don Gautier, consulting hydrogeologist, Don Gautier LLC, and Scientist Emeritus USGS, presented *Petroleum in California: Its historical development, recent trends, and resource potential, including new field discoveries, further development of existing fields, and uncertainties surrounding the potential for shale oil resources*. He emphasized that California oil basins are characterized by the highest crude oil sediment concentration in the world; billions of barrels of oil remain in on-shore and off-shore existing fields, undeveloped and undiscovered fields, and in source-rock systems. He described the distinctions between source-rock plays, such as California's Monterey shale versus the Eagle Ford and Bakken shales in other states, concluding that the San Joaquin Basin is the most likely location for shale-oil production in California, if it were to occur.

Brent Miyazaki, associate VP at AECOM, presented *California Groundwater Basins – An introduction to California Groundwater history and use. Where are the basins and bedrock aquifers in relation to oil and gas fields?* Brent generally characterized groundwater basins' locations, quantity and usage in California, listing the concerns associated with the state's groundwater resources, including overdraft, quality degradation, reduced storage, pumping from greater depths, and land subsidence. Added concerns stem from various oil and gas activities. He described the chemical additives used in well stimulation activities, and emphasized the need to protect groundwater resources by documenting baseline conditions, identifying data gaps, developing regulatory monitoring plans, monitoring supply wells, and delineating aquifers and barriers. He also pointed out the need for the water, and oil and gas industries to develop sound mutual understanding of their concerns and present sources of information.

Dr. Jane Long, California Council on Science and Technology (CCST), concluded the session with *An Independent Scientific Review of Advanced Well Stimulation Technologies in California*. The review, performed with the support of multiple agencies, is being documented in three volumes, the first published in 2014, and the others scheduled for July 2015. She pointed out that of all stimulation methods used in California, on-shore hydraulic fracturing constitutes over 85%, of which 96% occurs in the San Joaquin Valley, yielding 20% of the oil and gas production in the state since 2001. The application of hydraulic fracturing in California is simpler than in other states due to shallower production wells depths and smaller water volumes, and result in simpler fractures; however, recoverable shale oil estimates are highly disparate and uncertain. She clarified that the high-volume hydraulic fracturing cutoff imposed in New York is greater than more than 90% of California's operations. Volumes II and III of the study will focus on analyzing potential impacts from well stimulation activities and case studies, respectively.

Dr. Jane Long. Photo by Ted Johnson.

Risks to Groundwater: SB-4 and UIC Considerations

Moderated by Lynn Edlund, PG, Senior Geologist for Trihydro Corporation

Dr. Steven Bohlen, State Oil and Gas Supervisor, Division of Oil, Gas, and Geothermal Resources, presented DOGGR's *Response to SB-4. Where Are We & Where Do We Go From Here?* He summarized the SB-4 regulations required before, during, and after well stimulation activities, and the public notification requirements prior to stimulation. He provided an overview of the Environmental Impact Report (EIR) and the Underground Injection Control

Dr. Steven Bohlen. Photo by Ted Johnson.

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(UIC) programs, and the Memorandum of Understanding between the oversight agencies. He also discussed the water quantities used for well stimulation, the flow-back, and reinjection requirements. Dr. Bohlen stated that SB-4 requirements, properly implemented, should protect California groundwater.

Phyllis Stanin, Principal and Vice President of Todd Groundwater, presented *Results of DOGGR's Statewide EIR – Risks to Groundwater*. She included a summary of potential impacts to groundwater quantity and quality associated with hydraulic fracturing, and proposed mitigation measures to address them. The proposed mitigation measures to address groundwater quantity included the use of alternative water sources and an evaluation of the contribution from hydraulic fracturing to overdraft and localized impacts of pumping. The proposed mitigation measures to address groundwater quality are to (1) provide a surface seal to prevent spills from percolating into groundwater, (2) install a full-length cement seal in wells used for well stimulation, (3) demonstrate the effectiveness of the cement seal, (4) install methane sensors, (5) conduct field surveys to locate improperly abandoned wells, and (6) add tracers to well stimulation fluids.

Jonathan Bishop, Chief Deputy Director, State Water Resources Control Board, presented *Underground Injection Control Drinking Water Source Evaluation*. He summarized the background of the UIC program, current program issues, and the path forward for this program. One issue is that some aquifers may not have been properly reviewed before exemption; these will be evaluated. Jon stated that the SWRCB and DOGGR will be working more closely to address the aquifer exemption program and will review the existing and proposed injection well projects to asses if injection wells are potentially impacting freshwater aquifers and water-supply wells. Jon stated that no new injection wells will be permitted unless EPA approves the aquifer exemption, and that the goal of the SWRCB is to bring all Class II injection wells into UIC compliance.

SB-4 and SWRCB's Activities

*Moderated by **Ghina Yamout**, Principal Scientist at Weston Solutions Inc.*

John Borkovich, State Water Resources Control Board (SWRCB), presented *Overview of SWRCB's Activities and Schedule for Developing Model Criteria for Groundwater Monitoring and Protection of Groundwater Resources*. He discussed events leading to the groundwater criteria development requirement by SWRCB, which will have oversight over the regional groundwater monitoring program to be implemented by January 2016. He listed the agencies involved in the criteria development, and summarized the elements of the monitoring program, such as monitoring methods, chemicals, frequency and duration, and area-specific and regional extent. Mr. Borkovich confirmed that the state will be using 10,000 ppm TDS as the basis for protected water. The draft model criteria are to be released and discussed with the public between April and June; the final criteria will be adopted by July 1, 2015.

Dr. Justin Kulongoski, U.S. Geological Survey, presented *Tools for Distinguishing Sources and Pathways of Groundwater Contamination from Oil Exploration and Development*. He discussed the importance of developing tools to characterize the feasible potential pathways to groundwater contamination and identify their sources, anthropogenic or natural. Methane in groundwater, for example, has a range of compositions indicating microbial to thermogenic sources. He demonstrated that it is possible to distinguish the presence of fracking chemicals in produced water from a fracked well, which are absent in the case of a typical production well. Another example showed that the presence of benzene in groundwater was geogenic, and higher detection frequencies were associated with deep, older, saline groundwater closer to oil or gas fields. He concluded by stating that 3-D characterization of basins is important for identifying transport pathways and risk areas, and can be used along with multiple tracer approaches to distinguish the sources and movement of groundwater contamination.

Dr. Justin Kulongoski. Photo by Ted Johnson.

Dr. Brad Esser, Lawrence Livermore National Laboratories (LLNL), presented *SB-4 Model Criteria for Groundwater Monitoring*. After defining the role of LLNL as technical experts to the SWRCB in developing groundwater monitoring criteria, as required by SB-4, he presented the timeline of the process; draft and final criteria are to be released for public comments on April 30 and June 19, 2015, respectively. Monitoring will be required on a range of spatial scales, including well-by-well (by the operators) and regional-based or oil-field based (by SWRCB). The required monitoring will consider source characteristics (such as location, quality, and usage) and potential pathways (such as surface operations; vertical zone separation; and conduits, such as faults, wellbores, and wastewater disposal wells). Dr. Esser outlined the components of a permit-required versus regional-based groundwater monitoring plans. He recommended that vulnerability be used as basis for monitoring prioritization.

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Industry Activities and Technologies for Groundwater Monitoring, Monitoring Reservoir Stimulation, Well Competency, and Production Water Conservation

*Moderated by **Dr. Jean B. Kulla**, President and Principal Geochemist and Hydrogeologist at K2 Enviro, Inc. and K2 Energy and Environment*

Rob Gailey, Consulting Hydrogeologist, presented *Groundwater Monitoring Plans under SB-4*. Mr. Gailey addressed three key themes in his presentation: the regulatory framework, activities during the first year under SB-4, and prospects for the coming years. Due to public concerns, problems from hydraulic fracturing in other parts of the U.S., and the California legislature not being satisfied with available information on hydraulic fracturing in California, SB-4 was passed to further regulate oil and gas well stimulation operations. Initial interim regulations were developed, and Mr. Gailey discussed their implementation, including the development of groundwater monitoring plans under the currently active interim regulations. Final regulations become effective on July 1, 2015. He summarized the plans already approved and some challenges in obtaining information for the plans, including depth to fresh water and water-supply well information. He also addressed potential future questions when regulations become finalized, including the necessary 'learning curve' and the importance of communication.

Dr. Norman Warpinski. Photo by Ted Johnson.

Dr. Norman Warpinski, Technology Fellow, Pinnacle – A Halliburton Service, presented *Hydraulic Fracturing, Where Does the Science Lead Us?* He described the significant importance of hydraulic fracturing to the production of oil and gas, particularly gas in the U.S. Dr. Warpinski summarized the intensive research history of fracturing beginning in the 1940s, government (DOE) research in the 1960s and 1970s involving nuclear fracturing; diagnostic research and modeling beginning in the 1970s and 3-D modeling in the 1980s. Extensive research was carried out at Los Alamos, Sandia, the USGS, and AMOCO. More recently, the oil industry (i.e. Halliburton and Schlumberger) have been researching and developing micro-seismic monitoring techniques to measure fracture length and height, propagation, and induced seismicity in real time for environmental purposes and to optimize hydraulic fracturing program design and well spacing for oil and gas production.

Ned Clayton, Senior Engineer, Schlumberger Water Services, presented *Testing and Logging for Well Integrity and Reservoir Information, and Translating between Oil and Groundwater*. He gave an overview of downhole geophysical logging and testing as used in oil & gas, compared to groundwater, and briefly described some logging techniques for well integrity evaluation. There are many technologies available to demonstrate competency of a well construction project, and if problems are found they can be isolated and repaired. He covered induced fracture monitoring using microseismic methods, caprock integrity evaluation, and opportunities for cross discipline/resource collaboration. Ned also provided slides to link the nomenclature of petroleum exploration and the groundwater industry, such as permeability versus hydraulic conductivity, and absolute fluid pressure versus hydraulic head.

Dr. Ted Frankiewicz, Engineering Advisor, SPEC Services, Inc., presented *Produced Water Management in California Oil Fields*. He summarized: produced water management; the cost and value for beneficial use of produced water in California; disposal options; the removal of dispersed contaminants and the challenges of removing dissolved components. Dr. Frankiewicz showed several examples of produced-water treatment systems in use at various oil production facilities, including the Chevron San Ardo Facility, where produced water is treated and reused for irrigation. He concluded with a discussion of emerging technologies, such as the use of ultra-filtration and microfiltration for the future use of produced water in aquifer recharge and other beneficial uses.

The Final Word – Concerns, Solutions and the Future of Wise Production of California Oil, Gas and Groundwater

Moderated by Tim Parker, Parker Groundwater

This final session of the Symposium was a panel discussion featuring the following panelists:

- Dr. Donald Paul, USC Energy Institute
- Rob Gailey, R.M. Gailey Consulting Hydrogeologist
- Jon Parker, Kern Water Bank
- John Borkovich, SWRCB

One of the key actions identified as a result of the many excellent talks over the previous two days, was the need to engage in issues across industry to cross-pollinate across technical and regulatory challenges and solutions in the oil, gas and groundwater industries. As Dr. Paul put it, there are two communities (petroleum and groundwater) that often don't interact or understand each other's activities, but should.

There is potential in California to extract more oil with improved recovery

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Final panel: from left, moderator Tim Parker, Rob Gailey, Dr. Donald Paul, John Borkovich, and Jon Parker. Photo by Ted Johnson.

technologies. With the associated issues and challenges comes the realization of new opportunities, including using the approximate 300,000 acre-feet per year of produced water generated in oil and gas activities statewide in more beneficial ways than reinjection, such as treatment and reuse, thus adding new water supplies to depleted areas. However, ensuring groundwater protection cannot be overlooked in the face of a potential oil bonanza and associated new source of water.

There are legacy oilfield issues that continue to crop up in places. What is to be done if legacy (preexisting) contamination is found when exploring groundwater monitoring under SB-4? There is a timescale issue as well—our largest problems may not be with risk to groundwater from well stimulation activities, but from the thousands of old, forgotten, abandoned (either properly or not) oil and gas wells that cross the aquifers and from unlined wastewater pits. Will these become conduits for oil and gas reservoirs to mix with fresh groundwater? Current regulations seem to focus on short timeframes, but should consider a more risk-based approach to the nature and need for monitoring petroleum operations in general, including old wells, current activities of well stimulation, waste handling, and underground injection control.

Groundwater monitoring was recognized as a tricky endeavor if the goal is to find leaks from well stimulation activities. Distance, gradients, heterogeneity, travel times, dilution, conduits, etc., are all factors that can influence how contaminants migrate, and finding it in a monitoring well may be extremely difficult. Risk-Ranked scenarios were discussed, whereby consequences, probabilities, and resultant risk associated with various events are quantified, and decisions of monitoring rigor are applied by level of risk.

There are data gaps and a lack of comprehensive data management systems, which should be created to combine hydrogeologic tabular and spatial data with those for oil & gas fields. There is a need to characterize and map the base of fresh water (protected water) in oil field areas, particularly where the overlying aquifers are usable or potentially usable. In closing, this final session of the Symposium was a broad discussion with active attendee participation.

Posters

Three informative and practical posters were presented throughout the Symposium and drew broad interest from the attendees, especially during the reception and networking session. **James Lehman**, PG, CHG, of Parsons, Walnut Creek presented a poster on *Limited Impacts of Natural Gas Gathering Operations on Shallow Groundwater in the Sacramento Basin*. **Nicky White** and **Dr. Matt Becker** of Cal State University Long Beach presented a poster on *Passive and Active Fiber Optic Distributed Temperature Sensing for Downhole Lithologic and Porosity Characterization at Terminal Island, Los Angeles County, California*. Finally, **Kimberly Gordon** presented, along with coauthors **D. Jordan**, **W. Oliver**, and **D. Lupton** of INTERA Inc., a poster on *Alternative Water Resources for Drilling and Completions*. GRA and LABGS appreciate the submittal and presentation of these terrific posters that helped educate the attendees during breaks and the reception.

Field Trip

John Jepson, Senior Geologist with the City of Long Beach Gas and Oil Department, organized and led an impressive field trip on Friday, February 20, to several nearby oil operations of interest. The first stop was a short boat ride to Island White, one of the four THUMS offshore oil islands that sit on top of the famous Wilmington Oil Field that has produced over 2.6 billion barrels (335,000 acre-feet) of oil since its discovery in 1936. **Bill O'Toole**, HSE Manager of California Resources Corp, guided the group on the Island. The four THUMS Islands (short for Texaco, Humble, Union Oil, Mobil, and Shell) were constructed in 1965 and currently have 731 active production wells and 457 water injection wells that produce 1,036,608 barrels of fluid a day (137 AF), of which 2% is oil; the rest is water that is reinjected after the oil is separated out. Because of land subsidence issues in the Wilmington Field, more fluids need to be reinjected than are pumped out—normally about 103% to 105% of what is produced; recycled water from the City of Long Beach is added to the produced water to make up the injection volume.

After returning to shore, Mr. Jepson led the group to an oil field area in the Port of Long Beach that is ground zero for the historic land subsidence problem in the Wilmington Field that occurred roughly from 1928 through 1970, with a

Continued on the following page…

Summary of GRA's California Oil, Gas, and Groundwater Symposium – *Continued*

Field trip to "Island White," an offshore oil drilling facility. The tour bus is more than 25 feet below sea level due to land subsidence from historic oil operations. Photo by Ted Johnson.

subsidence rate of about 2.4 feet per year measured in the 1950s. About 20 square miles was affected by subsidence, with a maximum of about 29 feet near the field trip stop. The tour bus parked on a dirt lot surrounded by active oil wells, and we hiked up a large earthen berm to see the harbor and ocean above; that's right, our bus was about 25 feet below sea level. Without the berm, the entire area would be flooded by the sea; the only thing keeping it out was the manufactured earthen walls. Today, subsidence is controlled by 'water flooding' (re-injection of water) to replace the extracted oil. The injected water not only has eliminated subsidence, but acts to push the oil toward the extraction wells. The City of Long Beach uses continuous GPS to monitor the land surface to ensure subsidence control, and works with the oil operators to shift locations and amounts of injection to balance the extraction at any given time.

The final stop was in the City of Signal Hill and at the facilities of Signal Hill Petroleum. **Sean McDaniel** and **Devon Shay** provided a tour of how their company produces oil and reinjects 100% of the water produced with the oil. They have over 400 wells and produce over a million barrels of crude oil per year (130 AF). From the top of Signal Hill, there is a terrific view of the Long Beach area, including the THUMS islands, downtown Long Beach, the ports, and the subsidence area. Signal Hill Petroleum is operating oil wells literally feet from beautiful hilltop homes, and prides itself in keeping good community relations by minimizing noise, working limited hours, and developing open spaces and planned communities to weave their oil operations unobtrusively with the residential environment. We all enjoyed a nice lunch on top of the hill, then rode the bus back to the hotel past numerous other active oil fields that dot the Long Beach landscape.

Closing

The *Oil, Gas and Groundwater in California Symposium* was very well received. Many attendees said it was one of the most organized and informative conferences they had attended. A key to this success was the weaving together of the often separated petroleum and groundwater professionals, who united for three days to learn from and better understand each other, and how to both produce and protect our valuable natural resources. The petroleum industry heard from the groundwater industry—how precious our groundwater resources are and why monitoring is so important—and the groundwater industry heard from the petroleum industry—how advanced technologies are used to ensure safe practices and that over-regulation and cost of compliance could threaten exploration in the state.

We also heard that it would be important to have an update to this conference in about 18 to 24 months, after the groundwater monitoring criteria have been finalized and put into practice by the State Water Resources Control Board. The purpose would be to learn what is working, what is not, and what changes might be appropriate to best serve the needs of the state and industry with regard to the wise production and protection of oil, gas, and groundwater resources. The Organizing Committee is up for that task, and will be looking forward to presenting such updates in the not too distant future.

Organizing committee, from left: Tim Parker, Lynn Edlund, Brent Miyazaki, Dr. Jean Kulla, Ted Johnson, and Ghina Yamout. Not pictured: Rob Gailey and Brian Lewis. Photo by Peter Piestrzeniewicz.

Dates & Details

GRA EVENTS & KEY DATES

(Please visit www.grac.org for detailed information, updates, and registration unless noted)

GRA-CGC Annual Legislative Symposium
Apr. 29, 2015 | Sacramento, CA

GRA Board & Planning Meeting
May 2-3, 2015 | Santa Barbara, CA

Groundwater Sustainability Agency Formation Workshop
Solid Steps Forward, Boundary Determination, Legal Agreements, and Public Participation
Jun. 2, 2015 | Sacramento, CA

30th Biennial Groundwater Conference & 24th GRA Annual Meeting
Oct. 6-7, 2015 | Sacramento, CA

For information on how to sponsor or exhibit at an upcoming event, please contact Sarah Kline at skline@grac.org.

SAVE THE DATE

Groundwater Resources Association of California in cooperation with California Groundwater Coalition presents:

ANNUAL LEGISLATIVE SYMPOSIUM:

The Infancy of California's Sustainable Groundwater Management Act – What's Next?

APRIL 29, 2015 – SACRAMENTO, CA

As California's drought conditions persist, state agencies and local stakeholders are gearing up for implementation of the Sustainable Groundwater Management Act (SGMA). Many questions remain on how implementation of SGMA should be approached at the state and local level, and how the Act itself should be changed in 2015. Join us for a dialogue on this and other subjects with California's most influential Legislators and Administration Officials.

Topics:

- "Streamlined adjudication" – aid or oxymoron?
- BDCP: what's in it for groundwater?
- Annual update on fracking, oil and gas
- Water bond funding for groundwater management and development
- CWAP update
- Impact of the Chrom 6 MCL
- The need for and benefits of enhanced recharge across California
- The return of the debate over public access to well logs
- And much more!

Speakers:

This year's invited speakers include Senate and Assembly Water Committee Chairs Pavley and Levine; Assembly Speaker Toni Atkins; Senate President Pro Tem Kevin de Leon; Senators Canella, Stone, Wieckowski and Wolk; and Assembly Members Alejo, Bigelow, Mathis and Rendon.

Note: All speakers are not yet confirmed and subject to change.

Questions?

Contact Rosanna Carvacho at 916.594.9700 or email Wendy Smith at wsmith@bhfs.com.

Register for this event
http://grac.org/event/er_regform.asp?eid=402

SAVE THE DATE

Groundwater Resources Association of California in cooperation with California Groundwater Coalition presents:

GROUNDWATER SUSTAINABILITY AGENCY FORMATION: A WORKSHOP

Solid Steps Forward, Boundary Determination, Legal Agreements, and Public Participation

JUNE 2, 2015 – SACRAMENTO, CA

The Sustainable Groundwater Management Act (SGMA), signed into law September 16, 2014 and effective January 1, 2015, requires that approximately 100 high- and medium-priority basins form Groundwater Sustainability Agencies (GSAs) by June 30, 2017. To propose to be a GSA, a notice of intent that includes the local agencies of the GSA and the GSA boundary must be submitted to DWR, and a public hearing held. Subsequently, the GSA must submit the GSA legal agreement, list of interested parties and how they can participate in the development of a groundwater sustainability plan. The SGMA requires that GSAs consider the interests of all groundwater users and beneficial uses, as well as other relevant groundwater sustainability plans.

Figure courtesy of the Water Education Foundation

Discussion topics are planned to include:

- SGMA and Challenges to GSA Formation
- Determination of GSA Boundaries
- Legal Agreements – Concepts and the Devilish Details
- Interested Party lists and Public Participation
- Facilitation as a Key Tool for Public Participation

Questions?

Contact Sarah Kline 916-446-3626 or Tim Parker at 916-596-9163 or email skline@grac.org or tim@pg-tim.com

SAVE THE DATE

Groundwater Resources Association presents:

30th Biennial Groundwater Conference & 24th GRA Annual Meeting

OCTOBER 6-7, 2015
SACRAMENTO, CA

In keeping with the 60-year tradition of the Biennial Groundwater Conference, sessions will include:

- A broad range of groundwater topics, including contamination and water-supply issues, how-to sessions for groundwater practitioners, the latest technological advances, and legislative directions;
- Detailed coverage of today's issues, including implementation of the Sustainable Groundwater Management Act, and the ongoing drought.

Questions?

Contact Sarah Kline: 916-446-3626 skline@grac.org

For additional information, including scholastic, sponsorship and exhibitor opportunities, please visit www.grac.org/am2015.asp.

Wells and Words

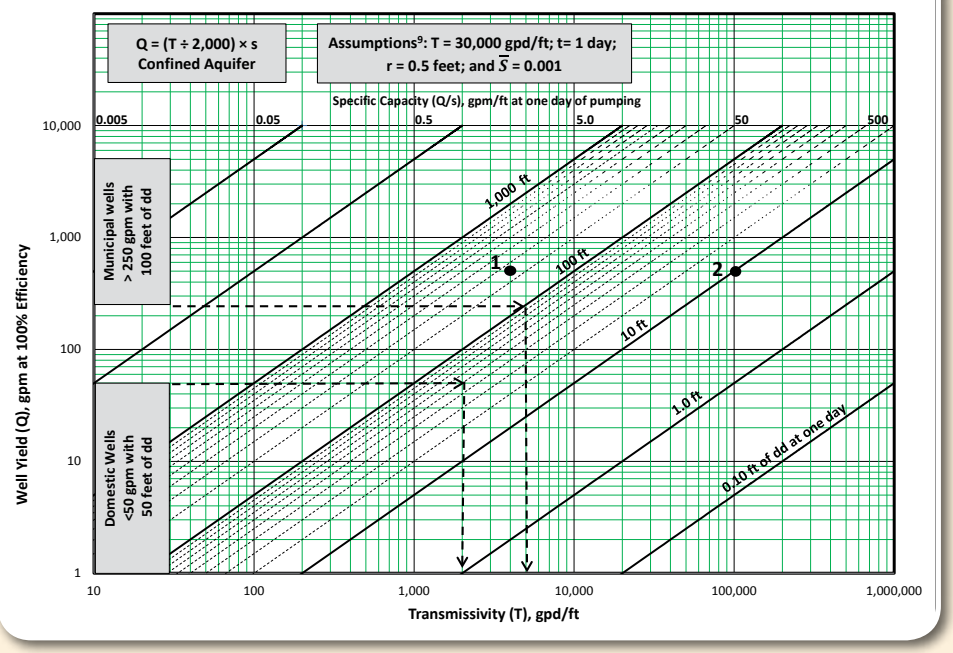
By David W. Abbott P.G., C.Hg., Consulting Hydrogeologist

The Relationship between Drawdown, Transmissivity, and Well Yield

There are infinite combinations of drawdown and transmissivity that will produce a given well yield, but the realistic set of such combinations is constrained by physical and economic limitations associated with well construction and the power requirements for lifting water to ground surface. Drawdown (s) is the vertical distance between the static (non-pumping) water level (SWL) and the pumping water level (PWL). Transmissivity (T) of an aquifer, commonly expressed in gallons per day per foot (gpd/ft), is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient[1,2]; it is also equal to the hydraulic conductivity times the aquifer thickness. Well yield (Q) is the discharge of a pumped or free-flowing well[3], or the maximum safe volume of water discharged per unit time; it is usually expressed in gallons per minute (gpm)[4].

T is proportional to the specific capacity (Q/s), which is the ratio of discharge to drawdown at a specific time while pumping: T = (Q/s) × C; note that Q/s varies with time and well efficiency. Various authors[5,6,7,8,9] have described different derivations and presentations of this relationship and their corresponding constants. The proportionality constants (C) for unconsolidated aquifers from Driscoll[7] are used here and seem to work quite well for this author in most field applications for high-yield production wells (T > 5,000 gpd/ft) as long as the applied assumptions are fully understood and adjusted to meet actual field conditions. For unconfined aquifers C = 1,500 and for confined aquifers C = 2,000. An exponential relationship was developed for low-yield fractured rock aquifers as well: T = $(Q/s)^{1.18}$ × C (where C = 291)[10].

Figure 1: Drawdown, Transmissivity, and Well Yield



C is empirically derived by applying certain logical assumptions to the Cooper-Jacob modified non-equilibrium equation, which describes groundwater flow to a pumping well.

$$s = \frac{264 \times Q}{T} \text{ Log } \left(\frac{0.3 \times T \times t}{r^2 \times \bar{S}}\right)$$

where: "little" s is the drawdown in feet (ft), Q is in gpm, T is in gpd/ft, t = elapsed time of pumping in days, r = horizontal distance in ft from the center of the well to a point of interest, and "big" is storativity (unitless). Driscoll[7] assumes that t = 1 day and r = 0.5 ft, and rearranges the equation:

$$\text{Specific Capacity} = Q/s = \frac{T}{264 \times \text{Log } \left(\frac{1.2 \times T}{S}\right)}$$

Note that T/$\bar{S}$ in the denominator is the hydraulic diffusivity, which is the conductivity of the saturated medium when the unit volume of water moving is that involved in changing the head a unit amount in a unit volume of medium[11]. Let T = 30,000 gpd/ft, $\bar{S}$ = 0.001 for confined, and 0.075 for unconfined aquifers. Inserting these values in the logarithmic argument of the denominator and solving for the denominator yields values for C of 1,995 for confined aquifers and 1,500 for unconfined aquifers[12]. These estimates of C embrace the assumptions[13] associated with the Cooper-Jacob equation, including, for the water bearing formations, (1) uniform in character and permeability in both horizontal and vertical directions, (2) uniform thickness, (3) infinite areal extent, (4) receives no recharge from any source; and for the well, (5) penetrates and receives water from the full thickness of the aquifer, (6) storage is discharged instantaneously with lowering of the head, (7) is 100 percent efficient, (8)

Continued on the following page…

Wells and Words – *Continued*

all water removed comes from aquifer storage, (9) laminar flow exists throughout the well and aquifer, and (10) the water table or potentiometric surface has no slope.

Similar constants have been evaluated and used by other authors using slightly different methods and assumptions. Remarkably, for high-yield aquifers, C ranges from 1,262 to 2,477 (confined) and from 469 to 1,764 (unconfined); for low-yield aquifers, C ranges from 939 to 1,467 (confined) and 300 to 972 (unconfined). Note that even though T varies by 5 orders of magnitude and varies by several orders of magnitude[14], the range of values for C is slightly less than one order of magnitude, from 300 to 2,477!

Figure 1 is a graph of T in gpd/ft on the x-axis and Q in gpm on the y-axis; both axes are logarithmic. A draft of this unpublished graph was originally provided by David K. Todd, Ph.D. to his staff in the late-1990s; the graph has been reproduced here in Excel format with minor modifications for clarity. The resulting family of parallel diagonal lines represents various drawdowns in ft that span at least seven orders of magnitude, from 0.1 to 100,000 ft for a confined aquifer that uses the Driscoll[7] empirical approach. Realistically, s is typically less than 200–300 ft; the lower end of T for small water-supply wells is usually >100 gpd/ft, or equivalent to well yields >3 gpm with about 50 to 100 ft of drawdown. High-yield municipal and industrial wells usually have T > 5,000 gpd/ft, which are equivalent to Q >250 gpm with 100 ft of drawdown.

It follows that different combinations of T and s will produce identical well yields. For example: an aquifer with a T = 4,000 gpd/ft and 280 ft of drawdown (Point 1 on Figure 1) or an aquifer with a T = 123,000 gpd/ft and 10 ft of drawdown (Point 2) will yield 500 gpm; the former would be a marginal or low-yield aquifer at that pumping rate and the latter would be a very productive aquifer capable of much higher yields. Note that the recommended long-term well yield (100 ft of drawdown) for the former aquifer (T= 4,000 gpd/ft) would be about 180 gpm rather than 500 gpm.

The proportional relationship between transmissivity and specific capacity is an extremely useful field term and a valuable tool to apply for estimating the transmissivity of the aquifer if unknown, or to evaluate the effectiveness of well development programs and the well efficiency if the transmissivity is known[15]. Careful inspection of the assumptions used to determine the proportionality constant helps to validate transmissivity estimations or validate optimal specific capacities.

[1] Todd, David K., 1980, *Groundwater Hydrology* (second edition), John Wiley & Sons, New York, 535 p.

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[6] Bentall, Ray, 1963, Methods of Determining Permeability, Transmissibility, and Drawdown, U.S. Geological Survey Water Supply Paper 1536-I, Washington, D.C., (see p. 331–340 and note especially the two brief papers by Theis and by Brown).

[7] Driscoll, Fletcher G. (editor), 1986, *Groundwater and Wells* (second edition), Johnson Division, St. Paul, MN, 1089 pages (see specifically p. 1021).

[8] Bradbury, Kenneth R. and E.R. Rothschild, 1985, A computerized technique for estimating the hydraulic conductivity of aquifers from specific capacity data, Groundwater, Volume 23, Number 2, published by NGWA, Dublin, OH.

[9] Razack, M. and David Huntley, 1991, Assessing transmissivity from specific capacity in a large and heterogeneous alluvial aquifer, Groundwater, Volume 29, Number 6, published by NGWA, Dublin, OH.

[10] Huntley, David, R. Nommensen, and D. Steffey, 1992, The use of specific capacity to assess transmissivity in fractured-rock aquifers, Groundwater, Volume 30, Number 3, published by NGWA, Dublin, OH.

[11] American Geological Institute (AGI), 1987, *Glossary of Geology*, AGI, Alexandria, VA, 788 p.

[12] Weight, Willis D. and J.L. Sonderegger, 2001, Manual of Applied Field Hydrogeology, McGraw-Hill, New York, 608 p.

[13] Walton, William C, 1970, Groundwater Resources Evaluation, McGraw-Hill Book Company, New York, 664 p.

[14] Gabrysch, R.K., 1968, The relationship between specific capacity and aquifer transmissibility in the Houston area, Texas, Groundwater, Volume 6, Number 4, published by NGWA, Dublin, OH.

[15] Helweg, Otto J., V.H. Scott, and J.C. Scalmanini, 1984, *Improving Well and Pump Efficiency*, American Water Works Association, Denver, CO, 158 p.

Legislative Update

By Tim Parker, GRA Legislative Committee Chairman,
Chris Frahm and Rosanna Carvacho, GRA Legislative Advocates

As the Legislature returned in January for the first half of the 2015–16 Legislative Session, water is still a significant issue in the Capitol and across the state. Even though December brought higher than average rainfall, January brought record lows. Much more rain and snow is needed to bring the state's surface and groundwater levels back to pre-drought conditions, keeping water at the forefront for policy makers.

On April 29th, GRA's Legislative Committee will host the Annual Legislative Symposium, in partnership with the California Groundwater Coalition. With water being a major focus of the Legislature and the Administration this year, the Symposium will be an outstanding opportunity to present GRA's agenda.

Sustainable Groundwater Management Act

As was detailed in the winter 2014 Legislative Update, the Sustainable Groundwater Management Act (Act) was passed by the Legislature and signed by Governor Brown in September. On January 1, 2015, the Act went into effect, turning the primary focus to Act implementation.

Under the Act, the bulk of the implementation work during the first few years will occur at the Department of Water Resources (DWR). Specifically, the DWR must update Bulletin 118, including the ranking of basins or sub-basins as very low-, low-, medium-, or high-priority basins based on the current threat to each basin's integrity. The Act required that DWR establish the initial groundwater basin prioritization by January 31, 2015; DWR has done so, for now, by using the current CASGEM prioritization, available at http://www.water.ca.gov/groundwater/sgm/SGM_BasinPriority.cfm. DWR currently is compiling habitat and streamflow data for consideration in potential basin prioritization revisions. DWR is also responsible for adopting regulations covering potential revision of basin boundaries and evaluation and implementation of local groundwater sustainability plans.

Figure RES-01

2015-16 Proposition 1 (Water Bond) Expenditure Plan

(Dollars in Millions)

Bond Investment Category	Department	Program	Amount
Safe Drinking Water	State Water Resources Control Board	Wastewater Treatment Projects	$66.3
	State Water Resources Control Board	Safe Drinking Water in Small Disadvantaged Communities	$69.2
Watershed Protection and Restoration	State Conservancies	Watershed Projects	$83.5
	Wildlife Conservation Board	Enhanced Stream Flow Projects	$38.9
	Santa Monica and San Gabriel Conservancies	Urban Rivers and Creeks	$19.1
	Department of Fish and Wildlife	Watershed Restoration Projects (Non-Delta and In-Delta)	$36.5
Regional Water Reliability	Department of Water Resources	Integrated Regional Water Management Program	$32.8
	Department of Water Resources	Water Conservation	$23.2
	State Water Resources Control Board	Stormwater Management	$0.6
Water Storage	Department of Water Resources	Statewide Water System Operational Improvement	$3.3
Water Recycling	Department of Water Resources	Water Recycling and Desalination	$5.5
	State Water Resources Control Board	Water Recycling and Treatment Technology Projects	$131.7
Groundwater Sustainability	Department of Water Resources	Groundwater Management Planning	$21.3
	State Water Resources Control Board	Groundwater Contamination	$0.6
Total			$532.5

A complete summary of the Governor's proposed 2015–16 Budget proposal is available here.

GRA has already had meetings with the DWR and State Board staff responsible for Act implementation and will continue to stay engaged with them throughout this process.

Additionally, even though the Act is now law, there will likely be proposals to change the Act's provisions both by proponents and opponents of the original measure. GRA will monitor any new legislation introduced that attempts to modify the Act in order to help maintain the integrity of the Act.

The Governor's 2015–16 proposed budget includes $6 million from the General Fund for the DWR to provide additional technical assistance to local agencies on the development of groundwater sustainability plans. Uses of these funds include the proposed addition of five staff, and implementation of specific requirements of the Act, such as the adoption of basin boundaries and best groundwater protection practices.

Continued on the following page…

Legislative Update – *Continued*

Water Bond

AB 1471 (Rendon), after being passed by both houses and signed by Governor Brown in August, went on the November 2014 ballot as Proposition 1. Proposition 1 was passed by the voters with 67.1% voting in favor of the measure.

The Governor, in his 2015–16 budget, outlines a Proposition 1 expenditure plan that allocates a total of $532.5 million to different state departments, with a 5 percent administrative cost cap included for Proposition 1 Bond funds. On page 16 is a chart that outlines the Governor's proposed expenditures. Given all the work that GRA has done to elevate the issue of groundwater management and contamination, it is nice to see that the Governor included a separate section on groundwater sustainability, allocating money to DWR for Groundwater Management Planning and to the State Board for groundwater cleanup.

Changes in the Legislature

The statewide general election in November resulted in 27 new Assembly members and 12 Senators. The new Legislators for the 2015–16 Legislative Session were sworn in on December 1, 2014.

A special election was held on December 9, 2014 to elect a replacement for the 35th Senate District created by the resignation of Senator Rodrick Wright. Former Assembly member Isadore Hall, III won the election, and was sworn in on December 10, 2014.

There are currently three vacant Senate Districts (the 7th, 21st, and 37th) created by the election of the Legislators to Congress. The special primary election for these three districts will be held on March 17, 2015 and the special general election on May 19, 2015.

With the start of a new Legislative Session comes new committee Chairs and committee assignments in both houses; those most relevant to GRA are outlined below.

Senate President pro Tem Kevin DeLeón appointed Senator Ricardo Lara as Chair of the Appropriations Committee, Senator Bob Wieckowski as Chair of the Environmental Quality Committee, and reappointed Senator Fran Pavley as Chair of the Natural Resources and Water Committee.

Assembly Speaker Toni Atkins appointed Assemblymember Jimmy Gomez as Chair of the Appropriations Committee, Assemblymember Das Williams as Chair of the Natural Resources Committee, Assemblymember Marc Levine as Chair of the Water, Parks and Wildlife Committee and reappointed Assemblymember Luis Alejo as Chair of the Environmental Safety and Toxic Materials Committee.

Appointments

On January 2, 2015, Governor Brown reappointed Felicia Marcus as a member and Chair of the State Water Resources Control Board where she has served since 2012. This reappointment will require Senate confirmation.

Looking Ahead

Groundwater and water in general in California will continue to be important topics over the next two-year Legislative session. With the enactment of the Sustainable Groundwater Management Act (SGMA) and the passage of the Water Bond, water is and will continue to be at the forefront of California policy discussions. Additional legislation emerging or expected to emerge includes ministerial fixes to SGMA, streamlined adjudication, and SB20 to make well logs publicly available. As things take shape, we will continue to keep GRA members apprised of the evolving political and policy landscape in Sacramento.

SAVE THE DATE
April 29, 2015

2015 Annual Legislative Symposium

Find out why the new groundwater legislation and water bond are important to you—and what's next!

The Federal Corner

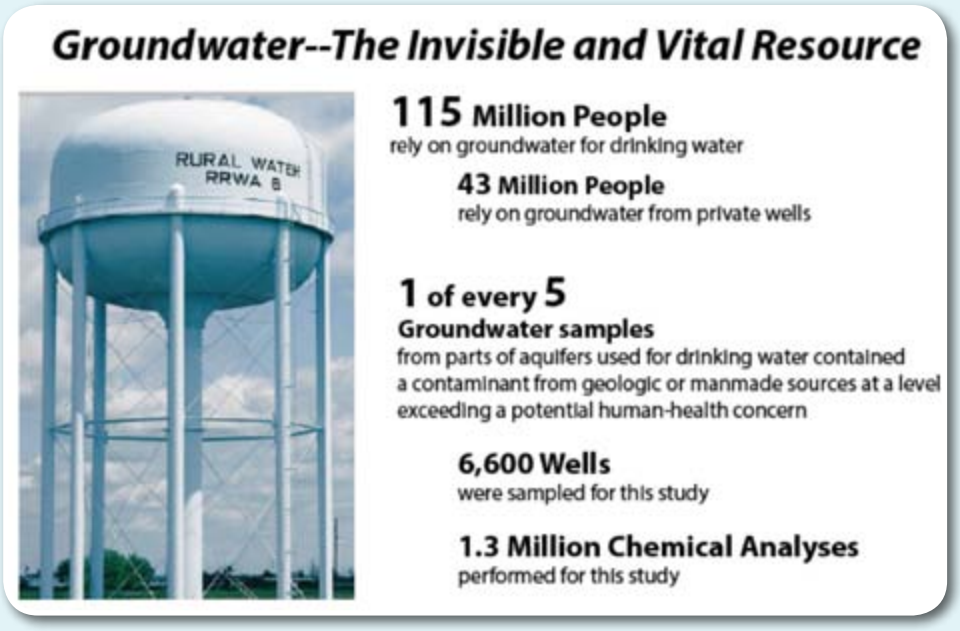
By Jamie Marincola, U.S. EPA

USGS Posts Report on the Quality of the Nation's Groundwater

The USGS found that more than one in five groundwater samples across the country contained at least one contaminant at a concentration of potential concern for human health, with contaminants from geologic sources accounting for about 80 percent of the exceedances of health-based standards. Regional results of the Southwest Principal Aquifers found that contamination in one of every three drinking-water wells could be a human-health concern and that geologically-introduced arsenic and uranium were of particular concern. The southwest report also indicated that dissolved-solids concentrations in groundwater are increasing in certain areas and that artificial recharge and groundwater withdrawals are moving contaminants to deeper parts of basin-fill aquifers. For the national report, please visit: http://www.usgs.gov/blogs/features/usgs_top_story/the-quality-of-the-nations-groundwater/.

EPA Publishes Microbial Risk Assessment Framework for Waterborne Pathogens

EPA has published the document, *Microbial Risk Assessment Tools, Methods, and Approaches for Water Media*, to assist risk assessors and scientists in the development of rigorous and scientifically defensible risk assessments for waterborne pathogens. The document describes a human health risk assessment framework for microbial hazards in water media that is compatible with other existing risk assessment frameworks for human health and chemical hazards. Risk assessment is a science-based tool and is used to help managers explore the relative merits of various management alternatives, identify important gaps in knowledge, and inform regulatory actions. Learn more at: http://water.epa.gov/scitech/swguidance/standards/criteria/health/microbial/index.cfm.



From USGS national summary report of the quality of the nation's groundwater.

Natural Breakdown of Petroleum Underground Can Lace Arsenic into Groundwater

In a long-term field study, USGS and Virginia Tech scientists have found that changes in geochemistry from the natural breakdown of petroleum hydrocarbons underground can promote the chemical release (mobilization) of naturally occurring arsenic into groundwater. This geochemical change can result in potentially significant arsenic groundwater contamination. The findings were based on a 32-year collaborative effort between government, academic, and industry-supported scientists studying the natural attenuation of a 1979 petroleum spill near Bemidji, Minnesota. The scientists attributed the elevated arsenic in the hydrocarbon plume to a series of interrelated geochemical and biochemical processes that involve arsenic and iron oxides and the metabolization of carbon-rich petroleum by microbes in anoxic (low oxygen) conditions. For more information, visit: http://www.usgs.gov/newsroom/article.asp?ID=4110.

EPA, States and Automotive Industry to Reduce Copper in Motor Vehicle Brake Pads

EPA, the automotive industry and the states signed an agreement to reduce the use of copper and other materials in motor vehicle brake pads. The Copper-Free Brake Initiative calls for cutting copper in brake pads to less than 5 percent by 2021 and 0.5 percent by 2025. This voluntary initiative also calls for cutting the amount of mercury, lead, cadmium, asbestiform fibers and chromium-6 salts in motor vehicle brake pads. These steps will decrease runoff of these materials from roads into the nation's streams, rivers and lakes, where these materials can harm fish, amphibians and plants. Read more: http://water.epa.gov/polwaste/npdes/stormwater/copperfreebrakes.cfm.

Arsenic: The Cure

By Bart Simmons

Paracelsus (1493-1541) has been credited with the saying: "The Dose Makes the Poison." Apparently, Paracelsus never wrote that, but what he did write was (translated from German): "All things are poison and nothing is without poison, only the dose permits something not to be poisonous." Arsenic is proving to be a prominent example of that principle. For millennia, arsenic has been used as a poison of choice for offing one's enemies. In addition to its acute toxic effects, chronic exposure to arsenic, as in drinking water, can lead to skin pigmentation, thickening of the skin on the foot, and a variety of cancers. Alan Smith and his collaborators at the U.C. Berkeley School of Public Health have documented extensive incidence of arsenic-caused cancers in exposed populations in Asia and South America.

As part of one study on people from South America, The Berkeley Group documented a significant *decrease* in deaths due to breast cancer in women with high arsenic consumption. And as arsenic exposures varied, so did the breast cancer. The higher the arsenic concentration in drinking water, the lower the breast cancer incidence.

The result is not without precedent. Arsenic trioxide (trade name Trisenox®) is already used as a drug for the treatment of acute promyelocytic leukemia (APL). The Berkeley Group is urging the clinical study of arsenic for the treatment of advanced breast cancer.

The regulation of arsenic in drinking water has a tortured history in the U.S. The Clinton Administration had proposed lowering the Maximum Contaminant Level (MCL) to 1 µg/L (ppb). The George W. Bush administration put the rule on hold, but ultimately yielded to the question: "Do you want **more** or **less** arsenic in your drinking water?" The public perception of arsenic as a toxin was a key force in the policy reversal. The findings on arsenic and breast cancer create a paradox: how do we regulate arsenic in drinking water if it increases the risk of some cancers, and *decreases* the risk of other cancers? How should risk assessment methods address a substance which is both a carcinogen and an anti-carcinogen?

If arsenic is proven to be safe and effective for the treatment of breast cancer, this may add another valuable weapon to the arsenal for cancer treatment.

Epidemiology can be a powerful tool for understanding causes of disease. Time and time again, research findings can challenge the conventional wisdom about environmental pollutants.

Bart can be reached at bartonps@aol.com.

One Alternate Exposure Pathway of VOC Vapors from Contaminated Subsurface Environments into Indoor Air – Legacy Sewer-Plumbing Systems

By James A. Jacobs, Olivia P. Jacobs, and Kelly G. Pennell

Abstract

Sewer-plumbing systems, land drains and subsurface utility conduits/lines/trenches are alternate exposure pathways for volatile organic compounds (VOCs) in the shallow subsurface to migrate into indoor air. Sewers which are well past their design life, or legacy sewers, allow for leakage into and out of the pipes. Legacy sewers that intercept VOC-contaminated groundwater or vapor likely contain VOCs in the sewer air. This article highlights an often overlooked implication of legacy sewers and their interception of VOC plumes—the potential for VOC-impacted sewer air to enter indoor air spaces.

Introduction

Sewer systems were designed to deliver residential, commercial, and industrial liquid wastes to treatment plants without loss of wastes in transit. Sewer-plumbing systems inside buildings were designed to properly vent sewer gases, preventing their entry into inhabited indoor space. Several decades, or even centuries, after the installation of sewer collection systems under the streets and the construction of vented plumbing in buildings, many components of sewer systems develop leaks, and some vapor seals designed to protect against sewer air intrusion into structures become compromised (pipes crack, fittings loosen, wax seals degrade and crack, and P-traps dry out). When compromised sewer and plumbing systems intercept contaminated groundwater plumes, indoor air becomes directly connected to sewer air that can contain VOCs.

Nationwide, legacy sewer lines are unintended conveyance systems for VOCs in sewer air. VOC-impacted groundwater (and vapor in the vadose zone) infiltrates leaky sewer trunk lines and laterals. The VOCs volatilize from the sewer/groundwater liquids into sewer air, which allows for migration throughout the sewer system, and into indoor air through failed vapor seals in plumbing systems.

This paper presents (1) currently used vapor intrusion conceptual models, (2) leakage and pipe damage as documented in a northern California sewage conveyance system, (3) two case studies demonstrating the presence of VOCs in indoor air resulting from the intersection of breached sewer systems with failed plumbing seals and PCE plumes, and (4) recommendations.

Indoor Air Quality Studies

There are many sources of indoor air pollution, but one that has captured the attention of regulators and managers of hazardous waste sites is the transport of subsurface vapors into indoor air spaces (i.e. vapor intrusion). U.S. EPA (2002) developed a series of models for estimating indoor-air concentrations of VOCs and the associated health risks from subsurface vapor intrusion into buildings. These vapor intrusion models were based on the analytical solutions of Johnson and Ettinger (1991) for contaminant partitioning and subsurface vapor transport into buildings. Figure 1 shows a common site conceptual model for VOC vapor intrusion, based on US EPA (2002) and modified by others. Since that time, several revisions to the vapor intrusion models have been made and a series of new models have been developed.

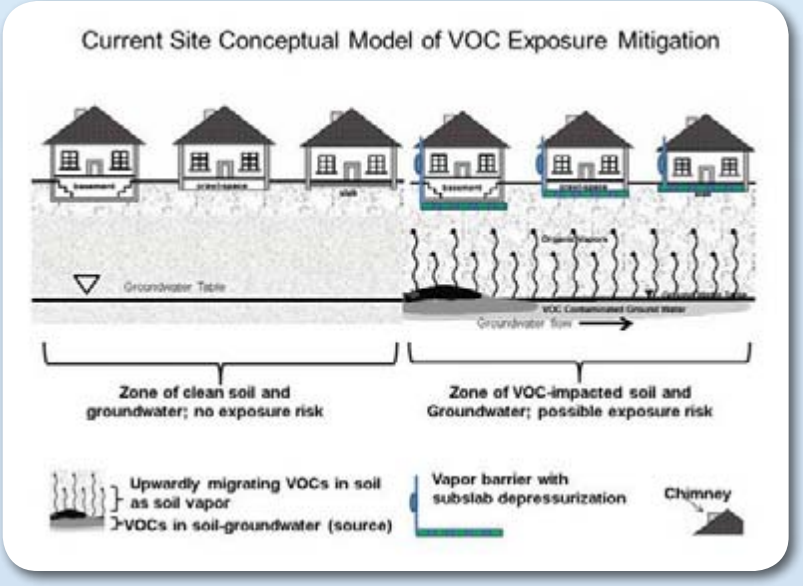


Figure 1: A common site conceptual VOC vapor intrusion model (modified after others; original from US EPA, 2002).

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One Alternate Exposure Pathway of VOC Vapors from Contaminated Subsurface Environments into Indoor Air – *Continued*

After nearly two decades of indoor-air monitoring in structures above contaminant plumes, practitioners have developed a term, "alternate exposure pathways," to address contaminated vapor intrusion into indoor air from sources other than underlying groundwater plumes. Many regulatory documents reference trench backfill containing piping conduits as a potential pathway for contaminated vapor exposure, but few, if any, discuss the implications for the piping conduits (pipe interiors) themselves to serve as vapor exposure pathways. The current term alternate exposure pathways commonly refers to trenching and piping for sewer-plumbing systems, land drains, storm drains, abandoned pipelines, cable ducts, steam lines, utility lines, other pipes and other conduits. When these alternative exposure pathways enter, or are proximal to, structures, they may serve as unintended conveyance systems for VOCs. A land drain beneath a research house in northern Utah owned by Arizona State University was documented to be a VOC conduit for detected indoor air impacts (Johnson, 2014). Field investigations at Hill Air Force Base have shown some indoor air contamination to be the result of the connectivity of contaminated sewer air to indoor air (Gorder and Dettenmaier, 2011). Two other studies (Pennell et al., 2013; and Riis et al., 2010) documented tetrachloroethene (PCE) in sewer gas as an important source of indoor air contamination at two vapor intrusion study sites.

Based on these reports of sewer-plumbing systems as alternate pathways, an updated conceptual model to guide vapor intrusion studies is needed. Some of the combinations of factors related to plume location, vapor seal integrity, and possible VOC exposure in indoor air are shown in Figure 2. Not all permutations of foundation, subsurface depressurization system (SSD) and sewer configuration are shown. The rationale for this updated conceptual model is provided below.

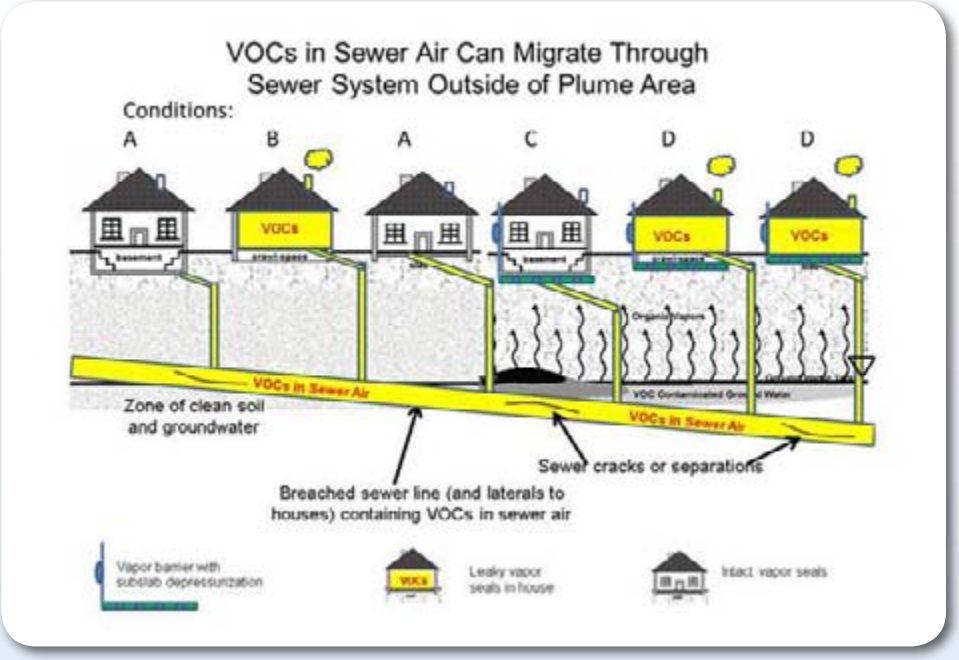

Figure 2: An example of an alternate exposure pathway model showing sewer gases and VOCs entering indoor air through ineffective plumbing vapor seals. Note: VOCs are released to the indoor air and through the vent line on roof. VOC data (Riis et al., 2010; Pennell et al., 2013) support this alternate VOC exposure pathway into indoor air. Conditions in the houses reflect exposure pathways. A) Intact vapor seals and not over VOC plume (exposure pathway not completed); B) Leaky vapor seals and not over VOC plume (exposure pathway completed); C) Intact vapor seals and working SSD over VOC plume (exposure pathway not completed); D) Leaking vapor seals and working SSDs over VOC plume (exposure pathway completed)

Note that in Figure 2, the SSD protects buildings overlying VOC-contaminated groundwater plumes from VOCs rising through the vadose zone into indoor air. SSDs cannot protect indoor air quality in buildings where VOCs in sewer air leak into indoor air through failed plumbing seals.

Legacy Sewers, Mains, Laterals and Plumbing Systems meet VOC plumes

There are hundreds of thousands of shallow VOC groundwater plumes in urban areas in North America. Urban sewer systems installed 50–100 years ago are well past their design life. These legacy sewers develop cracks, separations and other damage over time associated with earth subsidence, corrosive substances, pipe settling, biological intrusion and pipe material failure. Video camera inspections of sewers show that breaches are common in or between concrete, clay or transite pipes, and from corrosion in cast iron pipes. Tree and plant roots grow into the sewer system and commonly damage sewer pipe integrity. Pipe connections, junctions, manholes, etc., likewise develop structural damage resulting in both leaks of sewage from the pipes/structures and inflow of groundwater and vapors (Jacobs et al., 2014).

Legacy sewer system pipes experience a baseline of infiltration and inflow (I&I)

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One Alternate Exposure Pathway of VOC Vapors from Contaminated Subsurface Environments into Indoor Air – *Continued*

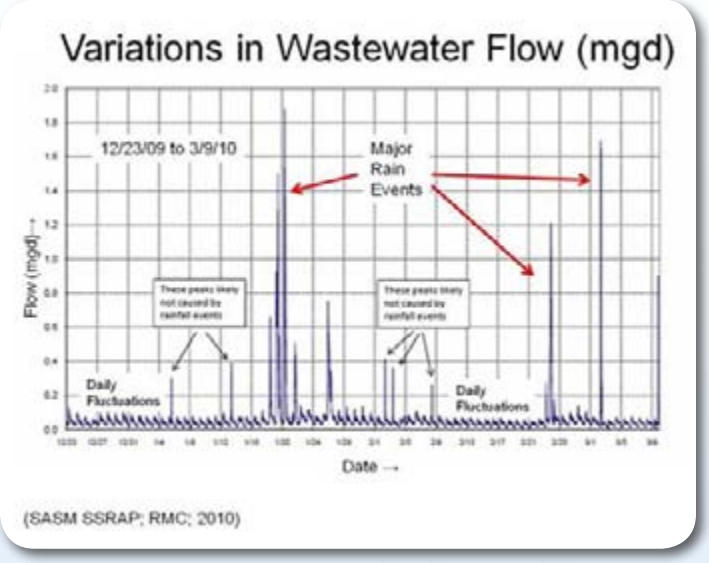

Figure 3: Variations in wastewater flow within a sewer pipeline (modified after SASM, 2010).

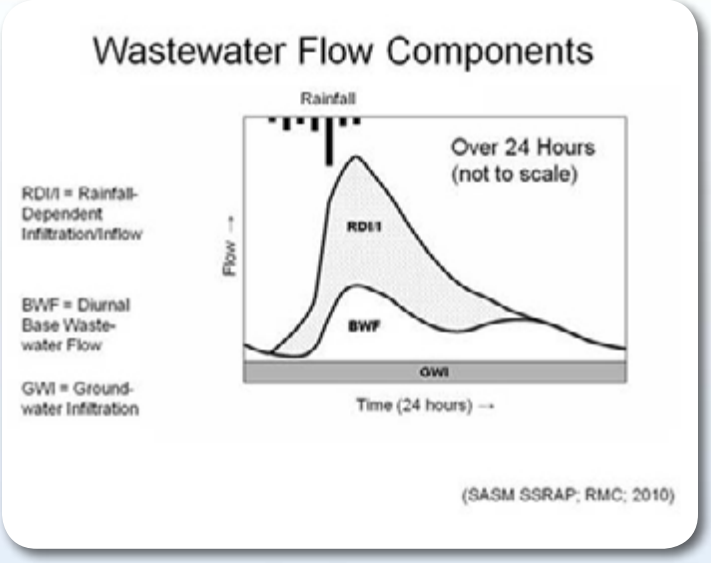

Figure 4: Conceptual diagram showing wastewater flow components (modified after SASM, 2010).

of groundwater throughout the year, but experience significant increases in groundwater I&I during the rainy season (Figure 3). I&I within a wastewater pipeline system in northern California was shown to contribute 8 to 33 times the amount of daily sewer flow shortly after a strong storm (SASM, 2010). This wastewater system, including the trunk lines and sewer laterals, was originally installed 6 or more decades ago. Figure 4 is a conceptualized diagram showing the wastewater flow components of rainfall-dependent infiltration/inflow (RDI/I) into sewer pipes, and illustrates the lag between the timing of rainfall and its infiltration into the sewer pipes. Unlike storm-induced increases in wastewater flow, diurnal base wastewater flow (BWF) shows increases only during early-morning and dinner through evening hours. During dry weather, groundwater infiltration (GWI) into sewer pipes is relatively constant during the day in an area with no tidal influences. I&I leakage in sewer sections in northern California is frequently confirmed using smoke testing, flow meters and video inspections. These inspections consistently indicate that breaches of unpressurized sewer lines are common, and that failed sewer lines provide opportunities for vapors and groundwater to enter and exit the sewer system.

Leakage into and out of the sewer system (from the inside drain to the wastewater plant) is not limited to subsurface fixtures. Within buildings, examples of ineffective vapor seals in plumbing systems include dry P-traps, breached toilet wax rings, cracked pipes, loose pipe fittings and gaskets, improper repairs or additions, and settlement. Examples of vapor leak locations (Figure 5), a close-up of a P-trap (Figure 6) and the migration pathway of sewer gas and VOCs into indoor air (Figure 7) illustrate how VOCs in sewer air can migrate into indoor air.

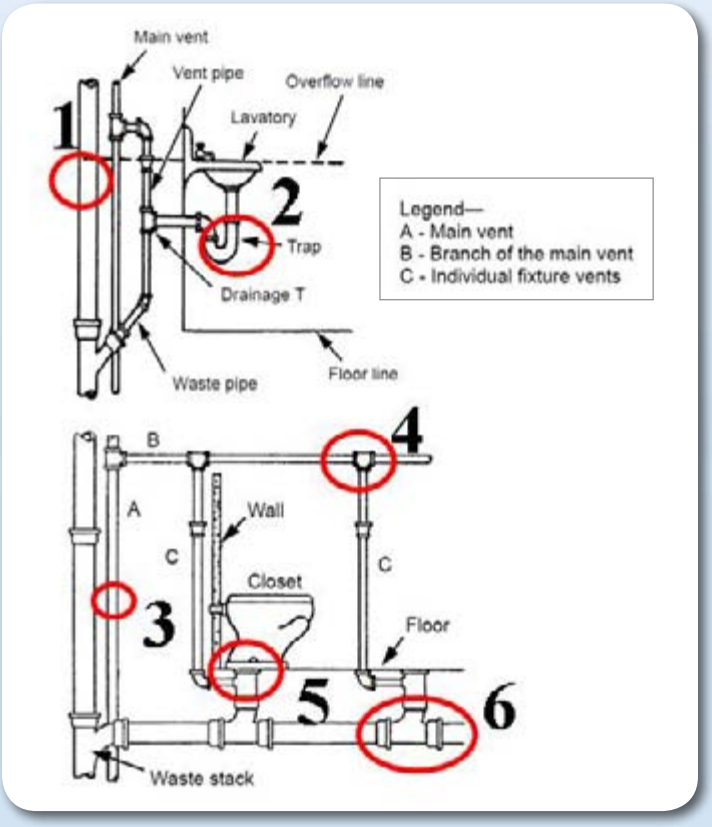

Figure 5: Examples of vapor leak locations (modified after U.S. Department of the Army, 2001). 1) Cracked waste stack; 2) Dry P-trap; 3) Cracked main vent; 4) Loose fittings; 5) Faulty wax ring seal; 6) Leaking joints

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One Alternate Exposure Pathway of VOC Vapors from Contaminated Subsurface Environments into Indoor Air – *Continued*

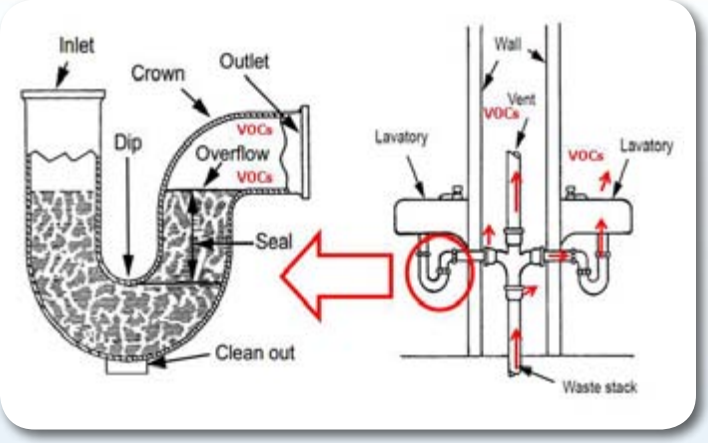

Figure 6: Anatomy of a P-trap vapor seal in cross-section. Water in P-trap seals VOCs from entering indoor air. If water evaporates, or is siphoned to below the upper part of the trap dip, sewer air can be released into indoor air. (Modified after U.S. Department of the Army, 2001).

Breached Sewer Lines Intersecting Subsurface VOC Plumes

When breached sewer collection pipes intersect VOC-contaminated soil and groundwater, water and vapor containing VOCs infiltrate the breached sewer pipes. While VOC-containing fluids flow downgradient in the sewer pipes toward the wastewater treatment plant, the VOCs contained in the groundwater, pipe debris/solids and soil vapor have an opportunity to volatilize into the sewer air. Once in the sewer air, the contaminants can migrate within the connected sewer pipes independently from the liquid waste stream. Sewer air movement is dependent on a number of variables, but VOCs in vapor form are not exclusively gravity-driven, and could exit the sewer at any point where the sewer or plumbing is not vapor tight.

Sewer Air Considered with Respect to Indoor Air Quality Investigations

Indoor air quality degradation caused by vapor intrusion of VOCs into structures has been a health concern investigated by US EPA and other agencies for decades. However, public sewer and private plumbing systems have not been evaluated systematically for their role as vapor conduits in the standard site conceptual models for indoor air quality developed by US EPA (2002) and others.

Recent PCE-specific vapor intrusion studies in Denmark and Boston document PCE indoor air concentrations resulting from failed plumbing-sewer systems that intersect mapped PCE groundwater plumes (Riis et al., 2010; Pennell et al., 2013). In both studies, iterative testing of indoor air (after PCE was detected indoors) led to direct sewer-air testing. The findings established that the sewer air contained PCE and that the sewer intersected a PCE groundwater plume. The sampling also established that the sewer air was contributory to the presence of VOCs in the indoor air. In both cases, the concentrations of PCE detected inside the buildings were orders of magnitude higher than levels generally considered safe for long-term indoor air exposure.

In the Denmark study (Riis et al., 2010), PCE was reported in the cabinet under a kitchen sink at levels as high as 810 µg/m³. In the Boston study, the concentration of PCE detected in bathroom air was 37 µg/m³. A faulty plumbing connection to the toilet was presumed to be the source of PCE. The concentration of PCE detected in the sewer gas (sampled directly from the sewer pipe connected to the toilet) was 58 µg/m³. When the toilet connection was sealed, the PCE concentration in the bathroom air decreased to 2.6 µg/m³. It was documented in the Boston case that variability of VOC concentrations in sewer air between sampling events depended on many factors, including the integrity of the sewer seals.

Regulatory Levels

The concentrations of PCE measured at these two sites, compared to the Massachusetts Department of Environmental Protection (MassDEP) threshold (risk) value of 1.4 µg/m³, were 1 to 2 orders of magnitude higher. The California Department of Toxic Substances Control's (DTSC) Human and Ecological Risk (HERO) recommended values for residential air screening for PCE, calculated using the Regional Screening Level (RSL)

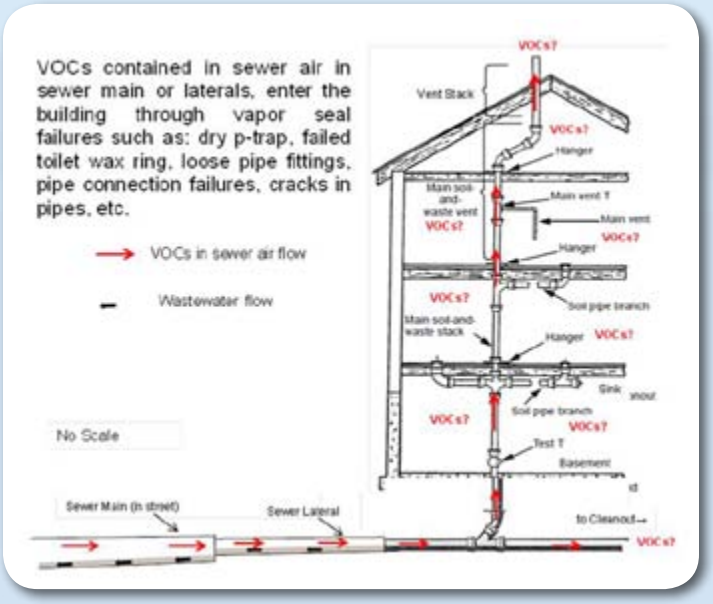

Figure 7: Migration pathway of sewer gas and VOCs into indoor air (modified after U.S. Department of the Army, 2001).

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One Alternate Exposure Pathway of VOC Vapors from Contaminated Subsurface Environments into Indoor Air – *Continued*

calculator, are 0.41 µg/m³ for cancer risk and 37 µg/m³ for non-cancer risk (DTSC, 2010). The San Francisco Bay Regional Water Quality Control Board's (RWQCB, 2013) Environmental Screening Level (ESL) for PCE in residential indoor air is 0.41 µg/m³.

The levels of PCE detected in indoor air (Riis et al., 2010; Pennell et al., 2013) are small compared to those immediately dangerous to life and health (IDLH) for an instantaneous exposure of PCE. However, exposure to a low-concentration carcinogen (such as PCE and other VOCs) over a long period of time is a clear health risk; the hypothesis of sewer air exposure should be tested to document the incidence of VOC exposure through vapor seal failures (see Figure 7) and to minimize the VOC exposure to unsuspecting occupants.

Recommendations

Alternate vapor exposure pathways should be considered in environmental indoor air assessments. The scientific and regulatory community needs to update vapor intrusion models and consider alternate exposure pathways in health risk evaluations and regulatory decision making. To establish the risk of exposure of individual building inhabitants to VOCs, we recommend screening (PID and sorbent tubes), or laboratory testing (passive sorbents and air samples) of nearby sewer manholes and building sewer system cleanouts or vent stacks. Further evaluation of inside vapor seals and plumbing connections can be performed using smoke testing.

To clear high VOCs in sewer pipe air, active venting in manholes has been shown effective. The remedy for the vapor seal failure may be as simple as filling a dry P-trap with water or replacing toilet wax seals. For leaking underground sewer system repair, the capital costs, including leak inspection and testing, pipe engineering design, and installation is millions of dollars for municipalities or sewer agencies. Ultimately, the breached pipe network should be fixed in order to prevent VOC intrusions into indoor air.

Nationwide, U.S. EPA's focus on I&I issues of sewer systems has been as a major source of sewer overflows of untreated wastes onto land and into water bodies. Prioritizing sewer replacement projects in areas where known shallow VOC groundwater plumes co-exist with breached sewer systems would decrease the potential for VOCs to enter sewer air and reduce the risk of indoor air exposure.

More research is needed into assessment and mitigation methods to address the presence of VOCs in sewer-plumbing systems and their migration into indoor air.

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An Introduction to Hydraulic Fracturing of Petroleum Reservoirs in California

By GRA's Technical Committee

Introduction

Protecting and improving California's groundwater is GRA's mission. As an organization, GRA has strived to highlight the importance of proper groundwater management. Hydraulic fracturing in oil and gas production (also known as fracking) has increased in practice during the last several years and is often controversial. GRA is therefore making efforts to educate the public and professionals, support regulators, and promote dialogue on the ramifications of this petroleum reservoir stimulation practice. GRA submitted a letter on May 15, 2013 to the California Department of Conservation Division of Oil, Gas, and Geothermal Resources (DOGGR) regarding their pre-rulemaking discussion draft regulations on hydraulic fracturing. Additionally, both GRA and the Association of California Water Agencies (ACWA) jointly submitted a letter on January 14, 2014 to DOGGR on proposed regulations. GRA is also hosting a series of GRACasts on hydraulic fracturing and on February 18–19, 2015 co-hosted, with the Los Angeles Basins Geological Society, a symposium called *Oil, Gas, and Groundwater in California* (see page 1 of this issue). The purpose of this article is to provide useful information and a set of recommended references for those who want to delve deeper into the practice of hydraulic fracturing used for oil and gas production in California.

Definitions

Senate Bill 4 (SB4) (Section 3157) defines "**well stimulation treatment**" as any treatment designed to enhance oil and gas production or recovery by increasing the permeability of the formation. Well stimulation treatments include, but are not limited to, **hydraulic fracturing and acid well stimulation;** they do not include steam flooding, water flooding, cyclic steaming, routine well cleanout work, other well maintenance, or routine removal of formation damage caused by drilling. Hydraulic fracturing includes the pressurized injection of hydraulic fracturing fluid into the formation with the intent to fracture the formation. Acid well stimulation treatments may be applied at any pressure, and may be used in combination with hydraulic fracturing; however the applied pressures are lower than the pressure necessary to fracture the formation.

Historically, hydraulic fracturing was a method of enhancing extraction of oil and gas with a vertical well tapping a single fracture or multiple fractures created by the injection of relatively low volumes of high-viscosity fluid. A more recent method, called *super fracking* by some (Turcotte, Moores and Rundle, 2014), often generates higher production rates by using horizontal drilling within the target zone, and taps multiple fractures created by the injection of large volumes of low-viscosity fluid. For both methods the fluids are principally water and additives (guar gum, potassium chloride and many other chemicals), including proppants, typically silica sand, to hold fractures open (Council of Canadian Academies, 2014). Liquids used in the hydraulic fracturing process are defined below, as paraphrased from Brent Alpach (AWWA, 2014):

- Hydraulic fracturing water – water used to make-up the majority of the fracturing fluid
- Hydraulic fracturing fluid – liquid injected into the subsurface through the well to increase fracture permeability in oil/gas production zones, typically a mixture of the hydraulic fracturing water, proppants, and chemical additives
- Formation water – water naturally present in the petroleum formation that sometimes returns to the surface through the well
- Flowback water – the hydraulic fracturing fluid that returns to the surface through the well after the completion of hydraulic fracturing
- Produced water – the combination of flowback water and formation water that returns to the surface through the well, often with the produced oil and gas.

Differences between California's Monterey Shale Formation and several other somewhat comparable Oil/Gas Producing Shale Formations in other states

California's Miocene Monterey Formation was formed in a complex depositional environment associated with an active tectonic plate margin. The depositional environment created thick sequences of marine sediments consisting of multiple lithofacies of siliceous, phosphatic, organic, and clay-rich shales along with mudstones, dolomites, and turbidite sandstones. The active plate margin caused subsidence of the sedimentary basins, and created highly folded and faulted rocks along with structural traps for migrating petroleum. Most of the oil produced in California is from reservoirs associated with structural traps overlying the Monterey source rocks, and not from the Monterey Formation shales themselves.

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An Introduction to Hydraulic Fracturing of Petroleum Reservoirs in California – *Continued*

The Bakken and Eagle Ford shale plays in North Dakota/Montana and Texas, respectively, are considered analogous to the Monterey shale play because they are similar in terms of total organic content, depth, porosity, and permeability. However, there are significant differences in depositional age, extent of natural fracturing, thickness, number of lithofacies, tectonic activity, and structural folding (California Council of Science and Technology, 2014). For example, the Monterey Formation was deposited in the Miocene, the Bakken in the Devonian/Mississippian and Eagle Ford in the late Cretaceous. The younger Monterey Formation generally has much higher natural permeability than the older Bakken and Eagle Ford Formations. These differences affect the type of well stimulation processes appropriate for economic recovery.

In California, oil is produced using conventional drilling, where vertical wells intersect structural or stratigraphic traps containing oil. This is different from practices used for unconventional shale reservoirs, such as the Bakken and Eagle Ford Formations, where the oil production occurs primarily from horizontal wells drilled within thin, and laterally extensive, low-permeability (tight) shale formations. Well stimulation in vertical wells typically requires only low-volume, low-pressure processes, as compared with the higher volume and pressure processes required for horizontal wells to economically recover product. The Monterey Formation is also more permeable due to natural fractures in the shale, which is not conducive to high-volume, high-pressure hydraulic fracturing. The differences between the Monterey Formation and key unconventional shale plays are summarized in Table 1.

The organic-rich phosphatic shales found within the Middle Monterey may be the most promising source rocks for hydraulic fracturing (and a possible unconventional shale target). Hydraulic fracturing has been attempted in the Monterey Formation; however, the results have not been promising. More exploration is needed to know how much oil has been retained in the Monterey source rock, or if the oil has largely migrated away. Also, it is unlikely the entire source rock will be productive, given the extreme heterogeneity in the Monterey Formation (CCST, 2014).

Regulatory Overview

Introduced on December 3, 2012, and signed into law by California Governor Jerry Brown on September 20, 2013, Senate Bill (SB) 4, sponsored by Fran Pavley (D – Agoura Hills), is the first California statute specifically regulating hydraulic fracturing in oil and gas reservoirs. Recent technological advances (such as advances in directional drilling) have made hydraulic fracturing for oil and gas more common and lucrative. Since about 2007, facilitated partly by the hydraulic-fracturing boom, production of oil and gas in the U.S. has increased more than five-fold and four-fold, respectively.

Upon learning of a gap in regulatory oversight in 2011, the California Legislature proposed numerous bills related to hydraulic fracturing. In the 2012–2013 legislative session, proposed legislation ranged from mandating drilling regulations more stringent than those proposed by DOGGR to a full moratorium on hydraulic fracturing in California. However, of the introduced bills, only SB 4 survived and became law, effective on January 1, 2014.

On December 19, 2013, DOGGR released "interim well stimulation regulations," which became effective on January 1, 2014. DOGGR revised these interim regulations on June 27, 2014 and the final regulations were approved by the Office of Administrative Law on December 30, 2014. The final regulations are scheduled to go into effect on July 1, 2015.

The final well stimulation regulations include the following requirements:

- Well maintenance and cleanout history report
- A permit for hydraulic fracturing must be obtained from DOGGR, and must include plans for water management, spill contingency, and waste disposal
- Well casing must be sufficiently cemented and mechanical integrity testing must be conducted
- Adjacent properties owners and tenants must be notified prior to hydraulic fracking
- Surface property owners identified may request water testing from property wells or surface water
- Well stimulation treatment area analysis and design
- Monitoring and evaluation of seismic activity in the vicinity of hydraulic fracturing
- Proper storage and handling of well stimulation treatment fluids and wastes
- Pressure testing and cement evaluation prior to well stimulation treatment
- A monitoring program must be implemented
- Well monitoring after well stimulation treatment
- Public disclosures
- A post-well-stimulation-treatment report must be generated.

A narrative description of the final well stimulation regulations prepared by DOGGR can be obtained here.

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An Introduction to Hydraulic Fracturing of Petroleum Reservoirs in California – *Continued*

SB 4 also requires that DOGGR complete an environmental impact report (EIR) pursuant to the California Environmental Quality Act by July 1, 2015, and that DOGGR's EIR must not conflict with EIRs conducted by other agencies that are certified on or before July 1, 2015. This provision has prompted some local governments, such as Kern County, to attempt completion of local EIRs before DOGGR's statewide EIR is finalized. The EIR for DOGGR is being developed by Aspen Environmental Group. The public review period for this Draft EIR began on January 14, 2015 and will end on March 16, 2015, the deadline for written comments. During the comment period, DOGGR will hold six public comment meetings throughout the state to receive verbal and written comments on the Draft EIR. To access the Draft EIR and detailed information on how to provide comments, please see the Department of Conservation's webpage.

Also, SB 4 requires the Secretary of California's Natural Resources Agency (which includes DOGGR) to complete an independent scientific study on well stimulation treatments, including, but not limited to, hydraulic fracturing and acid well stimulation treatments. The risks and hazards explicitly included for the study are: potential greenhouse gas emissions, water contamination, noise pollution, induced seismicity, and impacts on wildlife habitats. The first volume of the scientific study was released on January 14, 2015; the two remaining volumes are scheduled for release in July 2015. The study is being conducted by the California Council on Science and Technology and Lawrence Berkeley National Laboratory.

GRA's Technical Committee reviewed many documents; follow this link to Table 2, a list and descriptions of recommended documents with imbedded hyperlinks.

Conclusions

Hydraulic fracturing in oil and gas production has increased in the U.S., leading to lower energy prices and greater energy independence; however the new practice and the increase in oil and gas production has raised concerns related to impacts on the environment. To address these concerns, GRA and others have made an effort to summarize known information, provide guidance, and make recommendations. GRA's contributions thus far are through two comment letters, GRA-Casts, the recently held symposium on *Oil, Gas, and Groundwater in California* (see summary article on page 1 of this issue), and this white paper.

In summary, there are major differences between the Monterey Shale and other shale plays in the United States. California's unique geologic setting (based on tectonics and the sediment loading during the Miocene) allowed the formation of the Monterey Shale. Conventional oil production will continue to be used in the Monterey Shale; producing oil through the use of horizontal drilling and hydraulic fracturing, as done in the other major shale plays, has not yet been proven economically viable. California is also unique in its regulatory response to hydraulic fracturing, including enacting SB 4 and new regulations that require actions to prevent detrimental side effects and to improve documentation, transparency and notification.

Professionals in the petroleum and water resources industries recently accelerated the process of better explaining hydraulic fracturing and its effects on the environment through many recent publications and professional forums. GRA has made available to you in this white paper a list of recommended documents so that you can educate yourself. GRA is hopeful that future record keeping and results from monitoring, laboratory analyses and field studies will be shared to improve our understanding of what occurs during and after hydraulic fracturing, leading to a better dialogue on how to advance energy production while protecting our natural resources.

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Council of Canadian Academies. 2014. Environmental Impacts of Shale Gas Extraction in Canada: The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction. Ottawa, Ontario, Canada, 292 p.

Eagle Ford Shale.com

National Energy Technology Laboratory, Department of Energy. 2011. A Comparative Study of the Mississippian Barnett Shale, Fort Worth Basin, and Devonian Marcellus Shale, Appalachian Basin, 118 p.

Turcotte, D. L., Moores, E. M., and J. B. Rundle. 2014. Super "Fracking". Physics Today, v. 67, n. 8, p. 34 – 39.

GRA Requests Nominations for the 2015 "Lifetime Achievement" and "Kevin J. Neese" Awards

The purpose of the GRA Awards Program is to recognize noteworthy projects and exceptional individual contributions related to the understanding, protection, and management of groundwater resources. The objectives of the annual Awards Program are:

1. To provide recognition to individuals who have demonstrated leadership and continuous dedication in groundwater hydrology
2. To provide recognition for recent unique contributions to groundwater hydrology.

All nominations for the Lifetime Achievement and Kevin J. Neese Awards must be received by David W. Abbott (dabbottgw@gmail.com) or 607 Chetwood Street, Oakland, CA 94610-1433) no later than Friday, June 19, 2015.

Nominations should be completed using the nomination forms available on the GRA website at http://www.grac.org/awards.asp. Nominations should not exceed one page, identify the award for which the nomination is made, and include justification for the award based on the criteria listed below.

The GRA Awards will be presented to the recipients selected by the GRA Board of Directors during the 24th GRA Annual Meeting and 2015 Biennial Groundwater Conference in Sacramento, CA, October 2015.

Awards

Lifetime Achievement: presented to individuals for their exemplary contributions to the groundwater industry, and contributions that have been in the spirit of GRA's mission and organization objectives. Individuals that receive the Lifetime Achievement Award have dedicated their lives to the groundwater industry and have been pioneers in their field of expertise.

Previous Lifetime Achievement Award recipients include:

2014 – David Huntley, Ph.D.

2013 – Shlomo P. Neuman, Ph.D.

2012 – Anne J. Schneider*

2011 – Joseph C. Scalmanini

2010 – John A. Cherry, Ph.D.

2009 – T.N. Narasimhan, Ph.D.

2008 – Perry L. McCarty, Ph.D.

2007 – Herman Bouwer, Ph.D.

2006 – Glenn A. Brown

2005 – Luna P. Leopold, Ph.D.

2004 – John D. Bredehoeft, Ph.D.

2003 – Rita Schmidt Sudman

2002 – Thomas W. Dibblee

2001 – Carl J. Hauge

2000 – Joseph H. Birman, Ph.D.

1999 – David Keith Todd, Ph.D.

1998 – Eugene E. Luhdorff, Jr.

**posthumously*

Kevin J. Neese: recognizes a recent significant accomplishment by a person or entity that fosters the understanding, development, protection, or management of groundwater.

Previous Kevin J. Neese Award recipients include:

2014 – Governor Edmund "Jerry" G. Brown for his leadership in developing sustainable groundwater management legislation and shepherding it through the legislative process

2013 – Santa Clara Valley Water District for implementing its unique Domestic Well Testing Program

2012 – David L. Orth, General Manager of the Kings River Conservation District for his leadership and dedication to the collaborative initiatives to develop the Upper Kings River Basin Integrated Regional Water Management Plan

2011 – Sacramento County Environmental Management Department for its Abandoned Well program, the first of its kind in California

2010 – Senator Fran Pavley for leadership in the enactment of the comprehensive, statewide groundwater level monitoring legislation in California

2009 – U.S. Geological Survey, California Water Science Center for development of a new 3-dimensional groundwater-modeling tool for California's Central Valley and report "Groundwater Availability of the Central Valley Aquifer," Professional Paper 1766

2008 – Orange County Water District for its Groundwater Replenishment System, a new water purification plant

2007 – University of California Cooperative Extension Groundwater Hydrology Program for its efforts to engage scientists, regulators, farm advisors, dairy industry representatives, and dairy farmers to better understand the effects of dairy operations on water quality

2006 – Senator Sheila Kuehl for her work to improve the production and availability of information about California's groundwater resources

2004 – California Department of Water Resources for publication in 2003 of its updated Bulletin 118: "California's Groundwater"

2002 – Glenn County Water Advisory Committee for formulating a significant groundwater management ordinance that was adopted by the Glenn County Board of Supervisors

2001 – American River Basin Cooperating Agencies and Sacramento Groundwater Authority Partnership for fostering the understanding and development of a cooperative approach to regional planning, protection and management of groundwater

Continued on page 30…

2015 David K. Todd Distinguished Lecturer Series

The fifth year of GRA's David Keith Todd Distinguished Lecture Series is now underway! **Michelle Sneed** (northern California) and **Dr. John Izbicki** (southern California) will be delivering their lectures to GRA Branches and academic institutions throughout the spring. This Series furthers a key GRA objective: to develop scientific educational programs that promote the understanding and effective implementation of groundwater assessment, protection, and management.

The Winter 2014 *HydroVisions* included biographical introductions of the lecturers for this year. Below are abstracts for their upcoming talks. Further details on these lecturers can be found on the GRA website. Look for the lecture schedule to be posted online, and attend an event near you!

Michelle Sneed
(Northern California)
Hydrologist
United States
Geological Survey

Land Subsidence: The Lowdown on the Drawdown

Abstract:

Land subsidence caused by groundwater withdrawal in California, particularly in the San Joaquin Valley, has recently received increased attention from water-science professionals and the media because two recent droughts, 2007–09 and 2012–present, have triggered high rates of groundwater withdrawal and historically high rates of land subsidence (as much as about 1 foot per year). The compaction of susceptible aquifer systems caused by excessive groundwater pumping is the single largest cause of subsidence in California, and the 5,200 square miles affected by subsidence in the San Joaquin Valley during the better part of the 20th century has been identified as the single largest human alteration of the Earth's surface topography. In some areas that historically depend on surface-water resources, groundwater pumping has increased during periods of drought to compensate for reduced surface-water availability, resulting in large and rapid groundwater-level declines. In some areas where surface water is a minor component of the water supply or where land use has changed to more water-intensive uses, groundwater levels have declined during both drought and non-drought periods. While more focus has been placed on the highly visible infrastructure damage from subsidence, which generally can be repaired, compaction of the aquifer system, sight unseen, permanently decreases its capacity to store water such that subsidence occurring today is a legacy for all tomorrows. This presentation will include discussions of subsidence processes, measurements, analyses, and consequences by exploring selected case studies throughout California, including the San Joaquin Valley, the Coachella Valley, and/or the Mojave Desert.

John Izbicki, Ph.D.
(Southern California)
Research Hydrologist
United States
Geological Survey

Using Disparate, Process-Oriented Data to Solve Hydrologic Problems

Abstract:

Groundwater hydrologists have traditionally incorporated data from a wide range of disciplines into their work, often skillfully integrating geology, chemistry, physics, and other disciplines to solve hydrologic problems. Information from each discipline has strengths and limitations; collaboration between scientists having different skill sets can help interpret the disparate data sets developed by scientists from diverse backgrounds. These data sets are often process-oriented, and may incorporate results from laboratory and field-scale experiments, or integrate high-frequency data collected across a range of physical and temporal scales. As such, process-oriented data may differ greatly in scale and scope from more traditional hydrologic data collected in response to regulatory-driven mandates. For the purposes of this presentation, the specifics of groundwater source, movement, and age; trace-element occurrence, mobility, and pathways to wells; and anthropogenic contaminant movement through, and reaction within, the unsaturated and saturated zones (for example) are less important than the process-oriented approach used to understand and address these issues. The goal of process-oriented work and collaboration is to produce "more-correct" interpretations, in support of traditional field-data and model analyses, than is possible for individuals having limited perspectives and skill sets working alone or in "bureaucratic silos." Over the years, large societally-important problems have traditionally driven basic, multidisciplinary, process-oriented research. Successful solutions to these large problems have often required the creation of diverse data sets and a high degree of collabora-

Continued on the following page…

2015 UCOWR/NIWR/ CUAHSI Conference

JUNE 16-18, 2015
Green Valley Ranch Resort, Las Vegas, NV

Water is Not for Gambling: Utilizing Science to Reduce Uncertainty

The Universities Council on Water Resources (UCOWR) in collaboration with the National Institute of Water Resources (NIWR) and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) will hold a joint conference on June 16-18, 2015 at the Green Valley Ranch Resort in Las Vegas, Nevada. The conference is titled: "*Water is Not for Gambling: Utilizing Science to Reduce Uncertainty*."

Uncertainties in climate, population, land use, biodiversity, and infrastructure continue to pose enormous interdisciplinary challenges to our ability to effectively manage our water resources. UCOWR, CUAHSI, and NIWR invite you and your colleagues to join leading water managers, educators, researchers, and other professionals from across the country to the joint conference of these national organizations to address some of the most compelling and important challenges facing our profession.

For more information see http://www.ucowr.org/conferences.

GRA Requests Nominations for the 2015 "Lifetime Achievement" and "Kevin J. Neese" Awards – *Continued*

2000 – Board of Directors of the Chino Basin Watermaster for delivering a remarkable OBMP that created a consensus-based approach for making water supplies in the Chino Basin more reliable and cost effective

1999 – Governor Gray Davis for his work and leadership in addressing MTBE.

2015 David K. Todd Distinguished Lecturer Series – *Continued*

tive interpretation by numerous researchers. For local-scale agencies responsible for addressing smaller-scale hydrologic problems, scientific collaboration is expensive, and process-oriented work often appears excessively detailed or unnecessary. Why not simply respond solely to regulatory-driven mandates by just measuring water levels or only reporting data on regulated contaminants? However, as even small-scale hydrologic problems have become increasingly complex and as regulatory demands increase, the challenge is to apply the optimal mix of innovative and basic science, collaboration, and communication to solve those problems.

GRA Welcomes the Following New Members

SEPTEMBER 2, 2014 – FEBRUARY 3, 2015

Ainsworth, Lydia Beth	InterAct/AECOM
Anderson, Randy	CA High Speed Rail Authority
Anderson, Nathan	Layne Christensen Company
Andreson, Josh	S.S. Papadopulos & Associates, Inc.
Ashby, Karen	Larry Walker Associates
Barrese, Pat	Terra Pacific Group
Bartlett, Gina	Consensus Building Institute
Bean, Jessica	SWRCB
Bergfeld, Lee	MBK Engineers
Berka, Christopher	Bingham McCutchen LLP
Boettcher, Gary	Gary Boettcher & Associates
Boggs, Christina	California Department of Water Resources
Boland-Brien, Samuel	SWRCB
Bostick, John	Confluence Environmental Field Services
Brand, Marina	Delta Stewardship Council
Brandt, Justin	U.S. Geological Survey
Brewster, William	CA Department of Water Resources
Brown, Pete	Water Replenishment District of Southern California
Bucher, Karl	American AgCredit
Burgin, Andrew	BSK Associates
Cadenazzi Nolan, Dina	Madera Irrigation District
Callahan, John	Serialtone
Campbell, Lisa	CDM Smith
Canchola, Joe	BSK Associates
Carlson, Zoe	Ventura County Watershed Protection District
Carlson, Mack	Golden State Water Company
CARR, JIM	CDM SMITH
Ceesay, Abdoulie	National Water and Electricity Co.
Chang, Wei	SWRCB
Chhang, Sothea	Sacramento County EMD
Chowdury, Shyamal	Wood Rodgers, Inc.
Choy, Janny	Stanford, Water in the West
Christian-Smith, Juliet	Union of Concerned Scientists
Clark, Byron	Davids Engineering
Cohen, Daniel	SWRCB
Cooper, Clay	Desert Research Institute
Couch, Scott	SWRCB
Curless, John	Department of Water Resources
Dahlke, Helen	University of California, Davis
Dai, Isaac	Avanti Environmental, Inc
David, Christina	CSU Monterey Bay
Davis, Michael	Gresham Savage Nolan & Tilden, PC
Dhillon, Sheena	SWRCB
Doane-Allmon, Julie	AECOM
Dooley, Michelle	DWR
Dunaway, Donette	Regional Water Quality Control Board
Dutton, Philip	SWRCB-Division of Drinking Water
Dutton, Anona	Erler & Kalinowski, Inc.
Edwards, Mark	PM Environmental, Inc.
Edwards, Emily	UC Davis
Ekdahl, Erik	SWRCB
Ellsaesser, Adrienne	San Joaquin County EHD
Evans, Will	Water Resources Program
Evans, Will	Lake County Department of Water Resources
Fields, Sue	UC Davis
Firenzi, Tony	Placer County Water Agency
Fredrickson, Justin	California Farm Bureau Federation
Fry, Gil	TRC
Gable, Scott	Enercon Services
Genchanok, Jeanine	Water Systems Consulting, Inc.
Gibson, Maria	Oregon State University
Gibson, Charles	Santa Margarita Water District
Gilkey, Jeffrey	Summers Engineering, Inc.
Gill, Sheryl	CA Department of Pesticide Regulation
Gurney, Lisa	Cardno
Hallinan, Catherine	Department of Water Resources
Harty, J. Michael	Kearns & West, Inc.
Hensel, Jeff	ERM
Hertler, Thurston	Cal State LA
Hoffman, Derek	Gresham Savage Nolan & Tilden, PC
Hosangadi, Vitthal	NOREAS
Hovey, Lee	U.C. Berkeley
Howard, Mark	Layne Christensen Company
Hughes, Trudi	California League of Food Processors
Hull, Roy	CA Department of Water Resources
Hunt, Craig	SWRCB
Hurley, Matthew	Angiola Water District
Hytopoulos, Gregory	Golden West College
Ibrahim, Bunnie	Almond Board of California
Israelson, Brant	Layne Christensen Company
Iversen, Lloyd	ASHRAE and ISES
Jackson, Anne	PG&E
Jacobsen, Brittani	Geosyntec Consultants, Inc.
Jasper, Cameron	Luhdorff & Scalmanini C.E.
Jeung, John	SGBWQA
Jha, Aarushi	Bren School of Environmental Sciences & Management, UCSB
Jobst, Silke	Santa Clara Valley Water District
Jones, Whitney	WSP Services Inc.
Jude, Jason	Pace Analytical
Jurek, Anne	Alameda County Water District
Kalsi, Satpal	Bureau of Reclamation
Kaltreider, Misty	Solano County

Continued on the following page…

GRA Welcomes the Following New Members – *Continued*

Kamilos, Bruce	Elk Grove Water District
Kegel, Erika	Bureau of Reclamation
Kenner, Spencer	CDWR
Khan, Abdul	California Department of Water Resources
Kiger, Luana	USDA, NRCS
Kihara, Annalisa	SWRCB
Killeen, Katharine	CA Department of Water Resources
King, Aaron	Luhdorff & Scalmanini C.E.
Kinney, Phil	The Source Group, Inc.
Kraemer, Stephen	US EPA
Krohn, Joseph	EBI Consulting
Kupferschmidt, Larissa	California State Polytechnic University, Pomona
Lancelle, Karen	Environmental Science Associates
Landau, Katheryn	SWRCB
Lanza, Jodie	LACSD
Laroche, Tara	Eurofins Laboratories
Leffler, Sean	Air Technology Laboratories, Inc.
Leffler, Pete	Luhdorff & Scalmanini C.E.
Lillis, Rebecca	Placer County Dept. of Facility Services
Lopes, James	California Department of Water Resources
Loschke, Carrie	Modesto Irrigation District
Lucero, Christina	HydroFocus, Inc.
Ly, Hoang	LA County Fire
Macaulay, Steve	Macaulay Water Resources
Malama, Bwalya	California Polytechnic State University
Marcus, Laurel	CA Land Stewardship Institute
Margrave, Todd	NAVFAC Southwest
Marshall, Paul	Energy Commission
Matthew, Andrew	Cardno ENTRIX
Maulhardt, Tom	Campbell Soup Company
Maxwell, Karen	TestAmerica Laboratories
McLean, Laura	DWR
Mehl, Steffen	CSU Chico
Mendez, Greg	USGS
Mercado, John	Bureau of Reclamation
Moreno Jimenez, Jose	PG&E
Mueller-Solger, Anke	USGS CAWSC
Mugunthan, Pradeep	Anchor QEA
Munk, Daniel	UCCE
Mysel, Stefanie	CDM Smith
Nasaei, Elnaz	SWRCB
Nevarez, Manuel	Madera County
Norgaard, Kevin	City of Fresno
Nunez, Ernest	CSUN
O'Connell, Patrick	West Yost & Associates
O'Donnell, Cory	Sonoma County
OToole, William	California Resources Corp
Paddock, Emily	Driscoll's
Parker, Doug	UC California Institute for Water Resources
Parrott, Stanley	US Bureau of Reclamation
Partridge, Elizabeth	Bureau of Reclamation
Peters, Roger	
Plinski, Michael	City of Riverside Public Utilities
Porse, Erik	UC Davis
Porzio, Kevin	SWRCB
Poytress, Carrie	Penfield & Smith
Premzic, Rich	Pace Analytical
Rastegarzadeh, Lalei	SWRCB
Raybuck, Mark	Parsons
Reed, Richard	
Resvani, Ali	SWRCB
Rice, Erin	Bureau of Reclamation
Richardson, Kevin	DPR
Robb, Lora	Washoe County- Central Truckee Meadows Remediation District
Rong, Yue	LARWQCB
Rorty, Melitta	Pacific Gas & Electric
Rosenstein, Liaht	Lockheed Martin
Rowe, Ron	Merced County Environmental Health
Sanchez, Fiona	Irvine Ranch Water District
Satkowski, Casey	Sacramento State University
Satkowski, Rich	SWRCB
Schiratis, Stephen	TRC Solutions
Schumacher, Melanie	Soquel Creek Water District/ Golden Gate University
Schwarz, Ken	Horizon Water and Environment
Scruggs, Mary	CA Department of Water Resources
Seeley, Marc	Environmental Geology Services, Inc.
Segal, Daniel	Chevron
Shardlow, Jonathan	Gresham Savage Nolan & Tilden, PC
Shepard, Jeremy	Placer County Water Agency
Short, Lauren	URS Corporation
Shubert, Jack	MAR Systems Inc.
Siebal, Val	Sacramento County
Simmons, Albert	The Source Group, Inc.
Singh, Sandeep	KISTERS North America, Inc.
Singh, Abhishek	INTERA
Smith, Ross	Groundwater Consulting Services
Smith, Robert	
Smith, Richard	University of California
Smith, Christopher	Greenberg Glusker Fields Claman & Machtinger LLP
Smith, Brent	Placer County Water Agency
Sneed, Michelle	U.S. Geological Survey
Snyder, Ron	Santa Clara Valley Water District
Soehnen, Christopher	Merced County Environmental Health

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2014 Contributors to GRA – Thank You

(as of 11/5/2014)

FOUNDER *($1,000 and up)*
Brownstein Hyatt
Farber Schreck
Janie McGinn
Roscoe Moss Company

PATRON *($500-$999)*

CORPORATE *($250-$499)*

CHARTER *($100-$249)*
Bob Abrams
Bob Cleary
Stanley Feenstra
Adam Hutchinson
Sally McCraven
Steven Phillips
Brian Wagner

SPONSOR *($25-$99)*
Jerry Aarons
Charles Almestad
James Arnold
Maria Barajas
Gary Boettcher
Richard Booth
Frank Brommenschenkel
Ahnna Brossy
Kendra Brown
Kevin J. Brown
Kate Burger
Regina Bussard
Lisa Campbell
Andres Cano
Jim Carr
Alan Churchill
Billy Dixon
David Dunbar
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Edana Fruciano
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Eric Reichard
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Tito Sasaki
William Sedlak
Marc Seeley
Pawan Sharma
Marc Silva
Robert Smith
Tom Sparrowe
Phyllis Stanin
Ross Steenson
Kevin Sullivan
Chris Tatum
Eddy Teasdale
Sustainable Technologies
Mike Tietze
Troy Turpen
Mark Wanek
Tom Whitehead
Sam Williams
Cindy Xiong
BSK Associates
EMAX Laboratories, Inc.
Griffith & Masuda
Haley & Aldrich, Inc.
Horizon Environmental, Inc.
HydroFocus, Inc.
Iris Environmental
MAR Systems Inc
The Source Group, Inc.
WZI, Inc.

SUPPORTER
Aarushi Jha
Kit Custis
Richard Casias
Melanie Schumacher

GRA Welcomes the Following New Members – *Continued*

Spangler, Debbie	California Department of Water Resources
Staggs, Rosa	City of Fresno
Staggs, Rick	City of Fresno
Steenson, Ross	Water Board - SF Bay Region
Stolcenberg, David	AMEC Environment & Infrastructure
Stroika, Seth	Eco-Rental Solutions
Tatusko, Joseph	Borrego Water District
Tellegen, Gwen	Terraphase Engineering
Thissen, Ryan	SWRCB-Division of Drinking Water
Thomson, Robert	Dudek
Tiegs, Kathleen	Cucamonga Valley Water District
Turley, Todd	Agreserves, Inc.
Turpen, Troy	Pace Analytical
Turrubiartes, Salvador	SWRCB
Urban, Robert	AECOM
Van Den Hout, Allison	Driscoll's
Vanderburgh, Brent	SWRCB
Vargas, Rick	Stanislaus Food Products
Velasquez, David	Eurofins
Walker, Martin	Arup
Watada, Marianne	SWRCB-Division of Drinking Water
Weideman, Nicole	Sacramento Suburban Water District
Wespestad, Bjorn	Roux Associates
Woodworth, Bruce	Wramp Foundation
Xiong, Cindy	UCLA
Zellmer, Ashley	SWRCB
Zukin, Jeffrey	Geosyntec Consultants

Southern California

By Emily Vavricka,
Branch Secretary

On November 14, 2014, the GRA Southern California Branch held the first annual GRA Southern California Membership Drive in Los Angeles, CA. The event took place at the Roscoe Moss Company facility and included an open house where GRA Members and Non-Members were able to take an informative tour of the facility to see and learn about how water well casing and screen are manufactured. GRA Members and Non-Members were able to mingle and converse with GRA Directors and Officers throughout the evening over the course of appetizers and dinner, learning about GRA and the benefits of membership. The event attracted over 50 GRA Members and Non-members from the Southern California region.

The December meeting featured the Southern California Branch's Annual Holiday Mixer. The Branch hosted this free event, with food provided, in an effort to promote end-of-the-year spirit and to show appreciation to GRA Members. Branch Officers were on hand to talk to Members and Non-Members about membership benefits, GRA state and local events, and opportunities for Members to become involved in GRA, including participation on GRA committees and the potential for serving as a local Branch officer.

The Branch would again like to thank all GRA Members and Non-members for attending the November and December events, and the Roscoe Moss Company for hosting the GRA Southern California Membership Drive.

Palomarin Beach, Point Reyes National Seashore

As a field trip leader for the Point Reyes National Seashore Association, I am fortunate to teach geology to the general public. In preparing for a trip, I often revisit areas and observe dynamic and ephemeral changes to the landscape. For example, during this February 15, 2015 hike at Palomarin, I noticed a recent groundwater spring emerging from a winter gravel beach.

Although January was one of the driest months ever recorded in the Bay Area, a rainstorm passed through this region about a week before my hike. The Palomarin area is underlain by low-permeability Miocene Santa Cruz mudstones and relatively thin surficial Quaternary deposits, which results in rapid surface runoff from these small coastal watersheds.

Large winter storm waves also cause significant beach erosion and winnowing of sediment, which results in deposition of open-framework high-permeability gravels and offshore transport of sands, silts, and clays.

Surface runoff from the small creek infiltrates and recharges the gravel beach deposits near the base of the bluffs. Within a time span of minutes to hours and over a short travel distance of approximately 30 m, the groundwater discharges onto the lower beach. This seascape provides an interesting and instructive example of a groundwater system, albeit on a very small scale.

The author encourages you to hike and make your own hydrogeologic discoveries!

by John Karachewski, Ph.D.
(www.geoscapesphotography.com)