GROUNDWATER RESOURCES ASSOCIATION OF CALIFORNIA

HYDROVISIONS

VOLUME 23, NO. 1 SPRING 2014

Emerging Contaminants Symposium: Summary of the 28th Symposium in GRA's Series on Groundwater Contaminants

By Rula A. Deeb, Geosyntec Consultants; Adnan Anabtawi, MWH Global; Ramona Darlington, Battelle; William DiGuiseppi, CH2M Hill; Deepa Gandhi, Geosyntec Consultants; Elisabeth Hawley, ARCADIS; Brian Lewis, DTSC; Bruce Macler, EPA; Shaily Mahendra, UC Los Angeles; Richard Makdisi, Stellar Environmental Solutions; Ron Porter, Noblis; Eric Suchomal, Geosyntec Consultants; Kevin Sullivan, PG&E; Thomas Mohr, SCVWD; David Sedlak, UC Berkeley; Dave Woodward, AECOM

GRA hosted a 1.5-day symposium on emerging contaminants in groundwater, held February 4-5, 2014 in Concord, CA. The well-received event focused on key groundwater contaminants, including hexavalent chromium (Cr(VI)), 1,4-dioxane, perfluorinated compounds (PFCs) and others (e.g., 1,2,3-trichloropropane (1,2,3-TCP)), and profiled the latest developments on the detection, risk assessment, remediation and regulation of these contaminants. Over 180 attendees from consulting, industry, academia, national laboratories, regulatory agencies and law firms participated, of which 12 were students from 7 universities. The symposium was chaired by **Dr. Rula Deeb** of Geosyntec Consultants, **Dr. David Sedlak** of the University of California at Berkeley, and **Mr. Kevin Sullivan** of PG&E. Event co-sponsors included Geosyntec Consultants and ARCADIS. Luncheon, reception and refreshment sponsors included AECOM, Battelle, CH2M Hill, MWH Global, Roux Associates, Stellar Environmental Solutions, and the TRS Group. In addition to a robust technical poster session, many exhibitors showcased the latest advances in emerging contaminant detection, monitoring, characterization and treatment, including Accutest Laboratories, BC Laboratories, Blaine Tech Services, Confluence Environmental Field Services, EnviroTech Services, EOS Remediation, Maxxam Analytics, McCampbell Analytical, Metrohm, Pro-Hydro, Regenesis, Sustainable Technologies and Weck Laboratories.

Student poster competition winners (left to right: Peerapong Pornwongthong, UC Los Angeles; Katie Harding and Thomas Burton, UC Berkeley) with student advocates Brian Lewis (DTSC) and Rula Deeb (Geosyntec Consultants).

Below are a synopsis of the technical sessions, highlights from two keynote presentations by renowned experts, and an overview of a very special symposium feature, the student poster competition.

Opening Keynote Presentation

Dr. Andrea Leeson, SERDP/ESTCP's Deputy Director and Environmental Restoration Program Manager, gave an opening conference keynote with an overview of DoD's applied research and field demonstration efforts on emerging con-

Continued on page 5…

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

Inside this Issue

Features

Columns & Corners

HYDROVISIONS is the official publication of the Groundwater Resources Association of California (GRA). GRA's mailing address is 1215 K Street, Suite 940, Sacramento, CA 95814. Any questions or comments concerning this publication should be directed to the newsletter editor at editor@grac.org or faxed to (916) 231-2141.

EDITOR
Steven P. Phillips
editor@grac.org

EDITORIAL BOARD
Roy Herndon | Tim Parker | Sarah Kline
Tom Mohr | David Von Aspern | Vicki Kretsinger

Ready to Serve

By Ted Johnson

Greetings everyone, I hope you've had a good start to the New Year. Mine has started off with a BANG as the 12th GRA President! I am honored that the Board of Directors elected me to this position and I vow to work hard to stay the course and keep the association focused on promoting statewide groundwater excellence, leadership and education.

My brief bio is that I'm the Chief Hydrogeologist at the Water Replenishment District of Southern California and have been with that agency for over 17 years. Prior to that, I was with a few southern California groundwater consulting firms, starting as a college intern in 1985. I graduated with Bachelors and Masters Degrees from Cal State Fullerton and have been a continuous member of GRA since its inception in 1992. I have been on the Board of Directors since 2007, serving in various roles, including Chair or Co-Chair of the Membership, Events, and Finance Committees, Board Secretary, and Board Vice President. I have a wife and daughter; live in Long Beach; like rock-n-roll, biking, cooking and camping; and still greatly enjoy the profession and science of geology and its related disciplines.

This presidential assignment will be made easier with the invaluable help of other GRA volunteers, including newly elected officers Chris Petersen (Vice President), Bob VanValer (Treasurer), with side-kick and son R.T. the Bookkeeper, and Steve Phillips (Secretary). Committee volunteers keep the important missions of GRA going smoothly. Branch volunteers keep the GRA name going strong on a local level. Our new Association Management Company, Smith Moore & Associates, has high-quality and experienced staff, including GRA's new Administrative Director, Sarah Kline, who will see to the day-to-day business activities of the association. Kevin Blatt, our IT specialist and webmaster, is a guru with all things digital and manages every aspect of e-communication. I am lucky to have as a mentor for "on-the-job" presidential training the outgoing president, Sarah Raker, who showed me how to take on the duties and challenges with dedication, mixed in with lots of humor, smiles, class, collaboration, and conviction. I hope at least some of that has rubbed off on me. Thanks for everything, Sarah!

There are many things I like about GRA that make me want to continue to be a member and to contribute to its success. It's a forum where people with common groundwater interests come together to objectively express ideas, share opinions, teach others, and learn from others. Those of us who have been in the business for a long time can not only share with both our peers and the "newbies" our experiences learned, but can learn things ourselves as new ideas and new technologies emerge. I believe we should never stop learning – that's a big part of what makes science fun. I try to live by that belief.

As you all know, groundwater is a broad field of science, with practitioners in specialties such as water resources, contaminant hydrogeology, modeling, well construction and rehabilitation, regulatory issues, legislative activities, geochemistry, managed aquifer recharge, seawater intrusion, legal matters, overdraft/depletion, fractured-rock hydrogeology, remediation, academics and research, and many others. GRA is all about bringing these disciplines and issues to our members, primarily through hosting relevant and timely events, so we can all be exposed to the latest news, breakthroughs, findings, and technologies in groundwater-related fields. We appreciate the sponsors and exhibitors who contribute to these events to help make them a success, and expose us to their tools and technologies for collecting better groundwater information and achieving water management goals. So far this year, GRA has held events on Emerging Contaminants, Salt-Nutrient Management, and Groundwater Sustainability; others are being planned for Groundwater Management, Subsidence, Managed Aquifer Recharge, Site Closure, Hexavalent Chromium, our Annual Meeting in the fall, and others. Keep checking our web site at www.grac.org for a current listing of upcoming events.

HydroVisions is another great product of GRA. There are many fantastic articles on various topics within each release, and all past issues are archived on our web site for anyone to download and enjoy at www.grac.org/hydrovisions.asp. This edition of *HydroVisions* continues in that tradition of publication excellence, and I encourage you

Continued on the following page…

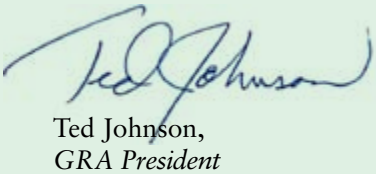
Ready to Serve – *Continued*

to read it from front to back and then over again. And certainly don't miss the special guest editorial by Bob Pierotti of DWR on the confidentiality of water well reports and his personal opinions on why they were made confidential and whether the arguments made today to release them to the public are valid or not. He includes a link to his impressive 41-page document, which has never before been published, that explains the history and current issues surrounding this controversial topic. Feel free to respond to this editorial, and we may be able to post your comments in an upcoming edition of *HydroVisions*.

This will be an exciting and challenging year for California groundwater, with many issues to keep close track of, such as the Governor-declared drought, the incorporation of the Department of Public Health Drinking Water Program (including recycled water) into the State Water Resources Control Board, the Central Valley groundwater depletion, subsidence and water quality issues, the Water Bond, new hydraulic fracturing groundwater monitoring criteria, new MCL for Chromium-6, Bay Delta proposed solutions, and the day-to-day management and problem solving in one or more of the 515 California groundwater basins and subbasins that most of us work in or have interests in every day. GRA will report on these issues and take active roles as necessary to promote responsible groundwater management based on factual information and good science. As a GRA member, you can help influence the direction the association takes on these very important issues by contributing as much time as you can afford.

I really enjoy being a part of GRA and hope you do too. If you have any suggestions for the association, or want to volunteer for a committee or to find out how to become more involved, please send me a note at tjohnson@wrd.org. I am ready and eager to serve as President this year and look forward to working with you to make your association the best it can be for all of us in the profession and for the betterment of California groundwater.

Rock on!



Ted Johnson,
GRA President

Groundwater Resources Association of California

Welcome to the new look of GRA. While staying true to the original logo designed over 22 years ago, the new logo incorporates the original design elements and objective of portraying groundwater as a vital component of the hydrologic cycle into a new, unique and creative design. From the first iteration of hand-drawn sketches in 1992, to the latest logo design, GRA has grown and established itself as a leading groundwater educator and advocate in California, and the new logo will help GRA stand out in today's marketplace.

More about the new logo – the hydrologic cycle, as demonstrated through the combined descending and ascending arrows in the clever shape of a water drop with varied representative colors, pulls focus to the relationship of the atmosphere, surface water, the vadose zone, and groundwater. The new logo reinvigorates GRA's role in promoting the importance of groundwater and accomplishing the organization's mission.

Emerging Contaminants Symposium: Summary of the 28th Symposium in GRA's Series on Groundwater Contaminants – *Continued from page 1*

taminants. The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) are the Department of Defense's (DoD) environmental research programs supporting the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities.

Dr. Leeson broadly discussed DoD's strategy around emerging contaminants. Following a summary of past research successes which enabled DoD to react early and cost effectively to emerging contaminants such as perchlorate, Dr. Leeson identified DoD's current contaminants of interest, including 1,4-dioxane, N-nitrosodimethylamine (NDMA), 1,2,3- TCP and perfluoroalkyl compounds. She articulated the challenges for DoD at installations impacted by these compounds, and provided an overview of currently funded projects which will help DoD to better respond to cleanup challenges associated with these contaminants. Dr. Leeson briefly discussed the scope of 21 projects covering a broad spectrum of research topics on emerging contaminants, including monitoring, fate and transport, and treatment (both conventional and innovative). For details on these projects, please visit the program's website at www.serdp-estcp.org.

Ted Johnson, GRA's President, welcoming attendees.

Dr. Andrea Leeson giving the opening keynote to a captive audience of 180 environmental practitioners.

Chromium and Other Metals

The first technical session following the opening keynote was chaired by **Mr. Kevin Sullivan**, PG&E, and **Mr. Richard Makdisi**, Stellar Environmental Solutions. **Dr. Bruce Macler** of EPA provided an overview of the current status of State and Federal chromium regulations. He discussed the California Department of Public Health (CDPH) proposed change of Cr(VI) MCL to 10 µg/L, and resulting implementation challenges, increases in treatment costs, and escalations in water rates for many communities. Dr. Macler ended his presentation with EPA's approach to revising the chromium MCL. **Mr. Ed Means** of Means Consulting then discussed the technical and economic challenges that will be faced by both large and small water systems in CA if faced with complying with the lower proposed MCL. Mr. Means provided detailed cost information, and compared CDPH projected increases in cleanup costs to other estimates from the Association of California Water Agencies (ACWA) and the American Water Works Association (AWWA).

Bruce Macler of USEPA discussing chromium regulations.

Mr. Means concluded his presentation with a water community perspective on the proposed MCL. The third presentation in this session provided an overview of the developing science on toxicological impacts of chromium ingestion. **Ms. Deborah Proctor** of ToxStrategies discussed the recent body of toxicological research on Cr(VI) and indicated that a much higher MCL than the one proposed in CA would still be protective of public health.

Two speakers then discussed real-world engineering and cleanup issues. **Ms. Yvonne Meeks** of PG&E discussed a management approach to a chromium plume adjacent to the Colorado

Continued on the following page…

Emerging Contaminants Symposium: Summary of the 28th Symposium in GRA's Series on Groundwater Contaminants – *Continued*

River at the Topock Compressor Station in Needles, CA. Components of the site remedy included an in-situ reducing zone to cut off and treat Cr(VI), combined with fresh water injection to accelerate plume movement and speed up remedial timeframes. In addition, carbon-amended water was injected where needed, and extraction wells were installed at the river bank to mitigate plume migration. **Mr. Leighton Fong** of Glendale Water and Power then shared a synopsis of the City of Glendale's Cr(VI) research program. Mr. Fong provided results from bench-scale and pilot studies which screened a range of technologies for Cr(VI) removal at Glendale, followed by results of full-scale demonstrations testing the two most promising technologies, Weak Base Anion Exchange (WBA) and Reduction/Coagulation/Filtration (RCF), for a target chromium level of 5 ppb. Mr. Fong provided operational and capital costs for these technologies, as well as disposal strategies of treatment residuals.

Dr. John Izbicki of the U.S. Geological Survey concluded this session by expanding the discussion from Cr(VI) to other metals and inorganics of concern. He indicated that arsenic and uranium exceed their respective MCLs of 10 and 30 µg/L in 10 and 3 percent, respectively, of public supply wells sampled by the State Water Resources Control Board's GAMA (Groundwater Ambient Monitoring and Assessment) Program.

Perfluorinated Compounds (PFCs)

The second day started with a session on perfluorinated compounds moderated by **Dr. Ron Porter** of Noblis and **Dr. Ramona Darlington** of Battelle. Dr. Jennifer Field of Oregon State University presented a tutorial on the types of per- and poly-fluorinated compounds present in aqueous film-forming foam (AFFF) mixtures. Dr. Field discussed the stability, occurrence, environmental

Shaily Mahendra of UC Los Angeles discussing PFC biodegradation by fungi.

fate and transport, and treatment of these compounds. **Dr. Chris Higgins** of Colorado School of Mines provided fate and transport observations of poly- and perfluoroalkyl substances (PFAS) based on soil and groundwater samples collected from an Air Force base. Dr. Higgins suggested that although PFAS components are recalcitrant to remediation by air sparging and bioremediation, remedial activities at the site altered the distribution of contaminant concentrations, likely due to subsurface transformations of perfluoroalkyl acid (PFAA) precursors.

Dr. Shaily Mahendra of the University of California, Los Angeles, provided evidence of the ability of wood-rotting fungi to degrade 6:2 fluorotelomer alcohol (6:2 FTOH), a polyfluorinated alcohol that is used in commercial and industrial products as a replacement for PFOA precursors. She demonstrated the conversion of 6:2 FTOH by fungi to less toxic polyfluorocarboxylic acids via pathways, which unlike bacterial pathways, do not lead to the accumulation of perfluorocarboxylic acid. **Dr. Linda Lee** of Purdue University provided an overview of laboratory tests evaluating a range of chemical oxidation and reduction techniques for the removal of PFCs. Dr. Lee demonstrated that persulfate activation at relatively low temperatures (20 to 60 degrees Celsius), high reagent concentrations (1,000 to 20,000 mg/L) and high reaction times was effective in defluorinating PFOA to shorter-chain molecules, but had no effect on PFOS.

Ms. Elisabeth Hawley of ARCADIS gave an overview of PFC treatment technologies. She stated that PFOS is not affected by air stripping, soil vapor extraction, air sparging, biodegradation or thermal treatment due to its physical and chemical properties. She reviewed traditional remediation technologies employed for PFC-contaminated soil, including excavation and landfill disposal, solidification, stabilization and soil washing. Ms. Hawley then presented an overview of common ex-situ treatment technologies, including granular activated carbon, ion exchange and membrane treatment using reverse osmosis. She also provided a summary of recent developments on potentially viable in-situ approaches.

1,4-Dioxane

The 1,4-dioxane technical session was moderated by **Mr. Bill DiGiuseppi** of CH2M Hill and **Mr. Adnan Anabtawi** of MWH. **Ms. Dora Ogles** of Microbial Insights first gave a detailed discussion of Stable Isotope Probing (SIP) using two versions of Bio-Trap samplers in wells to determine optimal in-situ biodegradation conditions for 1,4-dioxane. Ms. Ogles showed results from a commercial site in Texas where the use of SIP demonstrated that 1,4-dioxane biodegradation is occurring under natural conditions. She also discussed a suite of other microbiological tools that can be used to evaluate the potential of in-situ 1,4-dioxane biodegradation.

Dr. Pat Evans of CDM Smith presented results from an ESTCP research project on the use of slow-release

Continued on the following page…

Emerging Contaminants Symposium: Summary of the 28th Symposium in GRA's Series on Groundwater Contaminants – *Continued*

oxidant candles for 1,4-dioxane destruction. The project assessed both potassium permanganate ($KMnO_4$) and unactivated persulfate ($S_2O_8^{2-}$) in terms of release rates from paraffin candles. Dr. Evans' treatability studies showed 80-90% destruction of 1,4-dioxane using $KMnO_4$ within reasonable timeframes. In addition, Dr. Evans noted that persulfate did not necessarily need to be heated to generate free radicals to degrade 1,4-dioxane. **Mr. Daniel Oberle** of the TRS Group discussed results from a successful groundwater remediation project using electrical resistance heating (ERH) and associated steam stripping. For an ERH pilot test, Mr. Oberle reported that 1,4-dioxane partitioned into the steam as the temperature approached the boiling point of water, which resulted in the relatively easy removal of 1,4-dioxane from the vapor stream using vapor-phase granular activated carbon. With the 99% observed removal of 1,4-dioxane in this study, Mr. Oberle concluded that ERH is even effective in low permeability soils.

Lisa Alvarez-Cohen of UC Berkeley delivering a thought-provoking luncheon keynote address.

Mr. Thomas Mohr from Santa Clara Valley Water District presented 1,4-dioxane occurrence results from the first year of Unregulated Contaminant Monitoring Rule 3 (UCMR3) sampling. Mr. Mohr stated that detections in municipal supplies were surprisingly high relative to what was expected. He offered anecdotal reports of 1,4-dioxane detections in unlikely places, and underscored the importance of understanding impurities (e.g., methanol and polyethylene glycol) in commercial chemicals. Mr. Mohr concluded that there are many known and unknown uses of 1,4-dioxane, and that these multiple uses are likely responsible for its high prevalence in drinking-water supplies.

Luncheon Keynote Presentation

Dr. Lisa Alvarez-Cohen, Fred and Claire Sauer Professor in the Dept. of Civil and Environmental Engineering at UC Berkeley, gave a spirited and thoughtful keynote presentation titled "Bioremediation for Emerging Contaminants: A Historical Perspective and Current State of the Practice." Dr. Alvarez-Cohen presented important bioremediation milestones for legacy contaminants such as petroleum hydrocarbons, pesticides and chlorinated solvents, and also for various classes of emerging contaminants. Following a broad examination of the evolution and discovery of microorganisms shown to biodegrade contaminants initially believed to be recalcitrant, Dr. Alvarez-Cohen summarized recent findings from her own work on NDMA, 1,4-dioxane, polybrominated diphenyl ethers (PBDE) and perfluorinated compounds. She disclosed recent results demonstrating the successful application of culture-independent methods for understanding the structures and functions of microbial communities relevant for the bioremediation of contaminated subsurface environments. She concluded with a positive outlook on biological treatment efficacy for emerging contaminants in hazardous-waste streams and groundwater due to the development of powerful OMICS-based molecular biological tools, as well as technological advances capable of reducing bioremediation timeframes.

Other Contaminants of Emerging Concern

This session was moderated by **Mr. Brian Lewis** from DTSC and **Ms. Deepa Gandhi** of Geosyntec Consultants. **Dr. Kristin Robrock** of Exponent presented results from her work on polybrominated diphenyl ethers. PBDEs are a class of flame retardants used in consumer products that have been linked with neurotoxicity and endocrine disruption in mammals and fish. Dr. Robrock showed that, contrary to prior reports, population density and wastewater dilution indices are not good predictors for PBDE concentrations in rivers in the Pacific Northwest.

Mr. Matt Marlatt of CH2M Hill addressed the environmental uses and management of 1,2,3-TCP using a case study for a northern CA site impacted by TCP and other VOCs. He showed results from an in-situ thermal treatment application in the source zone, which significantly decreased contaminant concentrations in soil and groundwater to below cleanup goals. **Dr. William Moe** of Louisiana State University, Baton Rouge, discussed his research on the biological degradation of 1,2,3-TCP. Dr. Moe showed that microbial cultures of the genus *Dehalogenimonas* are able to reductively dechlorinate 1,2,3-TCP under anaerobic conditions. He indicated that some of these cultures are also able to reductively dehalogenate other polychlorinated alkanes, including 1,2-dichloropropane and 1,2-dichloroethane. Based on recent results from field-scale experiments, he concluded that these bacteria can be effectively used in bioremediation applications.

Richard Andrachek from MWH Global presented results from a fractured sedimentary rock site in southern CA where historic releases resulted in 1,4-dioxane, NDMA and perchlorate impacts to groundwater. Rock pore water and groundwater sampling revealed

Continued on the following page…

Emerging Contaminants Symposium: Summary of the 28th Symposium in GRA's Series on Groundwater Contaminants – *Continued*

Panel discussion (left to right: Dave Woodword, AECOM; David Sedlak, UC Berkeley; Chris Berka, Bingham McCutchen; Edgard Bertaut, Allegheny Technologies; Ali Haghani, Eurofins Eaton Analytical Laboratories).

that the extent of these impacts is within hundreds of meters from where the chemicals entered groundwater about 50 years ago. Mr. Andrachek concluded that the molecular diffusion of dissolved chemicals transported by water flowing through the fracture network into the nearly stagnant water of the porous rock matrix caused a strong retardation of 1,4-dioxane, NDMA and perchlorate.

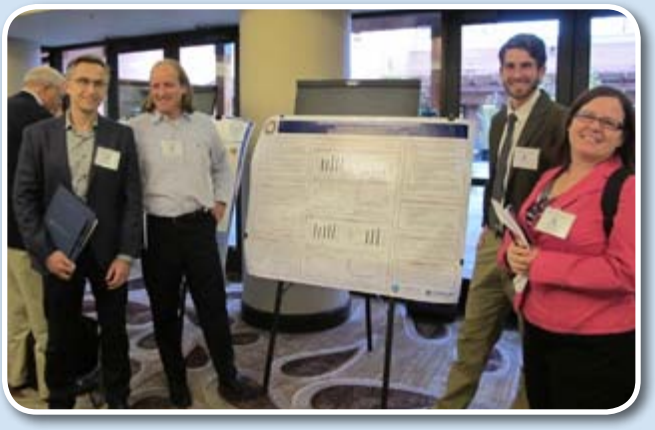
Dr. Kung-Hui Chu of Texas A&M University discussed PFC precursors. In an effort to eliminate the global production of PFOA and its precursors, manufacturers have recently adopted 6:2 FTOH as a raw material. Accordingly, a better understanding of 6:2 FTOH biodegradation potential is essential for assessing its fate and transport in the environment. Dr. Chu reported that a number of bacterial strains are capable of defluorinating 6:2 FTOH through multiple degradation pathways to produce various shorter chain poly- and per-fluorinated compounds. She indicated that the extent and mechanisms of 6:2 FTOH biotransformation are affected by bacterial strain types, enzyme inducers and levels of reducing energy.

Panel Discussion

The conference ended with a panel discussion on predicting and managing the next generation of emerging groundwater contaminants. The panel was moderated by **Mr. Dave Woodward** of AECOM and **Dr. David Sedlak** of UC Berkeley. The four distinguished panelists were **Mr. Ali Haghani** of Eurofins Eaton Analytical Laboratories, **Mr. Edgard Bertaut** of Allegheny Technologies, **Mr. Chris Berka** of Bingham McCutchen and **Dr. Bruce LaBelle** of Department of Toxic Substances Control. Each of the panelists initially provided responses to the following questions:

1. What classes of compounds or specific contaminants do you see as the next generation of emerging contaminants?
2. What are the pros/cons of monitoring when you aren't required to do so, and what drives decision-making at impacted sites?
3. How would you react to emerging contaminant data given the likely lack of toxicological studies and cleanup criteria?
4. In the absence of treatment technologies for some emerging contaminants, their high solubility and likely presence of large dilute plumes, how can we best manage impacts?

Mr. Ali Haghani emphasized that the discovery of new emerging contaminants is driven by which contaminants we look for, and that advances in analytical methodologies have matured over the past several decades to the point where very low detection limits can now be achieved at reasonable costs. Mr. Haghani stressed the importance of communications with the public about the significance (or lack of significance) of low-level detections of emerging contaminants in water supplies. **Mr. Edgard Bertaut** indicated that industry typically prefers to wait for the science to develop, and responds to regulatory requests to monitor for emerging contaminants rather than voluntarily doing so. Mr. Bertaut suggested that generating emerging contaminant data in the absence of cleanup criteria is often not useful. He also stated that waiting for



Poster session (left to right: Peter Zawislanski, Terraphase Engineering; Bruce Marvin, Geosyntec Consultants; Tom Burton, UC Berkeley; Michelle Crimi, Clarkson University).

Continued on the following page…

Emerging Contaminants Symposium: Summary of the 28th Symposium in GRA's Series on Groundwater Contaminants – *Continued*

contaminants to emerge makes it more likely that remedial technologies will have matured to address them. **Mr. Chris Berka** opined that pesticides and agricultural chemicals (e.g., Central Valley), chemical spills impacting drinking water, and hydrofracturing chemicals will likely constitute the next generation of emerging contaminants. He stressed the importance of practitioners knowing how to manage data, and he provided a summary of legal doctrines that could allow responsible parties to monitor for emerging contaminants without necessarily making the data public (i.e., Attorney Work Product Doctrine and Attorney Client Privilege). Mr. Berka cautioned that many state laws still require that the detection of emerging contaminants is reported to regulators, and he concluded by providing a perspective on managing contaminant legal liabilities via institutional controls and contract language.

Dr. David Sedlak provided closing comments on three key issues: (1) how green chemistry can be effectively used to avoid new emerging contaminants; (2) how the state of California is often a leader when it comes to responsiveness in dealing with new contaminants; and (3) the potentially increasing impacts of emerging contaminants due to ongoing and future droughts. Dr. Sedlak then highlighted the important role that innovation plays in dealing with emerging contaminants, and expressed a strong need to continually reinvigorate research and development funding.

Student Poster Competition

Scholastic scholarship support was provided by three GRA Branches (Sacramento, San Francisco and Southern California) and allowed 12 students from 7 universities (UC Berkeley, UC Los Angeles, UC Riverside, UC Davis, CSU Sacramento, Stanford University and Oregon State University) to attend the symposium at no cost to the students. All student attendees also received SERDP/ESTCP books on environmental remediation, courtesy of Dr. Andrea Leeson.

Student flash presentations providing snapshots of the latest research developments on emerging contaminants.

Six of the 12 students participated in a poster presentation competition. On the first day of the symposium, each student gave a one-minute flash oral presentation highlighting their research and inviting the audience to visit their posters. The students received valuable feedback during the poster session from environmental practitioners. A panel of judges evaluated the student posters, and selected three winning presentations based on several criteria, including presentation organization and structure, relevance and innovation of theme and topic, significance of work, quality of data and materials, and research completeness. The judges included **Dr. Jennifer Field** of Oregon State University, **Dr. Michelle Crimi** of Clarkson University, **Mr. Kevin Sullivan** of PG&E, **Dr. Bruce Macler** of EPA, **Dr. Ramona Darlington** of Battelle and **Mr. Bruce Marvin** of Geosyntec Consultants. The winners received cash prizes of $500, $300 and $200, which were generously provided by the three GRA Branches noted above. An overview of the students' research is provided below.

Mr. Thomas Burton, also a Ph.D. student at UC Berkeley, won first prize for his discussion of the fate of perfluoroalkyl acid precursors during AFFF chemical treatment. Mr. Burton investigated the fate of polyfluorinated compounds in synthetic groundwater containing one of two types of AFFF amended with iron and varying doses of H_2O_2 (i.e., Fenton's reagent). Fe/H_2O_2 treatment transformed the perfluoroalkyl sulfonamido amines into perfluorinated carboxylates, but did not affect the concentration of perfluorinated sulfonates in 3M formulations of AFFF. In contrast, the primary polyfluorinated components in AFFF manufactured by Ansul were n:2 fluorotelomer thioamido sulfonates, whose treatment with Fe/H_2O_2 resulted in transformation of n:2 fluorotelomer thioamido sulfonates to n:2 fluorotelomer sulfonates, which were subsequently transformed to perfluorinated carboxylates of equal or lesser fluorocarbon chain length. The results of Mr. Burton's research will be useful at AFFF-contaminated sites where chemical oxidation technologies are being considered for the remediation of polyfluorinated chemicals or co-contaminants.

The second place winner was Ms. Katie Harding, a Ph.D. student at UC Berkeley, who discussed her research on the aerobic biotransformation of

Continued on the following page…

Emerging Contaminants Symposium: Summary of the 28th Symposium in GRA's Series on Groundwater Contaminants – *Continued*

6:2 fluorotelomer thioamidosulfonate in aqueous film-forming foams (AFFF). Ms. Harding reported the biotransformation of fluorotelomer thioether amido sulfonate (FtTAoS) in microcosms established using AFFF-impacted top soil within 60 days. Several transformation products were identified using high-resolution mass spectrometry, indicating that the first two steps in the transformation of 6:2 FtTAoS were sequential oxygen additions to the thiol group, followed by dealkylation and formation of 6:2 FtS. The results of her study demonstrated that the most abundant PFAS in a widely used AFFF formulation aerobically biotransforms to persistent PFCAs. Understanding the transformation pathways of fluorinated surfactants will allow for the design of groundwater and soil remediation systems at AFFF-impacted sites.

The third prize was presented to **Mr. Peerapong Pornwongthong**, a Ph.D. student at UC Los Angeles, for his work on stable isotope fractionation during aerobic biodegradation of 1,4-dioxane. Mr. Pornwongthong demonstrated that Compound Specific Isotope Analysis (CSIA) can serve as an important monitoring tool for assessing the biodegradation of organic groundwater contaminants. He discussed the development of a novel CSIA method for 1,4-dioxane, which was successfully used to demonstrate the fractionation of ^{2}H and ^{13}C and establish enrichment factors associated with 1,4-dioxane biodegradation by Pseudonocardia dioxanivorans CB1190. This tool will be useful to environmental professionals for evaluating intrinsic or enhanced biodegradation in 1,4-dioxane-contaminated groundwater.

Mr. Han Sohn and **Ms. Michelle Chebeir**, graduate students at UC Riverside, jointly presented a poster on minimizing hexavalent chromium in California's water. Their work described the kinetics of Cr(III) oxidation and the formation of Cr(VI) in drinking water by two widely used disinfectants (chlorine and chloramine). They also evaluated and reported the effect of pH. Mr. Sohn and Ms. Chebeir reported that Cr(VI) was produced with disinfectant consumption, suggesting that Cr(III) was oxidized to toxic Cr(VI) by disinfectants. The oxidation rate was nearly ten times higher with chlorine than with chloramine. Results from this study will help to understand the redox chemistry of chromium and prevent the occurrence of Cr(VI) in drinking water.

Ms. Wei (Lucy) Li, also a graduate student at UC Riverside, presented her work on toxicity implications of sulfate radical based oxidative treatment. Sulfate radical-based treatment has gained more attention due to its high selectivity towards contaminants with high electron densities, such as hydrocarbons and emerging contaminants (e.g., pharmaceuticals and personal care products). Ms. Li's study was the first to report that sulfate radicals generated through activation of persulfate ($S_2O_8^{2-}$) oxidized benzene into phenol and an unexpected di-aldehyde product. GeneBLAzer cytotoxicity assay results suggested that this di-aldehyde compound induced higher toxicity to human cells than benzene. Ms. Li's research will provide guidance on optimizing oxidative treatment for groundwater remediation.

Collaborative Leadership Workshop
Negotiating Relationships to Improve Water Resources Planning

By Dorian Fougeres and Dave Ceppos, Center for Collaborative Policy, and Tim Parker, GRA Director, Parker Groundwater

GRA held its first Collaborative Leadership Workshop on November 4th in downtown Sacramento. This workshop, the second in GRA's series on Groundwater Management, covered the fundamentals of collaborative leadership and stakeholder involvement, which are necessary skillsets for technical professionals and public employees working with diverse stakeholders on complex natural resource management issues.

An introduction to the workshop, co-sponsored by GRA and the Association of California Water Agencies (ACWA), was given by **Tim Parker**, GRA Director, and **Dave Bolland**, Senior Regulatory Advocate, ACWA. Tim and Dave underscored that almost anything water-related in California is technically complex, politically contentious, has significant uncertainty, and quickly raises anxiety levels among local stakeholders. Collaborative efforts encourage open and honest dialogue among stakeholders, and have significantly advanced groundwater management and integrated water resources management planning efforts across the state.

Dave Orth, General Manager of Kings River Conservation District, provided the first keynote presentation. Dave observed that we all tend to work in silos, and that this tendency runs counter to the collaboration needed to address current and future water challenges. He recommended a bottom-up approach whereby collaborative groups are formed to jointly gather and examine information, evaluate options, and make decisions that are rigorous, durable, and innovative. Collaborative efforts have accomplished a lot in the Kings River area, including some 24 different plans and processes. This includes the highly successful Upper Kings Basin Integrated Regional Water Management (IRWM) Authority, which manages all aspects of water resources in the region. Such IRWMs provide a foundation for policy discussions and planning efforts that can maximize the efficient use of local and regional resources to address evolving water challenges.

Dave Orth's keynote on the Kings River basin collaborative efforts and his top-ten for success.

Dave's top ten recommendations for success summarized:

1. Willingness to set agendas aside and achieve goals via unconventional paths
2. Need the desire to understand opposing points of view
3. Need to see points of agreement
4. Need to stay focused on big issues – don't chase little bright shiny lights, and separate the 'must haves' from 'needs' and 'wants'
5. You sometimes have to take risks and stand out on a limb or take a few arrows – the risk is worth the reward, and the reward is worth more than status quo
6. Building trust with partners really changes the dynamics
7. Integrity – mean what you say and say what you mean, follow through, and be open and honest
8. Make values visible and viable – maintain your integrity and that of the process
9. Need to be contagious about your approach and desired outcomes
10. Need to be patient, this doesn't happen quickly.

Why collaborative leadership approaches?

1. Traditional methods don't work and tend to lead to conflict without resolution, e.g., adjudication – 10 years of conflict and getting stakeholders all lawyered-up costs time and lots of money
2. Delays in solutions lead to more risk – political, water resources, legal, water rights; it is in our interest to manage that risk for a better outcome
3. Provides the opportunity for sustainable outcomes.

Continued on the following page…

Collaborative Leadership Workshop: Negotiating Relationships to Improve Water Resources Planning – *Continued*

Dave Ceppos leads the discussion during one of the workshop collaborative exercises.

Dorian Fougeres introduces some of the key tenets of Collaborative Leadership.

Dave Ceppos and **Dorian Fougeres**, facilitators with the Center for Collaborative Policy (CCP), California State University Sacramento, planned and led the workshop. Dave started off by informing the attendees that collaborative leadership is hard work, complex, scary, and uncomfortable. It is hard to be collaborative; oftentimes the desire to be right outweighs the desire for a win-win outcome. Dorian introduced the initial concepts of collaborative leadership, focusing on the roles of the public, public agencies and technical aspects of interest-based negotiation. This approach to negotiation is the basis of collaborative processes, and is well described in the book Getting To Yes: Negotiating Agreement Without Giving In, by Roger Fisher and William Ury. It involves separating people from the problem; clarifying both what your interests—not your set positions—are, as well as those of others; sharing and gathering information; developing objective criteria for evaluating options; and then negotiating agreements on options that meet the range of interests involved without any party having to compromise on its core interests.

Grant Davis, General Manager for the Sonoma County Water Agency, provided the second keynote that focused on his experiences with collaboration. Grant indicated he had two key principles for collaboration: listen, and trust. Grant indicated that groups engage when there is no other alternative. He discussed the groundwater management program for the Sonoma Valley, which is at the end of the pipeline for imported Russian River water; has a sanitation plant that discharges to the San Francisco Bay; and has areas of chronic groundwater depletion and salinity intrusion in the southern portion of the valley. CCP conducted a stakeholder assessment to try to identify the concerns and level of understanding of basin stakeholders, and whether the time was right for a groundwater planning process. It was difficult for the Water Agency to back away from leading this effort themselves, and instead use a collaborative process. However, the collaborative process has had great success, with a groundwater management plan adopted in 2007 and having completed six years of implementation. Not all the challenges have solutions, but there is a robust monitoring program, studies regarding potential conjunctive use, and discussions on how to address groundwater depressions. A key to success has been public education about the science behind groundwater management, which ensures that everyone is on the same playing field.

Grant also discussed collaboration as a key element of the successful North Coast IRWM, which encompasses seven counties, three California Native American tribes, and the San Francisco Bay IRWM. For Grant, with a Water Agency Board of five County Supervisors, a principal in practice for him is to be on the "leading edge," not on the "bleeding edge." His recommendations for success are to get the governance structure right, and to use a facilitated, collaborative process.

Celeste Cantu, General Manager of the Santa Ana Watershed Project Authority (SAWPA), the third keynote, gave an overview of SAWPA and emphasized the need for collaboration in water management. Collaboration requires crossing boundaries – you can't do it alone, everyone needs to be at the table, and citizens need to find mutually agreeable solutions rather than fight for their interests in isolation. Collaborators need to think big, step back and expand the boundaries of their awareness, take off the blinders, and realize that the easier, quicker fixes do nothing to address deeper, structural dilemmas and chronic, persistent problems. Collaborative work is ultimately about building relationships and trust to find shared solutions, and addressing the challenges of institutional fragmentation.

Continued on the following page…

Collaborative Leadership Workshop: Negotiating Relationships to Improve Water Resources Planning – *Continued*

Celeste Cantu provides a keynote on the Santa Ana Watershed Project Authority, including their approach to One Water-One Watershed.

Celeste also discussed the importance of maintaining collaborative groups through transitions, such as leadership retirement, changes in funding, shifts from planning to implementation, facilitation changes, and long-term changes in organizational mission. Some recommendations include:

1. Investing in signature – invest in branding how you encourage collaborative behavior
2. Creating a gift culture through mentoring – the stronger the mentor you are, the better the collaborator
3. Support a strong sense of community by empowering the community with a strong understanding of the watershed
4. Relationships trump everything
5. Maximize the positive, long-standing relationships as a means to grow others
6. Understand role clarity and task ambiguity.

For more information on collaborative processes and leadership, Celeste highly recommended reading Beyond Reason: Using Emotions As You Negotiate, by Roger Fisher and Daniel Shapiro.

Dorian Fougeres provided principles and a framework for collaborative leadership, including the necessity of a transparent process that has executive commitment. He noted that collaborative leadership has emerged as a response to complex social and environmental issues that require working across individual jurisdictions, and greater demands for public participation in governance decisions. Similarly, organizations have realized the power of networks and horizontal relationships as a complement to vertical hierarchies—they still have their autonomous decision-makers, but are increasingly interdependent. At the same time, "big data" has placed a premium on the ability to track and organize data in a way that is both publicly accessible and immediately applicable to management. "Collaborative leadership" can be defined as facilitating change around complex issues that cannot be easily or durably managed by single entities, and that require multiple organizations to work together toward common goals.

Dorian also discussed the International Association of Public Participation's "spectrum of public participation," which includes:

1. Inform – provide with information, help to understand
2. Consult – obtain feedback on information
3. Involve – seek to incorporate and develop alternatives around feedback
4. Collaborate – work with stakeholders on all parts of the decision-making process
5. Empower – grant decision-making authority to another entity (rare for public agencies).

Finally, Dorian provided a high-level overview of the Five Phases of a Collaborative Process:

1. Assessment and Planning – determine whether convening is appropriate
2. Convening and Organization – establish representation and governance
3. Mutual Education – clarify issues, interests, and information
4. Capital-N Negotiation – establish criteria for decision-making, develop inclusive agreements; interest-based interaction critical to the work

Mark Norton, SAWPA, provides pros and cons, rationale and reasoning for a collaborative process to role-playing General Manager Lance Eckhart, Mojave Water Agency, during a workshop exercise.

Continued on the following page…

Collaborative Leadership Workshop: Negotiating Relationships to Improve Water Resources Planning – *Continued*

5. Implementation – operations, monitoring and adaptation.

These phases are not independent, but rather overlap into one another.

The stakeholder assessment process and product was discussed in some detail. Stakeholder assessments are a valuable tool to provide insight into stakeholders' levels of understanding of key issues and concerns, and also can be used to help identify the appropriate stakeholder groups and individuals to bring to the table for successful interest-based negotiations. All data are good data when it comes to a stakeholder assessment, which can be conducted at many levels, from phone calls to interviews. Key topics that are evaluated in a stakeholder assessment include:

1. Indications of clear desired outcomes
2. Existence of political leadership and executive commitment
3. Availability of economic and other resources to support process
4. Incentives for participation and opportunities to create shared value
5. Whether stakeholder groups have legitimate representatives.

Dave and Dorian then led four exercises that attendees participated in during the remainder of the workshop:

1. Sharing Examples of Collaboration – discussion and consideration of recent or current examples where stakeholder engagement was needed, who was involved and the process that was used
2. Developing Collaborative Governance – how does a process address stakeholder representation, decision-making, information and support, and communications
3. Building Support for a Collaborative Process – this involved a process to consider how to convince leaders and a governing body that a collaborative process is an appropriate effort to convene, and to sponsor this financially
4. Negotiating Authenticity – this exercise focused on developing and maintaining an authentic and transparent process when leadership wants to short-cut the process or make a back-room deal.

The exercises were designed to have participants work through their real-life experiences with the challenges of initiating and sustaining collaborative efforts. Subsequent discussion examined different options that participants had for addressing specific challenges, the tradeoffs associated with different approaches, and strategic tips for working through sticky situations.

In summary, collaborative leadership is a necessary skill for today's professionals working in the complex natural resource management field; it is hard work, takes time, and is outside most people's comfort zone, but the rewards exceed the efforts. Decisions reached through a collaborative process will endure better than quick, less difficult, so-called "fixes." With the very positive response from workshop participants, GRA will likely conduct more events involving collaborative approaches to groundwater management in the future, so stay tuned to our website at www.grac.org. To learn more about the Center for Collaborative Policy, visit http://www.csus.edu/ccp/.

GUEST EDITORIAL

California Well Completion Reports: Is there a compelling reason to make them more widely available?

By Bob Pierotti, PG, CEG, CHG

The State of California requires water well drillers to file Well Completion Reports (Reports) for water wells, cathodic protection wells, and groundwater monitoring wells. Those Reports are confidential and access to them is limited to governmental agencies for making studies, to persons conducting environmental site cleanup studies under order of a regulatory agency, to the well owner, and to persons with authorization from the well owner.

I have been working with the Reports at the Department of Water Resources since the mid-1980s and have a keen interest in any legislation that would affect the Reports. The issue of confidentiality may be the most controversial aspect of the Reports and tends to spark the most debate.

In 2011, Senate Bill 263 (Pavley) was introduced to extend access to the Reports to various groups of people, and in 2012, Senate Bill 1146 (Pavley) was introduced to make the Reports available to the public. Neither of these bills was enacted.

In following the progress of those bills through the Legislature, I found that proponents and opponents of these bills made several inaccurate, exaggerated, vague, and misleading arguments and assertions. For that reason, I was motivated to write a paper in which I critically evaluate arguments in support and in opposition to making Reports more widely available and present in-depth information regarding the purpose of the Reports and the reason for the confidential status.

Proponents of these bills generally argue that Reports should be available to the public because other states make well driller reports available to the public, other people need the Reports for various purposes, and that groundwater management requires the Reports be available to the public.

However, does California have the same history, the same approach to groundwater management, and the same reasons for requiring driller reports as other states? Are laws regarding driller reports in other states relevant to California?

If groundwater management is a role of governmental agencies, and if Reports are available to governmental agencies, have proponents persuasively argued that public access to Reports would improve groundwater management in California?

Opponents argue that making Reports available to the public would jeopardize security of water wells and make them vulnerable to vandalism and terrorist attack. However, is such an attack likely? Would water wells specifically be likely targets for terrorist attack? Would access to Reports increase the risk that water wells would be targeted? Have any water wells been attacked or sabotaged by terrorists in those states that make well logs available to the public?

Opponents make arguments related to property rights and proprietary rights of well owners. Should well owners be required to make detailed information about their water wells available to the public? Is it reasonable that information paid for by one person must be provided without their consent to other people who would use that information for their own benefit?

If property owners may extract groundwater from beneath their properties without obtaining a permit from the State and if owners are not required to report the amounts of water extracted or to allow their water levels to be measured, should they be required to make their Reports available to the public?

My intent in writing the paper (linked below) is not to argue either for or against making the Reports more widely available. Rather, I wrote the paper on the premise that public policy decisions should be based on accurate information and on sound reasoning. All parties should strive to present only accurate information, and parties seeking to change a policy have a responsibility to make compelling and persuasive arguments for the change. I hope that you find the paper informative, and I hope that the paper will provide more complete and accurate information, which will be useful for making good decisions about the appropriate use of the Reports.

The interpretations, opinions, and conclusions in the paper are those of the author, not the Department of Water Resources, the State of California, or the Groundwater Resources Association.

Link to the paper: http://www.grac.org/well-logs-pierotti.pdf

Bob Pierotti is Chief of the Resources Assessment Branch, California Department of Water Resources, Southern Region Office, Glendale, California. bob.pierotti@water.ca.gov.

Note from the Editor: GRA welcomes editorials from all perspectives, and will consider contributions with different points of view on this subject. Please submit short comments on the subject, or express interest in a guest editorial, to Steven Phillips at editor@grac.org.

Dates & Details

GRA EVENTS & KEY DATES

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

GRA Legislative Symposium and Lobby Day
Apr. 8, 2014 | Sacramento, CA

GRA Board Meeting
May 17-18, 2014 | San Diego, CA

GRA Symposium
14th Biennial Symposium on Managed Aquifer Recharge
Jul. 31-Aug. 1, 2014 | Anaheim, CA

Groundwater Resources Association of California

In cooperation with the

California Groundwater Coalition

Annual Legislative Symposium and Lobby Day

APRIL 8, 2014 – SACRAMENTO, CA

Register for this Event – http://www.grac.org/legreg

Hear from California's most influential Legislators and Administration Officials on California groundwater management, including these hot topics:

- Impacts of and planning for drought in California's groundwater basins
- 2014 Administration and legislative groundwater initiatives
- California Water Action Plan
- SWRCB Groundwater Management Work Plan
- 2014 water bond prognosis
- State Water Plan's groundwater content enhancement
- Fracking
- BDCP
- Delta Vision Foundation update including expanded storage
- Drinking Water Program transfer to SWRCB
- Funding for groundwater programs
- And much more…

SYMPOSIUM LOCATION: Citizen Hotel, 926 J Street, Sacramento, CA 95814
Register online at: http://www.grac.org/legreg
Questions? Contact Rosanna Carvacho RCarvacho@BHFS.com or Chris Frahm at cfrahm@bhfs.com or (916) 594-9714.

CALL FOR ABSTRACTS

Groundwater Resources Association of California and the Arizona Hydrological Society Present:

JULY 31 - AUGUST 1, 2014 – ORANGE, CA

Cooperating Organizations: Orange County Water District | University of Arizona Water Resources Research Center
California Association of Groundwater Agencies | Water Replenishment District of Southern California
United States Geological Survey | Lawrence Livermore National Lab | National Water Research Institute
Salt River Project (Phoenix, AZ) | California State University East Bay | California Water Boards
Orange County Water District Groundwater Guardian Team | City of Phoenix
The Recharge Initiative (University of California Santa Cruz)

From 1978 to 2007, thirteen symposia on Managed Aquifer Recharge (MAR) were held in Arizona at approximate 2 year intervals. These symposia were important venues for policy-makers, practitioners, researchers, and educators to learn about the policies, regulations, and technical challenges affecting MAR. The information shared at these symposia moved the understanding and utilization of MAR rapidly forward. Today, MAR is understood as being a key part of a sustainable water resources management strategy. Even so, there is still much work that needs to be done to better understand how MAR can be used to more efficiently utilize our increasingly scarce water supplies.

The Groundwater Resources Association of California and the Arizona Hydrological Society are proud to team up to re-start this symposia series with the location of the event alternating between California and Arizona. The 2014 event was designed with families in mind as the hotel is only two miles from Disneyland. The hotel offers discounted Disneyland tickets and has a dedicated shuttle that runs to and from Disneyland every hour. More information will be forthcoming about the venue and the many nearby attractions.

The 1.5 day symposium will feature numerous oral presentations, poster presentations, an awards luncheon as well an optional workshop and field trips the day prior to the symposium. Abstracts are being sought for oral and poster presentations on the topics listed below.

MAR Testing, Design and Construction

- Advanced methods for selection of aquifers, sites and methods
- Designing for storm water capture
- Predicting sediment loading/clogging
- Alternative recharge systems
- Innovation in harvesting and storing flood waters
- Overcoming the hydrogeology/engineering disconnect

MAR Operations and Maintenance

- Monitoring and modeling
- Tracer testing
- Clogging management
- Fate of pathogens and pollutants
- Geochemistry and hydrogeology
- Groundwater hydraulics and storage recovery
- Training for MAR operators
- Long-term maintenance requirements/budgeting
- Modifying operations for long-term sustainability

MAR Governance

- Integrated water resources management
- Recharge policies, standards and regulations

Continued on the following page…

14th Biennial Symposium on Managed Aquifer Recharge – *Continued*

- Community engagement and awareness in MAR
- MAR to complement groundwater demand management
- Legal issues related to storm water capture by MAR systems

MAR and Water Resources Management

- Reclaimed water reuse via MAR
- Storm water harvesting via MAR (MS4 permitting, etc.)
- Quantification of benefits and costs of MAR
- MAR for drinking water quality improvement
- MAR with desalinated water
- Mining and industrial applications of MAR
- MAR to source heat pumps and geothermal injection
- Mitigating geological problems using MAR - land subsidence, seawater intrusion, etc.
- MAR for rural and irrigation water supplies
- MAR in conjunctive use of surface water and groundwater

MAR Case Studies

- Success factors for projects that worked
- Lessons learned from projects that did not work

Other Issues related to MAR

- MAR and climate change
- MAR in urban areas
- Greenhouse gas considerations in MAR operations

Abstracts are due on March 21, 2014.

Guidelines for submitting an abstract can be found at: http://www.grac.org/abstractguidlines.asp.

To submit an abstract go to http://www.grac.org/BSMAR14-abstracts.

Optional Workshop and Field Trips: July 30

Jean Moran (California State University East Bay), Ate Visser, Michael Singleton and Brad Esser (Lawrence Livermore National Laboratory) will offer a workshop on application of extrinsic and intrinsic tracers in MAR.

Two field trips will also be offered with a morning trip to the Orange County Water District's (OCWD) Groundwater Replenishment System (www.gwrsystem.com) and seawater intrusion barrier and an afternoon trip to OCWD's surface recharge system. More information about the workshop and field trips will be forthcoming.

Herman Bouwer Award: July 31

In honor of Dr. Herman Bouwer's contributions to the field of MAR, an award named for Dr. Bouwer will be presented during a special luncheon on July 31. The award will be given to an individual or agency that has had a significant impact on increasing the understanding or utilization of MAR. A description of the award can be found at http://www.grac.org/bouwer-award.pdf. To nominate someone for the award, go to http://www.grac.org/bouwer-nomination.pdf.

Sponsor and Exhibitor Opportunities

If you are interested in exhibiting your organization's services or products, or being an event co-sponsor, please contact Sarah Kline at skline@grac.org or 916-446-3626.

For additional information: contact Adam Hutchinson (ahutchinson@ocwd.com; 714-378-3214) or Chris Petersen (cpetersen@westyost.com; 530-792-3239).

COMING THIS FALL

Groundwater Resources Association of California

Land Subsidence in California – a Continuing Problem

GRA is organizing a symposium on the subject of land subsidence to be held in the fall, in northern California (TBD). The prevalence of drought conditions in California since 2007, and the related decline in surface-water supplies, has led to extensive groundwater extraction and associated subsidence rates approaching 1 foot per year. Concern over these very high, unsustainable rates of subsidence and the resulting costly damages to flood-control, water-delivery and other structures is driving the need for this symposium.

Groundwater extraction is known to cause compaction of clay layers in the alluvial deposits of the Central Valley and other locations in the state, but there is no statewide program to monitor or address subsidence. The various causes of subsidence include those tied to geologic processes and those associated with man's extraction of groundwater and petroleum. Subsidence caused by petroleum extraction was addressed many years ago by the legislature. Subsidence caused by groundwater extraction, however, is like the wild west—there is little organized monitoring, little organized control, and minimal awareness of the issue.

This symposium will address those issues and the need for an organized statewide effort that couples the monitoring of changes in land-surface elevation (the effect) with changes in groundwater levels (the cause). Such an effort will require funding for establishment and long-term maintenance of monitoring networks, development of a database or data portal for compilation and dissemination of subsidence-related information, and establishment of a data analysis program. Results from this statewide effort would inform local, regional and statewide management actions and the need (or not) for supporting regulation. Funding for such data, evaluation, and regulatory programs is always a touchy political issue because of a lack of understanding on the part of many policy makers and local entities about the long-term consequences of ignoring subsidence, and many competing needs for limited funds. It is GRA's intent to bridge that lack of understanding with this symposium. Subsidence is an issue that has been ignored for too long.

Key topics to be addressed in the subsidence symposium include:

- The various causes of subsidence, the difficulty in distinguishing causes, and how monitoring can help discriminate
- Case studies of areas where groundwater extraction has caused subsidence
- The importance of depositional environment, clay mineralogy, and other geologic factors in determining subsidence risk
- Recent advances in subsidence monitoring methods
- Simulation of land subsidence
- The effects of land subsidence and associated economic and environmental costs
- Subsidence management – local case studies and considerations for statewide implementation.

For more information on the subsidence symposium, contact Vicki Kretsinger Grabert (vkretsinger@lsce.com), Sarah Raker (Sarah.Raker@amec.com), or Steve Phillips (sphillip@usgs.gov).

Wells and Words

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

Evaluation of the Recovery Period of a Pumping Test

A constant-rate pumping test includes pumping and recovery periods, as discussed previously in Wells and Words[1]. The recovery period is an important and independently-derived data set that measures well and aquifer performance and can serve to substantiate conclusions and parameter values estimated from the pumping period. The additional cost to record the recovery period is typically small relative to that for the pumping period. In addition, if the pumping period data are compromised or corrupted due to mechanical-, electrical-, or human-induced problems, then the recovery period may be used to salvage the test.

Problems occurring during a "constant-discharge" pumping period may include unstable and variable pumping rates and/or inaccurate or missing water-level measurements. Constant-rate pumping tests are *just that* – conducted at a constant discharge (Q); changes in Q exceeding 5% of the average Q are not acceptable for analytical analysis. Note that prolific or understressed aquifers may require a smaller tolerance level than 5%. Water levels should be measured to an accuracy of one-hundredth of a foot (0.01 feet) using an engineer's tape rather than one marked in inches. This will facilitate plotting and analyzing the data in the field – an important protocol. Field data analysis will allow adjustments (Q and elapsed time) to the pumping test to accommodate actual pumping water level (PWL) responses.

Unstable or variable pumping rates during a constant-Q aquifer test are common and can result from (1) a fluctuating power supply that operates the motor and pump, (2) excessive motor vibrations resulting in slippage of the engaged throttle, (3) excessively large PWL and/or total dynamic heads (TDH) that are not suited for the designed capacity and rating curves of the pump, (4) worn pump bowls and impellers affecting the pump efficiency curves, (5) extreme ambient air temperature fluctuations causing variability of the motor efficiency (especially diesel-powered engines), (6) entrainment of suspended solids and sand, (7) TDH fluctuations, and (8) operator negligence.

Inaccurate or missing PWL measurements can result from (1) improperly following pumping test protocols and data collection methods; (2) jamming (or getting stuck) of the water-level sounding probe between the pump column and the casing due to poor alignment and/or plumbness, or other issues; (3) poor (or no) calibration of the sounding device; (4) electrical power losses to data loggers; (5) insufficiently accurate sounding devices (e.g., air lines); (6) cascading water affecting small changes in the water level due to splashing, or causing false-positive water-level contacts; (7) operator error of sounding devices and measurement tools; and (8) clerical errors. Many of these water-level measurement issues can be eliminated or reduced with the installation of a small-diameter, rigid sounding tube strapped to the outside of the pump column. Note that PVC tubing used for a sounding tube has occasionally been observed to pinch and block access to the water level, resulting in measurement delays of water-level changes during pumping and recovery periods.

The recovery period can provide:

- "second-chance" opportunities from a flawed or poorly executed pumping period
- independent aquifer parameter estimates (especially transmissivity) for comparison with those from the pumping period
- supporting evidence of aquifer boundaries (recharge or barrier) determined during the pumping period
- verification of the relative efficiency of the pumping well[2].

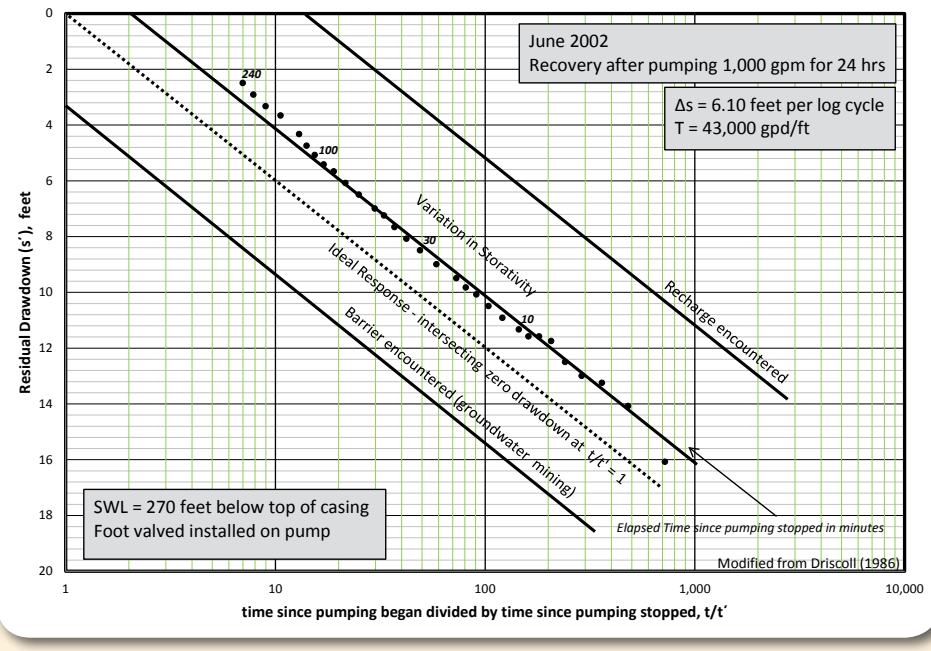
For most long-term pumping tests (> 8 hours), recovery measurements should be collected systematically for at least 120 minutes. An effective foot valve should be installed at the intake screen of the pump column such that when the pump is turned off the water in the pump column does not discharge into the well and impact the recovery period with an initial slug of water. Such a slug of water often "overcharges" the well, temporarily raising the water level above the original static water level (SWL). In addition, casing storage phenomena[3] can impact the early recovery data.

Figure 1 shows a family of possible plots for recovery data. The X axis (logarithmic scale) is the ratio of elapsed time since pumping began (t) to the elapsed time since pumping stopped (t´), or t/t´; it is unitless. The Y axis (arithmetic scale) is the residual drawdown[1]; the distance between the SWL and the recovery water level. Increasing elapsed time since pumping stopped goes from right to left, opposite the direction of similar semi-logarithmic plots of time-drawdown data for the pumping period. This type of analysis is referred to as the Theis Recovery Method[4,5]. It is important to select the straight-line segment of a t/t´ plot with the same interval used for the time-drawdown plot to estimate the transmissivity. Hence, it is recommended that some of the data

Continued on the following page…

Wells and Words – *Continued*

Figure 1: Theis Recovery Method or Residual-Drawdown Plot



points be labeled with the elapsed time since pumping stopped, as shown in Figure 1.

When the length of the pumping period is equal to that of the recovery period, the value of t/t´ is 2. The value of t/t´ approaches 1 as the length of the recovery period increases. Four recovery responses are shown on Figure 1. The middle solid line, which is associated with the recovery data in this example, shows a typical recovery response from a pumping test. The projection of the curve to zero feet of drawdown occurs at t/t´ = 2. This means that the well was pumped for 24 hours at 1,000 gpm and the curve projection for complete recovery is 24 hours. The dashed line shows an "ideal" or theoretical[6] response where the line intersects the t/t´ axis at 1 and the drawdown axis at zero. If the recovery curve is displaced upward, such that zero feet of drawdown occurs at t/t´ >> 2, then the cone of depression encountered a recharge boundary (e.g., surface water or a more permeable portion of the aquifer). A zero-drawdown intercept between a t/t´ value of 1 and 2 indicates a change in storativity[7] from the pumping period; this is where many recovery plots align. This change in storativity is commonly 20% of the storativity estimated from the pumping period[8]. If the recovery curve is displaced downward, such that zero drawdown occurs at t/t´ << 1, then the cone of depression encountered a barrier boundary (e.g., bedrock walls of an alluvial-filled valley or another cone of depression).

If the recovery response (not shown) is too rapid (recovering within minutes) then it may indicate the well is inefficient. An inefficient well will produce steep hydraulic gradients between the inside and outside of the casing. Accordingly, Darcy's Law predicts that a greater recovery rate would occur with an inefficient well with excessive drawdowns than would be anticipated with an efficient well with optimal drawdowns. A rapid recovery response is often confused with a "good" well, when in fact it may hint at an ineffective well development program[2]. Water-level recovery should mirror the drawdown observed during the pumping period. Because the hydraulic gradient from inside to outside of the casing decreases with t´, the recovery rate should also decrease with time, resulting in a methodical recovery rate rather than a rapid recovery response when the pump is turned off.

[1] Abbott, David W., 2010, Wells and Words - A Pumping Test Primer with Specific Reference to Time-recovery Data, *HydroVisions*, Summer 2010, Volume 19, Number 2.

[2] Noble, John B., 2000, Nobles Notes - *Bragging About Poor Wells* from Groundwater Reflections a Robinson & Noble Publication, Tacoma, WA, Volume 1, Issue 2, January-March. (www.robinson-noble.com)

[3] Abbott, David W., 2010, Wells and Words - Casing Storage - An often overlooked calculation that helps to interpret time-drawdown data from pumping tests, *HydroVisions*, Winter 2011, Volume 20, Number 4.

[4] Ferris, J.G., D.B Knowles, R.H. Brown, and R.W. Stallman, 1962, Theory of Aquifer Tests, USGS Water Supply Paper 1536-E, pages 69 to 174.

[5] Wenzel, L.K., 1942, Methods for Determining Permeability of Water-Bearing Materials, USGS Water Supply Paper 887, 192 pages.

[6] Driscoll, Fletcher G., 1996, Groundwater and Wells (second edition), published by Johnson Division, Saint Paul Minnesota, 1,089 pages.

[7] Bentall, Ray, 1963, Methods of Determining Permeability, Transmissibility and Drawdown, USGS Water Supply Paper 1536-I, pages 243 to 341.

[8] Hall, Phil, 1996, Water Well and Aquifer Test Analysis, Water Resources Publications, LLC, Highlands Ranch, Colorado, 412 pages.

Note from the Editor: in the previous edition of *HydroVisions*, the figure in Wells and Words was altered during the production process, which resulted in reduced clarity. The original version is posted here: http://www.grac.org/stokes-law.pdf

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 second half of the 2013–14 Legislative Session, it was immediately apparent that water would be a big issue in the Capitol and across the state this year. As the state continues to suffer through the driest year in recorded history, the Administration has spent the fall focusing on water, including a specific emphasis by the State Water Resources Control Board on groundwater. The fate of the water bond, still on the November ballot, remains uncertain.

On April 8th, GRA's Legislative Committee will host the Annual Legislative Symposium and Lobby Day, 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.

GRA Supported/Opposed Legislation

2013 was the first year of the two-year Legislative Session, and bills that did not move forward last year may move forward in 2014. Of all the bills that GRA took positions on in 2013, the following bills are considered "two-year bills" and may move forward this year. The Legislative Committee will review new bills introduced in 2014 to determine if GRA should take a position.

AB 69 (Perea) – Establishes the Nitrate at Risk Area Fund to fund solutions for disadvantaged communities with nitrate-contaminated drinking water. GRA supported the provisions of this bill that dealt with groundwater monitoring. The bill was not heard in committee but may receive a hearing in 2014.

AB 145 (Perea) – Transfers the duties and responsibilities related to the regulation and oversight of drinking water, including the authority to administer the Safe Drinking Water State Revolving Fund, from the Department of Public Health to the State Water Resources Control Board (SWRCB). GRA took an oppose-unless-amended position on the bill, which was held in the Senate Appropriations Committee.

Even though AB 145 did not move forward last year, the Administration has decided to move the Drinking Water Program (DWP) to the SWRCB. The Administration announced its intent to move the DWP in the summer of 2013, held stakeholder meetings throughout the fall and included the transfer in the Governor's proposed 2014–15 budget that was released on January 9th.

On January 15th, the California Environmental Protection and Health and Human Services Agencies held a joint hearing for public comment on the transfer of the DWP. Assuming the budget that the Legislature passes includes the DWP transfer, it will go into effect on July 1, 2014. More info. is available at http://www.waterboards.ca.gov/drinkingwater/.

Water Bond

The $11.14 billion water bond passed by the Legislature in 2009 is currently on the November 2014 ballot. Last year the Legislature grappled with proposals that would replace the current bond with a smaller bond. Both of the bond proposals outlined below are currently around $6.5 billion.

The Assembly Water Bond Working Group's proposal, AB 1331 (Rendon), is still in the Senate Natural Resources and Water Committee awaiting a hearing. It is expected that this bill, which is considered the Assembly's proposal, will get a hearing in the Senate in March.

Last year, Senator Wolk introduced SB 42, another water bond proposal that was amended in August to closely mirror AB 1331. Due to Legislative deadlines, SB 42 died in committee, but Senator Wolk introduced SB 848 on January 9th to take its place on this year's legislative agenda. On January 14th the Senate Natural Resources and Water Committee held an Informational Hearing on SB 848 and the committee members provided Senator Wolk with feedback on the current draft of the bill. SB 848, which is considered the Senate's proposal, will receive its official bill hearing in the Senate Natural Resources and Water Committee on February 11th.

As the year progresses and both AB 1331 and SB 848 move through the Legislative process, compromises will need to be made between the Senate and the Assembly, as well as the Governor, if the current bond will be replaced with something different. At this point the Governor has remained silent as to whether or not he wants to replace the current bond, and if so, what he wants to see in the new proposal. All indications are that the Governor does not believe that the water bond should be on the November ballot. Legislation can be viewed on the web at http://leginfo.legislature.ca.gov/.

Continued on the following page…

Legislative Update – *Continued*

California Water Action Plan

In late November, GRA submitted comments on the draft California Water Action Plan (CWAP) that was released in late October by the Natural Resources and Environmental Protection Agencies in conjunction with the Department of Food and Agriculture. The CWAP, according to the Administration, lays out "goals and vision for the next five years" and "will guide state efforts to enhance water supply reliability, restore damaged and destroyed ecosystems, and improve the resilience of our infrastructure."

The final CWAP was released on January 27th and can be viewed here. The Governor's proposed 2014–15 budget includes $618.7 million for implementation of the CWAP. The Legislative Committee will be reviewing the CWAP closely and will continue to provide comments.

SWRCB Groundwater Workplan Concept Paper

GRA submitted verbal and written comments to the SWRCB on its Draft Groundwater Workplan Concept Paper (Workplan). On January 22nd the SWRCB held an all-day public workshop to consider input on this Workplan. The Legislative Committee will continue to monitor the drafting of the SWRCB's Workplan and provide further comments. The draft SWRCB Work Plan can be found at http://www.swrcb.ca.gov/water_issues/programs/groundwater/workplan.shtml.

Hydraulic Fracturing Regulations

In January, GRA and the Association of California Water Agencies (ACWA) submitted comments on the proposed Division of Oil, Gas, and Geothermal Resources' (DOGGR) regulations for Well Stimulation Treatment Methods (includes Hydraulic Fracturing). Both Associations recognize that the potential for water-quality degradation through increased oil and gas development exists. That said, GRA and ACWA do not seek the much called-for moratorium on fracking. Instead, they remain focused on the preservation of the water quality in local and regional aquifers and watersheds. More information is available at http://www.conservation.ca.gov/dog/Pages/Well-Stimulation.aspx#Item1.

Continued Changes in the Legislature

In September, Assemblymember Holly Mitchell was elected to the Senate to represent the 26th Senate District. Senator Mitchell's election to the Senate left a vacancy in the 54th Assembly District, which was filled in December with the election of Assemblymember Sebastian Ridley-Thomas. Additionally, Assemblymember Matthew Dababneh was elected in November to fill a vacancy in the 45th Assembly District.

Lastly, as of December 1, 2013, Senator Bill Emmerson, who represented the 23rd Senate District, resigned. This is currently the only vacancy in the Legislature. A Special Primary Election will be held on March 25th and, if needed, a Special General Election on June 3rd.

These elections have led to only one change in the committees most important to GRA – Assemblymember Freddie Rodriguez was appointed to the Assembly Water, Parks and Wildlife Committee.

Appointments

In January, Governor Brown reappointed Dorene D'Adamo to the State Water Resources Control Board, where she has served since 2013. This position requires Senate confirmation.

Looking Ahead

2014 is shaping up to be a very important year for groundwater and water in general in California. With what appears to be the driest year on modern record in many areas of the state, water restrictions, reduced water deliveries, and a drought declaration made by the Governor on January 17th, all things water are and will continue to be at the forefront of California policy discussions. Of course, drought means expanded groundwater pumping to support demands usually met by limited surface-water supplies. GRA will continue to be a key source of information and sound science for Legislators and the Administration. As the year and legislative session progresses, GRA's Legislative Committee and its Legislative Advocates will continue to monitor issues and legislation important to GRA.

SAVE THE DATE
April 8, 2014
Annual Legislative Symposium and Lobby Day

The Federal Corner

By Jamie Marincola, U.S. EPA

EPA's Climate Change Adaptation Technical Fact Sheet: Groundwater Remediation Systems

EPA has undertaken efforts to identify potential impacts of climate change on site remediation projects and to identify adaptation strategies. EPA's new Climate Change Adaptation Technical Fact Sheet: Groundwater Remediation Systems is the first in a series intended to serve as an adaptation planning tool by providing an overview of potential climate change vulnerabilities and presenting possible adaptation measures that may be considered to increase a remedy's resilience to climate change impacts. To learn more about climate change adaptation being done by EPA's Superfund Program, visit www.epa.gov/superfund/climatechange.

EPA reaches $3 million settlement to clean groundwater in Mountain View

EPA reached a settlement with CTS Printex, Inc. and ADN Corporation to complete the remaining groundwater contamination cleanup at the CTS Printex Superfund site in Mountain View, CA. The companies will spend about $2 million to monitor and treat low levels of contaminated groundwater remaining at the site, and will monitor to ensure that vapor intrusion does not impact residents of current or future buildings on the site. This settlement also provides for reimbursement of $850,000 to EPA for costs incurred. For more information about vapor intrusion, visit http://www.epa.gov/oswer/vaporintrusion/.

Renewed Land Subsidence Poses Risk to Water Infrastructure in San Joaquin Valley

Extensive groundwater pumping from San Joaquin Valley aquifers is increasing the rate of land subsidence, or sinking. This large-scale and rapid (rates approaching a foot per year) subsidence has the potential to cause serious damage to infrastructure that brings water from the north to the south where it helps feed thirsty cropland and cities. According to a new report by the U.S. Geological Survey the subsidence is occurring in such a way that there may be significant operational and structural challenges that need to be overcome to ensure reliable water delivery. The report concentrates on subsidence along the economically vital Delta-Mendota Canal in the northern San Joaquin Valley, but also includes data from a subsequently discovered and much larger subsidence area that touches the canal on the southwest. The report, *Land subsidence along the Delta-Mendota Canal in the northern part of the San Joaquin Valley*, California, 2003-10, is available at http://pubs.usgs.gov/sir/2013/5142/.

CA South Coast Groundwater Quality: Nitrate More Prevalent at High Concentrations than Statewide

Nitrate was detected at high concentrations in 10 percent of the aquifer system used for public supply in coastal areas of Santa Barbara and San Luis Obispo counties, according to a new U.S. Geological Survey report. Trace elements, such as naturally occurring arsenic and molybdenum, were found at high concentrations in 27 percent of the aquifer system. Elsewhere in California, high concentrations of nitrate have generally been found in less than 1 to 8 percent of the groundwater used for public supply, and trace elements in 6 to 28 percent. To read more, visit: http://ca.water.usgs.gov/news/2013/SouthCoastRangeCoastalGroundwaterQuality.html.

EPA removes nearly 2,000 acres of El Toro site from Superfund list

EPA deleted more than 1,900 acres of the former El Toro Marine Corps Air Station in Irvine, CA from the National Priorities List of Superfund sites. Hazardous wastes at this major portion of the site were cleaned up through activities that included soil sampling and excavation. To date, the Navy has spent approximately $165 million on the cleanup, and anticipates that the remaining work will cost an additional $50 million. For more information on the El Toro Superfund Site, please visit: http://epa.gov/region09/eltorousmc.

Green Remediation Best Management Practices: Materials and Waste Management

The process of cleaning up a contaminated site often involves purchasing and consuming large volumes of manufactured items as well as raw or processed resources. Site cleanup can also generate significant volumes of waste that could be recycled or salvaged for reuse rather than disposed of at landfills. To help cleanup decision-makers reduce environmental footprints associated with materials and waste, the EPA recently issued a new "green remediation BMP" fact sheet on materials and waste management. The best management practices (BMPs) involve various approaches to purchasing greener products and expanding capability for material reuse or recycling. To view the fact sheet, visit: http://clu-in.org/techpubs.htm.

Jamie Marincola is an Environmental Engineer at the U.S. Environmental Protection Agency, Region 9. He works in the Water Division on Clean Water Act permitting and community outreach. For more information on any of the above topics, please contact Jamie at 415-972-3520 or marincola.jamespaul@epa.gov.

Martian Chronicles

By Bart Simmons

Whether Mars ever hosted life is still up for debate, but there is no question that water existed in sufficient quantity for erosion, deposition, and formation of rock. Elemental analysis of sedimentary rocks provided by the Mars Exploration Rovers Spirit and Opportunity has been supplemented by observations from the Mars Science Laboratory Curiosity. Curiosity landed in Gale crater, and then explored an area known as Yellowknife Bay, which contained a five meter thick succession of sedimentary rocks. There it studied the surfaces and drill cuttings, using a Dust Removal Tool. Samples were tested using an alpha particle x-ray spectrometer (APXS) and a laser-induced breakdown spectrometer (LIBS), which is part of the ChemCam remote sensing instrument package. APXS provides elemental analysis on areas about 2 cm^2. LIBS can provide elemental composition on areas about 1 mm^2 and up to 1 mm depth. Recently published reports (e.g., January 24, 2014, vol. 343, *Science*) show evidence of surface-water and groundwater effects.

The results suggest that surface-water conditions evolved from near-neutral clay to acidic sulfate-rich deposits. Thus, the Martian evolution has some similarity to Earth's geologic record.

Yellowknife Bay contained alluvial material which formed 2 to 3.5 billion years ago. There is evidence of chemical sedimentation with sulfates, carbonates, and chlorides in the Yellowknife Bay sedimentary system, similar to the deposits in Death Valley on Earth. Yellowknife Bay geochemistry is consistent with a highly arid climate and/or a significant effect of flowing water.

Comparing Yellowknife Bay findings with data from other locations on the planet shows a variety of conditions existed on Mars. Data from an area called Meridiani Planum suggest high ionic-strength surface waters, although it has evidence of an arid history. Groundwater was undoubtedly affected by the surface water. It would produce dilute, neutral-pH subsurface water in the Yellowknife system, but another element of the crater, the Burns formation, shows signs of very low pH and very high ionic strength. The Burns formation largely consists of chemically precipitated sulfates and chlorides formed by the evaporation of acidic brines.

Basaltic debris in the Burns element of Gale Crater was highly chemically weathered before deposition; in contrast, Yellowknife Bay detritus appears to be essentially unweathered. Alkaline deposits in an area called Glenelg are rarely found on Earth.

There is evidence of 1-3% meteoritic rock. Consistent with that finding was the inference of 300-1200 ppm carbon.

The geochemistry of Mars appears to be as varied as that of Earth, with water playing a major role in formation, alteration and movement of minerals. The same tools developed for Earth exploration are directly applicable to the Martian landscape, and presumably to other exoplanets as well.

Bart can be reached at bartonps@aol.com.

GRA Requests Nominations for the 2014 "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 20, 2014**.

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 23rd GRA Annual Meeting in Sacramento, CA, September, 2014.

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:

- **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*

Continued on the following page…

GRA Requests Nominations for the 2014 "Lifetime Achievement" and "Kevin J. Neese" Awards – *Continued*

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:

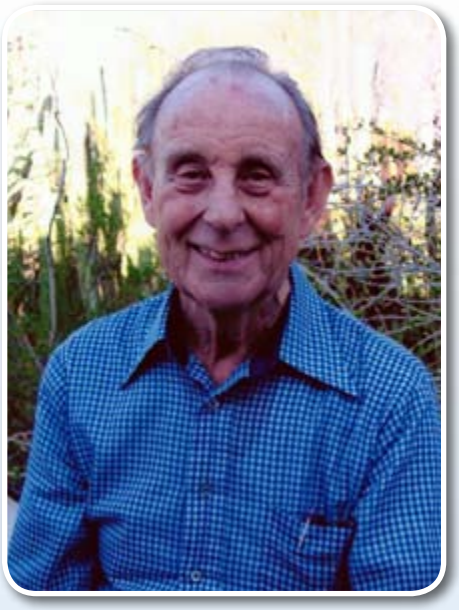
- **2013** – Santa Clara Valley Water District for implementing its unique Domestic Well Testing Program
- **2012** – David L. Orth, General Manager of the Kings River Conservation District for his leadership and dedication to the collaborative initiatives to develop the Upper Kings River Basin Integrated 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 (GRS), 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
- **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.

The Herman Bouwer Award

Herman Bouwer had a long and distinguished career and was one of the world's leading researchers in water resources management, particularly in the area of managed aquifer recharge. He authored more than 300 publications including 12 book chapters and the textbook *Ground Water Hydrology* (McGraw-Hill, 1978). He served on several US National Academy of Sciences – National Research Council committees, consulted on numerous recharge projects, received an OECD Fellowship in 1964 for studying recharge in The Netherlands and Germany, and gave seminars and short courses on artificial recharge in the U.S., India, Jordan, Tunisia, and Morocco.

He was a native of The Netherlands, where he survived World War II and the Nazi occupation. He received his MS from Wageningen University in drainage and irrigation in 1952, and his Ph.D. in 1955 from Cornell University in soil and water management. After five years in the Agricultural Engineering Department of Auburn University, Alabama, he joined the U.S. Water Conservation Laboratory, U.S. Department of Agriculture in Phoenix, Arizona where he worked for 43 years and served 18 years as Director. He retired in early 2002.

In 2004, Herman received the Prince Sultan Bin Abdulaziz International Prize for Water for his work on underground water movement with emphasis on artificial recharge, water reuse, and surface and groundwater interactions. Herman took a significant portion of the award money and gave it to the Arizona Hydrologic Society (AHS) to establish the AHS Foundation with the intent to provide long-term assured funding for annual scholarships to assist outstanding and deserving students in water resources. In 2007, Herman received the Groundwater Resources Association of California (GRA) Lifetime Achievement Award.



In honor of Dr. Bouwer's significant role in advancing our understanding of managed aquifer recharge, the GRA and AHS have created the Herman Bouwer Award. The award will be presented every two years at the Biennial Symposium on Managed Aquifer Recharge (BSMAR) to the person or agency that has significantly advanced the understanding or utilization of MAR. Members of the GRA and AHS can submit nominations for the award; however, sitting board members or branch officers are ineligible for the award. The BSMAR planning committee will select the award winner. The money raised for the award will be given to GRA/AHS student scholarship funds to be given to students studying MAR related topics.

To nominate someone for the award, please go to http://www.grac.org/bouwer-nomination.pdf.

The description of the award can be found at http://www.grac.org/bouwer-award.pdf.

Meeting on Improving Groundwater Management at the Governor's Office

February 12, 2014

A Summary by Tim Parker, GRA Director, Parker Groundwater

Improving Local Groundwater Management was the subject of a meeting in the Governor's Office from 12 to 1PM on February 12, 2014. The meeting was hosted by Martha Guzman-Aceves, Governor Brown's Deputy Legislative Affairs Secretary for Environment, Energy, Water and Agriculture; Mark Cowin, Department of Water Resources Director; Felicia Marcus, State Water Resources Control Board Chair; and Jim Houston, Legislative Deputy Secretary, California Department of Food and Agriculture.

The purpose of the meeting, attended by approximately 75 members of the water and groundwater industry, was for the Administration to recognize the immediate need for addressing groundwater challenges statewide.

1. The Administration acknowledged the importance of state groundwater resources, and understands that there are significant challenges, including long-term and chronic groundwater-level declines due to overexploitation in many basins, related land-surface subsidence, and groundwater quality degradation – many communities do not have clean drinking water.
2. The Administration also recognized the seriousness of the current drought, which has exacerbated declining groundwater conditions as water users turn to wells for relief; however, addressing the drought was not the meeting focus.
3. The Administration indicated that the time has come to address these groundwater quality and quantity challenges – not in the context of the drought, but for the long-term; California can wait no longer.
4. The Administration asked:
   a. What additional tools do local agencies need to help manage groundwater, and what barriers need to be overcome in areas where there are significant challenges; and
   b. At what time, and how, should the state step in when local agencies are not effectively managing groundwater resources?

Again, this is not just a reaction to the drought and our associated increased reliance on groundwater resources. We also use groundwater resources and storage to increase regional independence. The challenge at the state level is just how, and when, to leverage state resources to support local needs.

Currently, a myriad of conversations are taking place across the state regarding long-term sustainability of our groundwater resources. People are realizing that we need to figure this out together, as a series of communities. The State Board is asking how the state can, under appropriate authorities, be helpful in improving groundwater management, where needed, to address groundwater quality and quantity challenges. The groundwater community seems to cautiously appreciate the state leadership, and the state clearly appreciates the ongoing leadership of the groundwater community, because the reality is that we have to figure this out together. With climate change, we all clearly understand the need for enhanced surface-water and groundwater storage, and the need to optimize the local, state and federal surface-water storage and delivery systems in an integrated way. Enhancements are also needed for storm-water capture, recycled water use, and groundwater recharge.

The Administration is looking for help in refining the approach to groundwater management with the over-arching goal of long-term sustainability, and recognizes that the core principle must be local management. The backstop is the state stepping in when local management is not effective.

The state would like to put together a comprehensive legislative package to address groundwater management needs. To accomplish this, they need to know the types of legal authorities and technical support needed for local agencies to improve groundwater management. On a related topic, the state is interested in hearing how groundwater management plans relate to integrated regional water management plans.

The Administration will hold two public meetings, in March and April, to receive public input; they are requesting public input on these key issues by mid-April. It is anticipated that the Administration will address these issues with either legislation or a budget trailer bill in June of this year. The Legislature is also likely to have a number of groundwater bills this session.

Stay tuned to www.grac.org – it is going to be a busy session, and GRA will be actively participating and providing information to the membership through the webpage and mass emails as appropriate.

GRA Welcomes the Following New Members

NOVEMBER 16, 2013 – FEBRUARY 13, 2014

Anselmo, Alan	ETIC Engineering
Atkinson, Holly	S.S. Papadopulos & Associates, Inc.
Barajas, Maria	BSK Associates
Bauer, James	Sustainable Technologies
Borchers, James	Consultant
Brown, Carson	Curtis & Tompkins, Ltd.
Campbell, Michael	
Cannon, Debbie	Luhdorff & Scalmanini C.E.
Carte, Margaret	PIKA International, Inc.
Carvacho, Rosanna	Brownstein Hyatt Farber Schreck
Charter, David	
Dahl, Douglas (Jack)	E-PUR, LLC
Dhaliwal, Pavan	Luhdorff & Scalmanini C.E.
DiGuiseppi, William	CH2M HILL
Divine, Craig	ARCADIS
Dorrance, Lydia Roach	Dudek
Duncan, Mike	M.B. Duncan Inc.
Elarth, Vern	URS Corporation
Forbes, Scott	Kiff Analytical, LLC
Fuller, Peter	TERRA Solutions & Services
Gabriel, Ryan	San Francisco Public Utilities Commission
Gonzales, James	ARCADIS
Haney, Robert	MAR Systems Inc.
Hanzel-Durbin, Justin	TRC
Hart, David	
Hayes, Missy	MAR Systems Inc.
Heassler, Mary Jo	AMEC Environment & Infrastructure, Inc.
Jacobsen, Nathan	E-PUR, LLC
Jenkins, Charles	Charles Jenkins Law PC
Jimenez, Alejandra	
Kahn, Amanda	Taber Consultants
Kelley, Robert	ARS Technologies
Kievit, Kenneth	Roux Associates
Kincaid, Valerie	O'Laughlin & Paris LLP
Lalama, Richard	MAR Systems Inc.
Lee, Annie	Langan Treadwell Rollo
Leever, Bill	Brown & Caldwell
Lewis, Stephen	Barg Coffin Lewis & Trapp, LLP
Lojo, Andrew	Antea Group
Lopez, Jeana	San Jose State University
MacFarlane, Kim	E.&J. Gallo Winery
Marz, Nick	Eurofins Environmental Labs
Milczarek, Michael	GeoSystems Analysis, Inc.
Miller, Todd	Kennedy/Jenks Consultants
Montenero, Ernesto	Sustainable Technologies
Myers, Jason	Accutest Laboratories
Neil, Kenda	
Ohare, Michael	San Diego State
Panelo, Chris	Woodward Drilling Company, Inc.
Pattanayek, Mala	ARCADIS
Prentice, Craig	Fugro Consultants
Putty, Roger	MWH Americas, Inc.
Ries, Kim	Stantec
Rohrbaugh, Amanda	TechLaw, Inc.
Rojas, Esther	Water Replenishment District of Southern California
Sadwick, David	Tatro Tekosky Sadwick LLP
Shaw, Jeff	Stantec Consulting
Shoaf, Jena	Brownstein Hyatt Farber Schreck
Smith, Anthony	Geosyntec Consultants
Stallard, Mary	Montclair Environmental Management, Inc.
Stuebi, Richard	MAR Systems Inc.
Swanson, Catherine	Evoqua Water Technologies
Valdes, John	Sacramento Suburban Water District
York, Daniel R.	Sacramento Suburban Water District

GRA Extends Sincere Appreciation to the Co-Chairs and Sponsors for the 28th Symposium in GRA's Series on Groundwater Contaminants "Emerging Contaminants Symposium"

SYMPOSIUM CHAIRS

David Sedlak,
University of California, Berkeley
Kevin Sullivan, PG&E
Rula A. Deeb, Geosyntec Consultants

CO-SPONSORS

ARCADIS U.S.
Geosyntec Consultants

LUNCHEON SPONSORS

AECOM
MWH Global
TRS group, Inc.

RECEPTION SPONSORS

Battelle
CH2M HILL

REFRESHMENT SPONSORS

Roux Associates, Inc.
Stellar Environmental Solutions, Inc.

2013 Contributors to GRA – Thank You

(as of 2/24/2014)

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

PATRON *($500-$999)*

CORPORATE *($250-$499)*

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

SPONSOR *($25-$99)*
AECOM
Jeriann Alexander
Charles Almestad
Maria Barajas
Kevin J. Brown
Andres Cano
Han-Ting Chang
David Dunbar
Gail Eaton
John Elliott
EMAX Laboratories, Inc.
Joshua Ewert
Miranda Fram
Edana Fruciano
Scott Furnas
Jacob Gallagher
Chip Gribble
Griffith & Masuda
Haley & Aldrich, Inc.
David Harnish
Katrina Harrison
Carl Hauge
Barbara Hennigan
Hopkins Groundwater Consultants, Inc.
Mike Huggins
HydroFocus, Inc.
Hydrometrics Water Resources Inc.
Iris Environmental
Charles Jenkins
Christopher Johnson
Nicholas Johnson
Ian Jones
Karl Kienow
Valerie Kincaid
Ted Koelsch
Amalia Kokkinaki
Taras Kruk
Jeff Kubran
Peter Langtry
Joe LeClaire
Stephen Lewis
Wendy Linck
Mario Lluria
Richard Makdisi
Steven Michelson
Alec Naugle
Aaron O'Brien
Michael Ohare
Jonathan Parker
Tim Parker
PES Environmental, Inc.
Rob Pexton
Bryan Pilkington
Lisa Porta
Iris Priestaf
Richard Raymond
Eric Reichard
William Sedlak
Pawan Sharma
Marc Silva
Phyllis Stanin
Sustainable Technologies
Eddy Teasdale
The Source Group, Inc.
Stephen Van der Hoven
Michael Van Fleet
Donald Weir
WZI Inc.
Gus Yates
Steve Zigan

SUPPORTER
John W. Anthony
Guy Berger
Dan Day
Tim Rumbolz

GRA Extends Sincere Appreciation to the Co-Chairs and Sponsor for the "Groundwater Issues and Water Management – Strategies Addressing Challenges of Sustainability and Drought in California" Conference

CO-SPONSORS
Vicky Kretsinger-Grabert, Luhdorff & Scalmanini
Chris Petersen, West Yost and Associates
Steven Phillips, U.S. Geological Survey

REFRESHMENT SPONSOR
Hopkins Groundwater Consultants Inc.

Central Coast

By Jeff Kubran and Bryan Bondy
(outgoing and incoming
Branch Secretaries)

Dr. Loaiciga's presentation focused on the role of groundwater in soil stability during earthquakes. He discussed the effects of groundwater and seismicity on landslides, settlement, lateral displacement, liquefaction, and clay softening, and how these conditions can be analyzed via field measurements, laboratory analysis, groundwater-flow analysis, and numerical modeling.

Dr. Loaiciga discussed methods for evaluating slope stability and factor of safety determination with a focus on consideration of pore pressure. Results of a case study of a landslide where excess watering by an uphill neighbor caused a 200 foot long landslide showed that the slide initiated on the upper slope near a sand and clay contact where high pore pressures likely developed.

Given California's tectonic activity, Dr. Loaiciga stressed the importance of slope stabilities during earthquakes. He presented examples of large rotational toe slides in Japan that occurred after earthquakes and explained the role of groundwater in each case. He also discussed earthquake-induced liquefaction and soil deformation. Liquefaction is the loss of soil strength that occurs in saturated sandy soils under cyclic loading; examples were shown of buildings that sank and tilted during an earthquake. Soil deformation can occur in saturated clays and plastic silts during cyclic loading. He presented an example of a slide, that destroyed 75 homes, caused by clay softening during the Great Alaskan earthquake of 1964.

Mr. Bondy discussed the Calleguas Municipal Water District (Calleguas) Las Posas Aquifer Storage and Recovery (ASR) Project located near Moorpark, CA. Calleguas, an imported water wholesaler, built the project to provide an emergency water supply for its service area, which includes roughly three quarters of Ventura County's residents. As a project partner, Metropolitan Water District sought to store as much as 300,000 acre-feet of water to help provide a drought buffer in its service area.

The $155M Las Posas ASR project consists of eighteen wells and associated facilities, making it the second-largest ASR project in the United States. It was constructed between the mid-1990s and mid-2000s, and water storage began in 1995; by 2007, over 50,000 acre-feet of water had been placed into storage, mostly via in-lieu deliveries. In 2007, Metropolitan called for production to augment its supplies during the developing drought. By 2011, approximately 27,000 acre-feet of groundwater had been pumped from storage.

While pumping during the drought, it became apparent that project operations were impacting nearby wells and that the project has a unique set of challenges that had not yet been fully understood and addressed. Mr. Bondy was hired by Calleguas in 2012 to investigate these challenges and develop a long-term plan for sustainable operation of the project. He discussed hydrogeologic factors affecting the project, including structural groundwater flow barriers that limited access to stored water in some areas, complications related to trying to achieve net storage of water in a basin that is continually recharged by a perennial creek, and limitations on accessing available storage in an overlying aquitard.

Mr. Bondy described his current efforts to improve groundwater monitoring around the ASR well field, develop a groundwater model of the basin, and develop a long-term operations plan with mitigation measures to address potential impacts to local well owners. He concluded with a discussion of lessons learned, emphasizing the importance of monitoring, building projects incrementally, and developing operations and mitigation plans before initiating operations.

The Central Coast Branch would like to thank our scholastic sponsor, General Pump, for their support.

Sacramento

By Troy Turpen,
Branch Secretary

November's Branch meeting featured Larry Ernst and Scott Speath's presentation on the *Assessment and Development of a Virgin Groundwater Basin in the Kelso Valley, California*. Mr. Ernst is a Principal Hydrogeologist with Wood Rogers and has over 30 years of groundwater and well experience; Mr. Speath is a Professional Geologist with Wood Rogers.

In order to supply a large Kern County wind energy project with its required water supply of 100,000,000 gallons for a construction period of six months, the Kelso Valley Groundwater Basin was identified as an alternative source of water versus trucking the water in from the City of Mojave. Their assessment of the shallow basin suggested that groundwater could be developed from the basin for the

Continued on the following page…

Sacramento – *Cont.*

project's water needs. A well field was constructed and provided reliable project water at half the cost of trucking water. Using the well field also reduced the negative environmental impacts (dust, wildlife road-kills, and carbon emissions) associated with trucking.

Our December Branch meeting was the traditional holiday meeting with the Association of Engineering and Environmental Geologists and featured a presentation by Dr. Horacio Ferriz of the CSU-Stanislaus Geology Department. Dr. Ferriz, with 25 years of academic experience, leads the Applied Geology concentration of the CSU-Stanislaus Geology program. Dr. Ferris is a PG and CEG in California and Mexico and is the Director of Water for the World, an educational project of the California State University with the goal of promoting capacity-building in the areas of development, management, and utilization of water resources. In this capacity, he went to Ethiopia as part of a humanitarian effort to control poverty. His presentation was on the Water Resources of Ethiopia.

Dr. Ferriz' presentation took a bird's eye view of the technical aspects of development of water resources, from direct use of surface waters to the tapping of groundwater in Ethiopia. Ethiopia typifies the conditions of many developing countries in terms of infrastructure, technical expertise, agricultural and industrial development, and the scope of its public agencies. The development of major water works is beyond the capability of single individuals, so in Ethiopia, more than ever, there has to be an integrated effort between user communities, the scientists and engineers that design and construct the water works, and the public agencies that help fund and manage such works. The geology, topography and climatic conditions of Ethiopia range over such extremes that lessons learned within the country have almost universal application.

The Sacramento Branch thanks our Scholastic Sponsor for November, Wood Rogers. Our Scholastic Sponsors continue to allow the Sacramento Branch to financially support Geology students at California State University, Sacramento.

San Francisco

By Jenny Cherney
Branch Secretary

On December 5, the San Francisco Branch of GRA had the first annual holiday mixer with the Association of Engineering Geologists (AEG) and the Northern California chapter of the Professional Environment Marketing Association (PEMA). The event provided an opportunity for members of these groups to mix and mingle over delicious food, drinks, wonderful conversation and a premium raffle. Raffle items were donated by members and participants. All proceeds from the event were donated to City-Slicker Farms, a non-profit organization based in West Oakland. The mission of City Slicker Farms is to empower West Oakland community members to meet the immediate and basic need for healthy organic food for themselves and their families by creating high-yield urban farms and backyard gardens.

In January, the Branch featured the always popular Regional Water Board's Annual Regulatory Update. The distinguished panel of presenters included Stephen Hill, Chuck Headlee, PG, Uta Hellmann-Blumberg, PhD, and John Wolfenden, PE.

Stephen Hill is the Toxics Cleanup Division Chief at the San Francisco Bay Regional Water Quality Control Board, a position he has held since 2000. The division oversees cleanup at soil and groundwater contamination sites in the region. Chuck Headlee is a Senior Engineering Geologist at the San Francisco Bay Regional Water Quality Control Board. As Underground Storage Tank (UST) program manager for the Regional Water Board, he provides technical support and oversight for Regional Water Board staff and to local agency UST programs throughout the nine Bay Area counties. Uta Hellmann-Blumberg is a toxicologist at the San Francisco Bay Regional Water Quality Control Board and is responsible for the Environmental Screening Levels and for reviewing site-specific risk assessments. John Wolfenden is a Senior Water Resources Control Engineer at the San Francisco Bay Regional Water Quality Control Board and has worked in several programs including underground storage tanks, site cleanup, NPDES permits, waste discharge requirements, watershed management, and planning.

The Regulatory Update panel discussed a variety of significant Water Board activities and issues in the site cleanup programs, including:

- Implementation of the State Water Board's UST low-threat closure policy
- Environmental screening levels update
- Vapor intrusion developments
- Pending regulatory strategy for dry cleaner spill sites
- Other Water Board news.

Fossil Falls

When snow and glaciers melted during the Pleistocene ice ages, water east of the central and southern Sierran crest flowed into the Owens River, greatly increasing its discharge. Fossil Falls and the downstream gorge is a relic of erosion during the youngest (Tioga) glaciation. The rim and canyon walls of the lower falls shown in this photograph are characterized by polished basaltic bedrock and potholes that were scoured by high-velocity sediment-laden waters along an irregular stream bottom.

During the mid-Holocene, climate in the west shifted towards warmer and drier conditions. Research by Larry Benson (USGS) and colleagues suggests that an extremely prolonged period of drought between approximately 6,480 and 3,930 years ago resulted in desiccation of Owens Lake, located approximately 40 kilometers upstream of this site.

Archaeologists indicate that Native Americans favored the area and established a major village on the west bank of the gorge a short distance downstream of the falls as early as 10,000 to 20,000 years ago. They fashioned arrowheads and spear points of obsidian, which was obtained from volcanic glass domes in the nearby Coso Range. During periods of prolonged drought, prehistoric human populations may have partially abandoned low-lying desert areas in search of food and water in upland mountains and more distant coastal areas.

Fossil Falls is conveniently located along Highway 395 near the Red Hill cinder cone and is protected as an area of Critical Environmental Concern by the Bureau of Land Management. Additional information is available at: http://www.blm.gov/ca/st/en/fo/ridgecrest/fossil.html.

Photograph taken at Fossil Falls (approximate GPS coordinates: 35°58'13" N 117°54'30" W) by John Karachewski, Ph.D. (www.geoscapesphotography.com)