GROUNDWATER RESOURCES ASSOCIATION OF CALIFORNIA
HYDRO VISIONS
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Summary of GRA's Workshop on The Role of Models and Data in Implementing SGMA

By Steven Phillips, Chair; Co-Chairs Graham Fogg, Thomas Harter and Ali Taghavi; and Moderators Sam Boland-Brien, Murray Einarson, Rob Gailey, Rich Juricich, and Jon Traum

The Sustainable Groundwater Management Act (SGMA) went into effect on January 1, 2015, and draft regulations on the development of Groundwater Sustainability Plans (GSPs) came out soon after this workshop, which was help on February 8–9, 2016, at UC Davis. The local GSPs will be due by January 31, 2020 for the 21 recently-defined critically overdrafted basins, and two years later for the 106 remaining high- and medium-priority basins.

To help the newly-forming Groundwater Sustainability Agencies get a running start, GRA organized this workshop to provide information on the role that models and data can play in meeting SGMA requirements and enabling well-informed management decisions. The workshop featured topics critical to the success of GSP development and implementation, including:

- The State perspective on models and data in support of GSP development & implementation
- Water budgets – what they are, minimum data requirements, how best to quantify, and how they inform basin management
- "Undesirable results" – modeling and data approaches, and case studies
- Case studies of models currently used in basin management
- Addressing uncertainty in data and models
- Leveraging key data sources and data management considerations
- Updating and continual improvement of models
- Including economics in models & providing decision support
- Monitoring vs. Models – the challenge of developing a successful GSP with finite resources.

The workshop also featured several keynote speakers, including the 2016 Darcy Lecturer, and a President's Reception, which included an extensive and diverse poster session.

GRA thanks the Planning Committee; Co-Sponsors, the California Department of Water Resources, The Robert M. Hagan Endowed Chair of UC Davis, and UC Water; Reception Sponsors, CH2M and RMC Water & Environment; and all of the exhibitors for supporting this event.

The interest in this event was unprecedented, and the venue was limited to 160 attendees, so GRA hired a professional videographer to record the proceedings. Watch GRA's website, as it will soon be available for purchase. Also, keep an eye open for a GRA SGMA-related event in early June, when we will revisit and refine some of these topics in the context of the final version of the GSP regulations.

A summary of each session and keynote address follows.

Data & Models in the New Groundwater Sustainability Plans

*Moderated by **Rich Juricich**, DWR*

Dan McManus of DWR discussed the *Groundwater Sustainability Plan Draft Regulations*. Dan provided a detailed discussion of the soon-to-be-released regulations for groundwater sustainability plans, including key requirements related to data, monitoring, and water budgets. He also discussed the document on best management practices that will be developed by DWR to complement the regulations. These BMPs will go into more detail on data standards, data management, and record keeping. Water budgets are a key part of the basin setting in the new regulations and must account for major inflows and outflows for historical, current, and future

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

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Unprecedented, Exciting Times for Goundwater in California

By Chris Petersen

I am honored to serve as GRA's President heading into our 25th year as an organization. What an exciting time it is for groundwater professionals as we enter uncharted territory with the implementation of the Sustainable Groundwater Management Act (SGMA) and 5 years of crushing drought. I hope to uphold the tradition of excellence established by past GRA presidents and directors, many of whom continue to play important roles in our organizational leadership. GRA has had a profoundly beneficial impact on my career through the relationships I have developed and knowledge gained by working with GRA directors, attending GRA events, and, more recently, helping to create and lead new events. In this, my first President's Message, I will elaborate on why I believe these are unprecedented, yet very exciting times for groundwater in California; explain a little about myself and my journey; and describe who and what GRA is today and what we can become moving forward.

Why is this Such an Exciting Time in Groundwater?

In the 3rd year of drought in California, the Sustainable Groundwater Management Act of 2014 was adopted and the Proposition-1 Water Bond was passed. The drought continued into 2015. In many groundwater basins in California, especially San Joaquin Valley, we have watched groundwater levels decline to historic lows and continue to decline. With these declines, land subsidence has increased at an alarming rate and thousands of wells have gone dry. These declines also have caused other undesirable results, such as reduced stream flow in ecologically sensitive areas, degraded groundwater quality, seawater intrusion and a massive reduction in groundwater storage (our dry-year savings account). I think we're all hopeful that 2016 will mark an important "changing of the tide." El Niño seems to be delivering modest rainfall and snowpack, but we hope for more. Meanwhile, the SGMA is being implemented on schedule. DWR is accepting requests for revisions in groundwater basin boundaries, as promised, beginning on January 1, 2016. They continue to accept notifications of groundwater sustainability agency formation and will do so until June 30, 2017. When this issue of *HydroVisions* comes out, DWR will have released the draft Groundwater Sustainability Plan (GSP) regulations for public review; GSP regulations are scheduled to be finalized by June 1, 2016. Visit DWR's website here to track the latest SGMA-related developments.

Proposition 1 (Prop 1) is providing much-needed funding assistance for development of GSPs, improving groundwater quality, and increasing storage of both surface and groundwater. In fact, more than $1B in grants will be made available for relief to groundwater managers in these areas over the next 2–3 years; that's exciting. Visit the following web sites to track Prop-1 Funds that will help with sustainable groundwater management:

- Department of Water Resources
- State Water Resources Control Board
- The California Water Commission

GRA has played a very significant role in turning both Prop 1 and the SGMA from concept to reality through our legislative advocacy efforts, by providing accurate and timely information to the right people at the Capitol, and by raising awareness through education and information at our events and in our publications.

What Makes Chris Tick?

Nurture vs. Nature. I think geology and hydrology were hard-wired into my DNA from the beginning, but my home environment played a significant role too. My father is a watercolor artist and was an instructor at Modesto Junior College. Some of my earliest memories with my dad involved

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President's Message – *Continued*

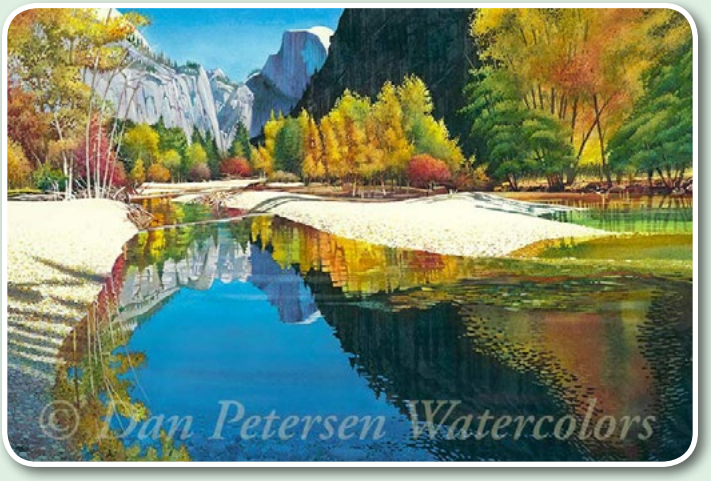
day-long treks through watercourses in the Sierra foothills as he searched for inspiration. Journeys farther into the Sierra with my dad continued into my college years and beyond. He taught me to appreciate the beauty and mystery of the created landscapes as well as the Creator (thank you Dad).

I wanted to know and understand how these water landscapes were formed and how it all worked. I found many answers through my Earth Science class at Modesto Junior College (thank you Don Ahrens), and really got into the details pursuing a B.S. in Geology at San Jose State University and Master's in Hydrology from University of Arizona. I began my groundwater consulting career in 1990 and have had tremendous opportunities, with excellent firms, delving into complex and challenging groundwater supply and quality problems for the past 26 years. During this time, GRA has enabled me to stay current on the latest technologies, case-study solutions, and technical experts that have helped me better serve my clients. Early in my career, I did a lot of field work…which is why I went into geology, right? Now, however, I spend the majority of my time in meetings, analyzing and evaluating data, writing reports and proposals, etc.…all indoors. Yet my heart still longs for the outdoors, which is why I love cycling, running, backpacking, or really anything that takes me outside. On a recent bike ride, I snapped my President's Message photo in front of an outcrop of the Merhten Formation near Lake Natoma in Fair Oaks. Just west of where I was standing, the Merhten plunges subsurface and is an important regional groundwater-supply aquifer for the greater Sacramento area. So cool!

GRA – Who Are We and What Can We Become?

GRA is an incredible organization led by individuals that share a common passion for groundwater in California. We are a volunteer organization; none of our officers or directors are paid, but instead serve because we believe in our mission: *The Groundwater Resources Association of California is dedicated to resource management that protects and improves groundwater supply and quality through education and technical leadership*. As I mentioned earlier, we are entering our 25th year as an organization and have many successes to celebrate. You'll be hearing more about these throughout the year, because I think it's important to remember our founding principles, and not lose sight of these, as we move forward and remain relevant with the issues and challenges facing groundwater resource professionals in California today. So where are we today as an organization? Here's GRA by the numbers:

- Our membership for Calendar Year 2015 was 1,442 members from all sectors of the industry (consulting; local, county, regional, state and federal government employees; educators; students; non-profit entities; and the environmental and legal communities).



"On a Clear Day," Watercolor by Dan Petersen, http://www.petersenwatercolor.com/

- GRA's Board of Directors is composed of 16 leaders, representing a broad cross-section of the industry, who meet face-to-face 4 times per year.
- We have 5 active Branches, each led by 3 to 9 volunteer officers.
- We have 12 very active committees chaired by a director or officer and composed of both directors and GRA members interested in helping lead the organization.
- We host 6–8 conferences and 10–15 GRACasts per year. Planning is well under way for a very exciting lineup of events in 2016. For more information on our events, please click here.
- We are fiscally strong, balancing income with expenses ($500,000 in 2015) each year, while at the same time growing a modest reserve account ($200,000 through 2015) to be accessed in case of financial emergency or to pay for special projects at the approval of the board.
- Membership dues are a bargain at $125 for regular members, $100 for state and federal employees and $10 for students. Members receive discounts at events, as well as a number of other benefits detailed here.
- We contract for services from a management association firm, Smith Moore & Associates (SMA). SMA provides excellent service to GRA in important areas of administration, including coordination with venues for conferences, collection of membership and events fees, paying vendors, and hosting GRACasts, just to name a few.
- We contract for services from a Legislative Advisor, Brownstein Hyatt Farber Schreck (BHFS). BHFS provides excellent service in organizing speakers and sponsors for our Legislative Symposium, help in the spring of each year.

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They keep us current on groundwater bills introduced, track these bills, and set up meetings for us at the Capitol with lawmakers interested or involved in groundwater bills for which we are able to provide technical advice and expertise.

- We have a Treasurer, R.T. VanValer, who provides timely financial information and advice to our finance committee each month and at all Board meetings. R.T. and his father, Bob, with the Roscoe Moss Company, have been serving GRA for the past 25 years by volunteering their time and talents, as well as financially sponsoring many of our events over the years; we are very thankful for their continued service.

There are 127 high- and medium-priority basins in California that must comply with the SGMA. There are 10 Hydrologic Regions in California overseen by Regional Water Quality Control Boards. GRA has had a total of 5 Branches for a very long time; why? I believe our organization would benefit from additional Branches to provide a more complete picture of the local and regional issues across this diverse state. I think our organization would further benefit from more coordination and communication between leadership at the state and local levels. I believe that if GRA can begin to make strides in this direction over the next two years, while staying true to our mission by maintaining and even improving the level of excellence we have achieved with our events and member benefits, then we will all succeed. To get there, we need your help! Please consider joining the organization and getting involved in our Branches, in committees and in our events. Students: we especially appreciate your energy and new ideas, and would like to see many more of you involved in the organization. We are always in need of fresh perspectives and new energy to help lead our many activities, so please don't hesitate to take the initiative today and become a part of the future of this great organization. The more you invest your time and talent into this organization, the more you will get out of it. Just contact our Administrative Director, Sarah Kline, at skline@grac.org for more information.

Until Next Time!

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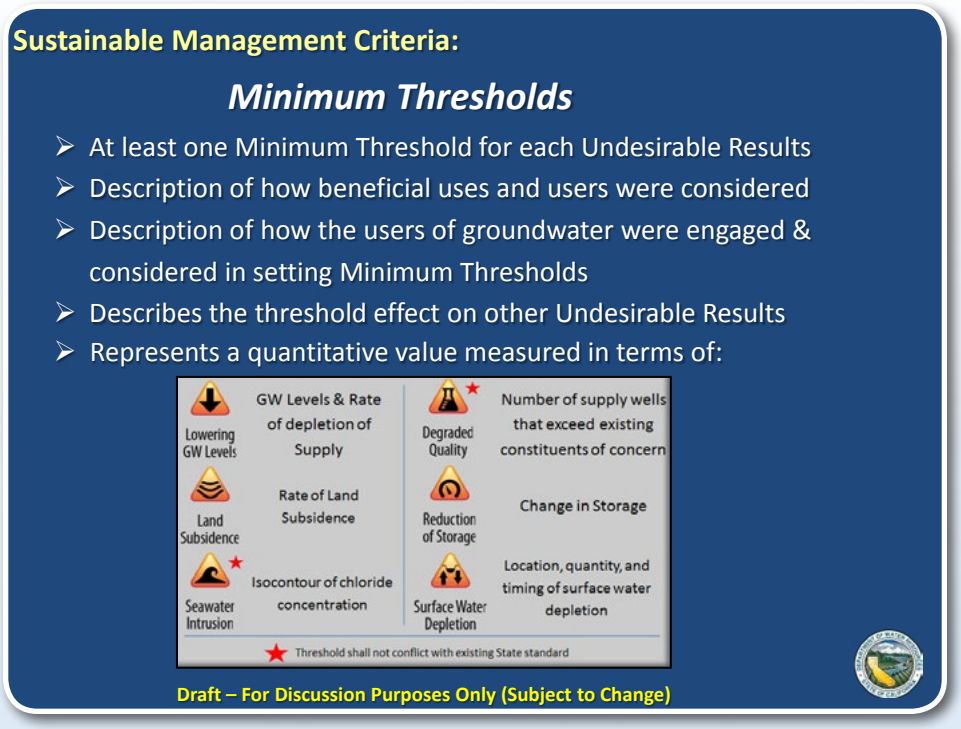

Dan McManus: Draft concept of minimum thresholds.

periods. An explanation was given of the monitoring needed for GSPs to evaluate undesirable results, including the development of objectives and minimum thresholds.

Lance Eckhart of the Mojave Water Agency presented *A Data-Focused Approach for Managing a Groundwater Basin*. Lance provided an overview of how MWA uses data and models to support management of the Mojave Basin. He described how the required water-level monitoring frequency can range from days to weeks, months, years or decades depending on the intended purpose. Five separate models of the basin were developed over 15 years by different entities and with different spatial coverage. These models are used to answer specific questions. MWA uses groundwater-level information from 409 key wells, 80 USGS cooperative wells, and 572 biennial wells to understand groundwater flow in the basin. MWA provides dashboards of different graphical outputs to show current basin conditions and places information on their public website.

Rob Swartz of the Regional Water Authority presented *A Modeling-Focused Approach for Managing a Groundwater Basin*. Rob described how the Sacramento Groundwater Authority uses models to help manage the American Basin. SGA is interested in answering questions about the sustainable yield of the basin, sources of groundwater recharge and movement of contaminant plumes. Models are based on a foundation of field data and development of a conceptual model of the basin, which are used for calibration and construction of the model. The IGSM model was updated in 2008 and used to answer a number of specific questions about groundwater banking, groundwater substitution transfers, contamination vulnerability analysis, and recharge analysis.

Tariq Kadir of DWR discussed *Technical Assistance by the State for Regional Models in Support of SGMA*. Tariq provided an overview of different types of financial assistance, data, tools, and models available from DWR to support sustainable groundwater management. DWR developed a framework for integrated data management that describes actions for data collection, reporting, management and exchange, and for water budgets. Key models available include the IWFM Demand Calculator (IDC), the Integrated Water Flow Model (IWFM) and the Central Valley application of IWFM, known as C2VSim. A summary of key features was provided for each model, as was a list of upcoming workshops to learn more.

Data Needs and Sources for Sustainable Groundwater Management

Moderated by ***Thomas Harter****, UC Davis*

Steven Phillips of the U.S. Geological Survey outlined some key data needs to analyze groundwater sustainability. Such data can generally be broken down into five major categories: data describing general aspects of the landscape, data that are part of the water budget, dynamic data describing hydrologic conditions, physical aquifer properties, and data specific to characterizing and describing undesirable results. Landscape-related information typically needed for modeling include such things as elevation, land use, irrigation methods, crop characteristics relevant to the water cycle, and climate data. Water-budget components, measured or estimated, include water application timing and amount, recharge, reuse, stream-aquifer interaction, pumping, and water banking. Dynamic data often describe the state of hydrology—water level, water quality, and stream flow.

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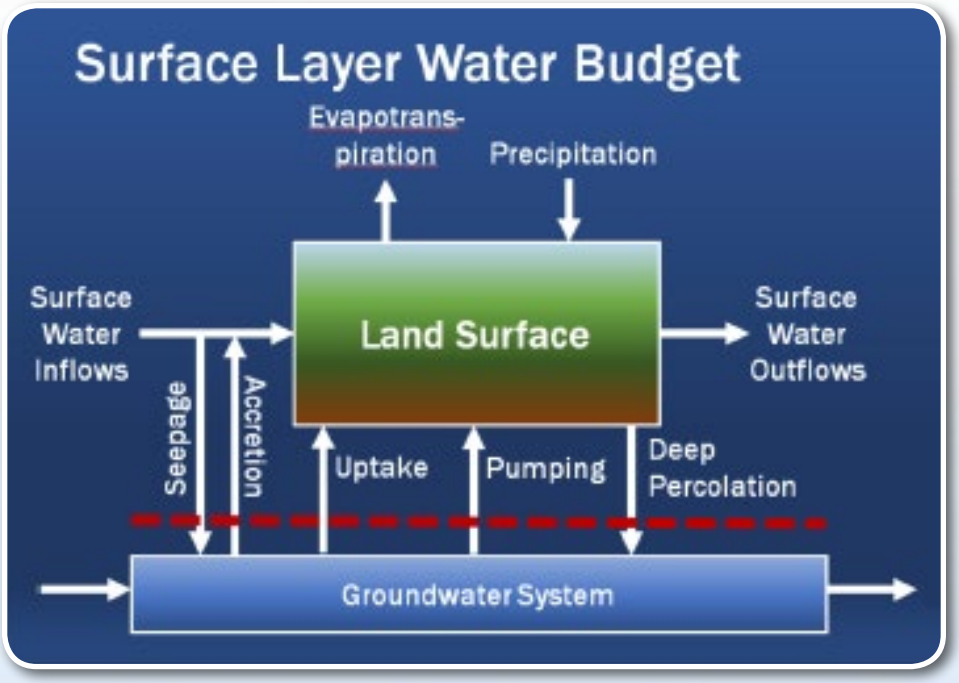
Byron Clark of Davids Engineering focused on tools available to compute crop consumptive use, which in turn drives groundwater pumping where surface water is not available. Consumptive use is a critical element of land-surface and root-zone water-budget software used in conjunction with groundwater models, e.g., the IWFM Demand Calculator (IDC), the FARM process in MODLFOW, or WEAP (Water Evaluation And Planning system). Approaches to computing consumptive use are divided into vegetation-index methods (NDVI, SAVI), temperature-index methods (e.g., SSEB), and methods based on the energy balance at the land surface (SEBAL, METRIC, SEBS, others). Some of these are applied using satellite remote sensing data. Byron used a case study from Colusa County to demonstrate the usefulness of satellite data to estimate crop consumptive use with an energy balance method (SEBAL). The purpose was to determine the water balance for areas where significant groundwater-level decline has been observed, mostly in orchard areas at least partly reliant on groundwater. Satellite information, combined with existing ground information, led to improved crop coefficients used to estimate crop ET. Unlike DWR land-use maps, satellite data were able to discern dynamic changes in between-field and sub-field land use, especially aging of orchards leading to reduced ET due to failing trees, or ripping of entire orchards not otherwise noted in land-use data. The resulting average estimated monthly net recharge (1990–2015) was nearly 20% lower than that estimated from traditional land-use mapping and crop-coefficient data.

Lisa Porta of CH2M reviewed existing sources of groundwater data that may be used for SGMA assessments. She began by drilling deeper into Steve's analysis of data needs, pointing out some common data analysis errors, and emphasizing the need to tie data-collection efforts into developing a strong conceptual model of the basin or sub-basin. Data gaps may be bridged with literature values (e.g., for basic aquifer properties), or by interpolating from nearby data stations, using estimation methods that derive critical data from other measurements, or calibration of groundwater models. For data sources, Lisa reviewed some local agency monitoring networks; DWR water-level and water-quality data; SWRCB groundwater-quality programs archived in GAMA Geotracker; DTSC's EnviroStor database; USGS sampling results documented in the National Water Information System (NWIS) database; Regional Water Boards' records (often not digitized), such as various site permits, the dairy program, or the irrigated lands regulatory program in the Central Valley; DWR well completion reports; DWR's water data library, CASGEM, and newly-available groundwater information center; DOGGR information on soil and gas wells (geologic logs); and land-use maps (current and historic) available from DWR and other organizations.



Byron Clark, Session 2: A basic surface layer/root zone water budget.

Lempi Miller of Locus Technologies provided a broader outlook at data management strategies. The key message was tri-fold: avoid the Big Data dilemma, create targeted data-collection strategies, and have solid data-management strategies in place. Lempi warned that using Big Data comes with significant risks related to data governance and defensibility, and potential privacy issues. Instead, a targeted data-collection strategy involves a well-defined final deliverable, solid evaluation of existing information, good source documentation, identification of barriers, exclusion of bad data, and then pursuit of missing information. Public records and reports, e-data, one's own data, and data from cooperating providers are good resources. Good data management includes prioritizing data-management tasks based on required outputs, regulation, and good meta-data management. Manual data input is best kept at a minimum and—if needed—done by a limited number of trained, professional staff. Lempi closed

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her talk by reminding everyone to say 'thank you' often to everyone who helps or influences the data collection and management process.

Keynote Speaker – NGWREF Darcy Lecture, Presented by Ty Ferré, University of Arizona; *Seeing Things Differently: Rethinking the Relationship Between Data, Models, and Decision Making*

*Introduced by **Tim Parker**, Parker Groundwater Management*

The National Ground Water Research and Educational Foundation presented the Henry Darcy Distinguished Lecture Series in Groundwater Sciences—a particular honor for GRA, and certainly a highlight for this workshop. Established in 1986, the Lecture Series has reached over 80,000 groundwater students, faculty, and professionals, honoring Henry Darcy of France for his 1856 work that established groundwater science's fundamental physical law.

The 2016 Darcy Distinguished Lecturer is Professor Ty Ferré, University of Arizona, who delivered an outstanding, lively, and thought-provoking lecture, *Seeing Things Differently: Rethinking the Relationship between Data, Models, and Decision Making*, that was also a perfect fit for this GRA workshop.

Dr. Ty Ferré

The motivation for Dr. Ferré's presentation was a core conundrum facing groundwater professionals and their clients: "Our data are sparse; all of our models are wrong; but, we must decide." How to best contribute as a hydrogeologist to effectively addressing groundwater related problems in the face of uncertainty was a key conversation sought by this presentation. Ty looked to Darcy for inspiration: Henry Darcy had spent much of his life to improve the lives of his fellow people. Ty pointed out that Darcy's strategy was two-fold: targeting science to address critical societal issues, and collecting "discriminatory data" to advance pure and applied sciences. For his presentation, Dr. Ferré's objective was to propose a framework for improving hydrogeologic investigations by rethinking the relationship between data, models, and decision making.

Data by themselves don't (always) have value. Intuitively, via simple physics, or using complex mathematical analysis, we use models to interpret data in support of decision making. In the particular case of groundwater models, a central theme at this conference, models are defined at three levels:

- Model parameters (e.g., aquifer properties)
- Boundary conditions
- Conceptual models and model complexity

In the context of uncertainty, the groundwater community has become accustomed to using calibration tools and stochastic methods to evaluate uncertainty about the first level (parameters). Much less frequently, groundwater modelers will explicitly address uncertainty about boundary conditions in a formal manner. Uncertainty associated with the conceptual model, or model complexity, is almost never considered.

Moreover, where uncertainty is represented through sensitivity analysis, and perhaps calibration, the model that represents an optimal solution is often taken as a universally true solution. Dr. Ferré questioned whether the optimal solution we seek is in fact also the best solution, and whether there is not value in looking at alternative models as well.

Using a simple game of chance that he played with the audience as an example, Ty explored various statistically-based concepts of decision making, from optimal likelihood (represented by Pascal's pioneering work), to the concept of utility (willingness to pay, represented by Bernoulli's work and captured in the field of behavioral economics, e.g., by Kahneman who, in 2002, wrote "Thinking Fast and Slow"). A key lesson, he showed, is that best-fit models alone are rarely useful for making decisions, in part because each decision-maker has a different value about, or stake in, the decision making. Uncertainty can therefore be paralyzing, unless we recognize that much of the uncertainty actually makes no difference to the decision-making process. Decision-making generally is focused on avoiding negative outcomes, rather than optimizing the outcome. Ty quoted baseball player and manager Sparky Anderson: "It hurts twice as bad to lose as it feels good to win."

Ty therefore suggested that discriminatory data are targeted in light of existing model uncertainty, but with a clearly-formulated decision framework in mind. Data collection ideally is driven by the decision space (not just the model). He acknowledged contemporary researchers Keith Halford, Mary Hill, Eileen Poeter, John Doherty, Jasper Vrugt, and Graham Fogg for their pioneering work in developing computational tools that hydrogeologists can use to evaluate parameter uncertainty and to generate multiple models of an aquifer, but also to guide the design of monitoring systems that best improve our understanding of groundwater system behavior. He further acknowledged

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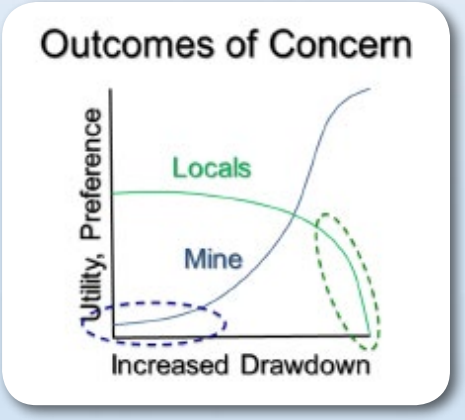
the significant contributions of Bruce James, Steve Gorelick, Patrick Reed, Wolfgang Nowak, and Mike Fienen who put forth fundamental contributions to use such tools specifically within a decision-making framework. Building on this work, his group recently proposed a new modeling framework: the Discrimination-Inference to Reduce Expected Cost Technique (DIRECT), published in Water Resources Research. The technique combines—in weighted fashion—multimodal analysis, stakeholder valuations, and discriminatory data collection to test specific outcomes. Dr. Ferré illustrated the methodology using a controversial proposed mining site with various stakeholders as an example, and encouraged the audience to work with his group to further apply this approach to groundwater decision making problems.



Ty Ferre, 2016 Darcy Lecturer: Outcomes of concern for two stakeholders.

The lecture to the GRA workshop was Ty's tenth presentation in the series—still at the beginning of a year of groundwater vagabonding around the world for 100 scheduled presentations. If you didn't have a chance to see his presentation and want to meet him on your own travels, or simply like to follow his adventures, see his blog and schedule at https://darcylecture2016.wordpress.com. The workshop organizers wish Ty all the best on his Darcy Lecture 2016 Tour!

After the workshop, Ty Ferré was kind enough to share some thoughts, shown here verbatim.

The conference was a significant step in bringing together water managers and consultants. The level of dialogue was impressive - seeming to be focused on framing the challenges ahead and discussing known challenges rather than positioning for 'turf'. The opening session really set a great tone; establishing a dichotomy between data and models set up very rich conversations. I tried to address the linkages between data and models - not because it was new to the audience, but because it seemed that it needed to be stated out loud! That said, I do think that there are at least two real opportunities that it would be great to inject into the process at this relatively early stage.

First, it would be great to see some intentional use of model-based screening to guide data collection. We need to break the linear-model-development-with-punctuations model whereby we spend massive resources to develop a single best model that is as complex as we can afford, then we trust that model until it is too obviously wrong, and then we undertake another massive modeling effort. The more dynamic the interplay between models and data, the better. Personally, I think that this will be achieved most effectively through a 'community ensemble' of models. They should be simple in structure but explore uncertainties in boundary conditions, processes, and parameters. Ideally, anyone should be able to run the model ensemble on an open platform. Alternatively, a government agency could host the models, make them available, and require that any alterations be given to them for inclusion in the community ensemble.

Second, given the huge efforts on the horizon, it would be fantastic to put aside some funds to document modeling and data collection efforts so that post-audits could be performed to assess the value/impact of these activities.

One thing that surprised me was the lack of focus on uncertainty and management under uncertainty. There were a few talks that touched on the idea, but stopped short of details. In some ways it is understandable that CA would follow the traditional trajectory of project development ... collect data, build model, perfect model, collect more data, calculate uncertainty, start thinking about how to make use of uncertainty information. But, I think that there is an opportunity to inject discussions of uncertainty and management under uncertainty from the onset of the SGMA-related efforts. We need to figure out how to communicate that quantitative uncertainty is useful rather than an admission of failure. If we could, as an industry, develop ways to communicate this idea I think that we would all benefit for years to come!

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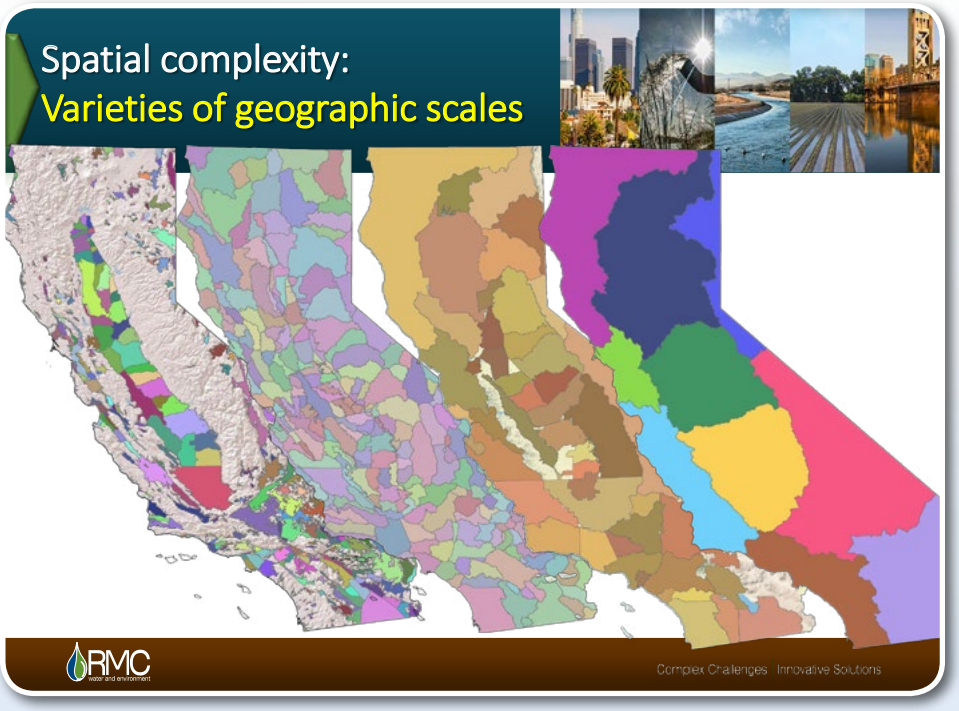
Water Budgets, With and Without Models

*Moderated by **Ali Taghavi**, RMC Water & Environment*

Saquib Najmus of RMC Water & Environment presented *Water Budget 101*. Saquib has been working with the DWR over the past several months to develop a basic understanding of water-budget requirements in the context of the SGMA. He discussed the "Total Water Budget," as defined in the SGMA, which was revisited from a systems approach; different types of water budgets, their interrelationships, and data needs were presented. The practical problem of data availability at the GSA level was discussed in light of pragmatic approaches for developing water budgets at different spatial and temporal scales, with or without a numerical model, using extensive, moderate, and limited data. The issue of inter-basin boundary flow estimation was also discussed.



Saquib Najmus: Scale is an important aspect of water budgets.

Charles Brush of DWR presented C2VSIM – *Simulating the Surface-Water and Groundwater Systems of the Central Valley*. His focus was on the use of regional integrated hydrologic models, which can play an important role in providing the information GSAs will need to develop their GSPs. These models serve as a repository for key data, such as historical land use, inflows, diversions and water demands. Charlie postulated that a well-calibrated model also can provide reliable estimates of water-budget aspects that are either unmeasured or difficult to measure, such as land-surface water budgets, stream-aquifer exchange, changes in groundwater storage, and groundwater flow across basin boundaries. DWR has released the Central Valley Simulation Model (C2VSim), which simulates the period October 1922 to September 2009 on a monthly basis. Charlie discussed how standard budgets and post-processors from C2VSim, including MS Excel and ESRI ArcMap add-ins provide easy access to model output, and showed an example, using the Tulare Basin, of how C2VSim's Z-Budget post-processor can be configured to output information on flows between GSAs.

Graham Fogg of UC Davis presented a *Model-Based Water Budget for Coachella Valley Aquifer System*. Graham's main theme was that by methodically building a groundwater model of the Coachella Valley Aquifer system, based on 61 years of data that include major fluctuations in groundwater conditions, and by engaging in minimal parameter 'tuning,' a relatively reliable, science-based estimate of the transient groundwater budget can be developed. This approach involved model calibration through a systematic collection and estimation of key model inputs, including land use, groundwater pumpage, Salton Sea water levels, and time-varying drain flows. A statistical regression 'surrogate' model, based on the 61-yr modeled groundwater budget, shows a near-perfect correlation between change in storage, pumpage, recharge and drainflow. This surrogate model demonstrates the crucial importance of good estimates of pumpage and recharge, while also encapsulating the groundwater budget in a simple equation for facilitating water management. The study illustrates how data, together with methodical model building, with minimal model tuning, can be used to constrain uncertainty and compute defensible groundwater budgets. Graham's presentation was dedicated to Harvey O. Banks, who originally suggested the study and helped guide early phases of the work.

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Case Studies – Evaluating & Managing Undesirable Results using Data and Models

Moderated by ***Graham Fogg****, UC Davis*

John T. Dupnik, General Manager of Barton Springs/Edwards Aquifer Conservation District, Texas, presented *Using Models to Manage Ecological Effects of Pumping*. The Barton Springs/Edwards Aquifer Conservation District (District) is a Groundwater Conservation District charged by its statutory authorities to provide for the conservation, preservation, protection, recharging and prevention of waste of groundwater in the Barton Springs segment of the Edwards Aquifer (Aquifer) near the City of Austin in Central Texas. The Aquifer serves as the primary source of drinking water for tens of thousands of people and is the source water for the Barton Springs complex, which is a heavily-used recreational resource and the only known critical habitat for two federally-listed endangered species of salamanders. The Aquifer is a highly developed karst system that experiences rapid recharge via creek flow across the recharge zone, but groundwater levels and spring flows are highly susceptible to limited recharge and continued pumping during droughts. The District has used a robust spring-discharge dataset, with over 100 years of record, to develop and refine a Groundwater Availability Model (GAM) used to simulate the effects of pumping on water levels and springflow. The GAM has served to establish a basin-scale water budget and a correlation of pumping to springflow that have been integral to establishing policies and a regulatory scheme to achieve the goal of sustainable yield for the Aquifer.

Jon Traum of the USGS presented *Use of Models to Estimate Long-Term Overdraft and Land Subsidence*. "Significant and unreasonable land subsidence that substantially interferes with surface land uses" is one of the six undesirable results identified in the SGMA. Jon discussed negative effects related to subsidence, when subsidence should be included in a groundwater simulation, how subsidence is simulated within the common groundwater simulation software used in California (MODFLOW-OHWM and IWFM), sources of subsidence data, and how subsidence is being simulated in the updated version of the USGS Central Valley Hydrologic Model (CVHM2). He also presented preliminary results of a case study using CVHM2 to estimate the distribution and magnitude of groundwater-level declines and land subsidence due to a proposed conjunctive-use project. The proposed project seeks to pump additional groundwater during drought periods to supplement depleted Central Valley Project supplies.

Brian Lockwood of Pajaro Valley Water Management Agency presented *Basin Modeling and Water Resources Management*, Pajaro Valley, CA. Groundwater overdraft and seawater intrusion are serious threats to the sustainability of the groundwater resources of the Pajaro Valley. Located adjacent to the Monterey Bay in central California, the Pajaro Valley produces more than $900 million/year of high-value fruit, flower, and vegetable crops on approximately 28,000 irrigated acres using predominantly groundwater. The Pajaro Valley Water Management Agency was formed in 1984 by an act of state legislature to "efficiently and economically manage existing and supplemental water supplies in order to prevent further increase in, and to accomplish continuing reduction of, long-term overdraft." Hydrologic modeling, supported by a rigorous data-collection program, in conjunction with stakeholder-driven Basin Management Planning committees and public participation, have played an important role on the path toward long-term sustainability.

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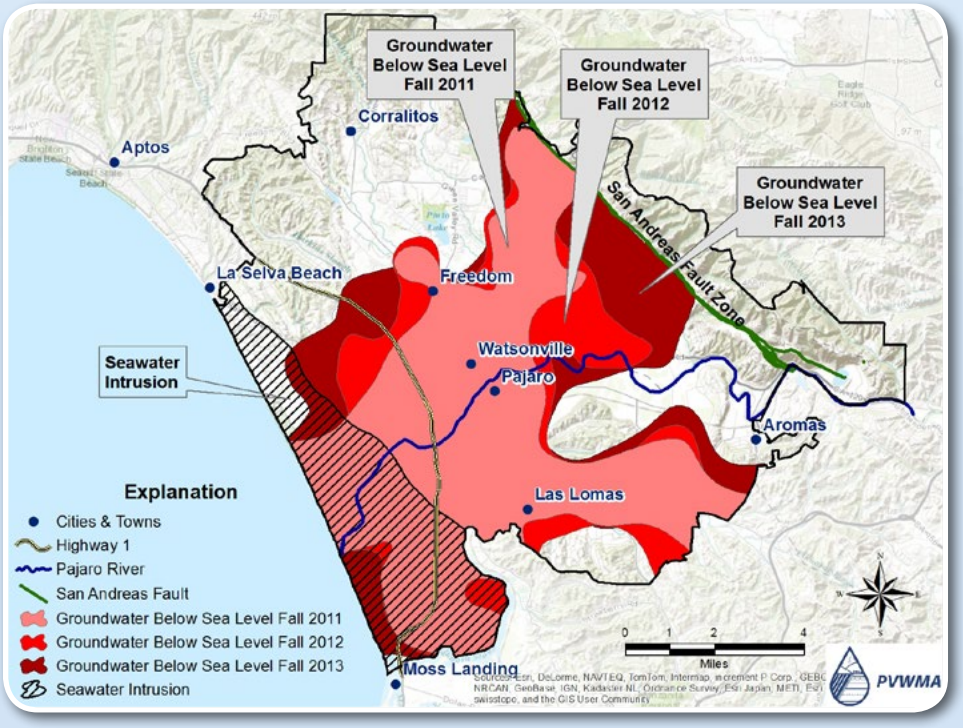
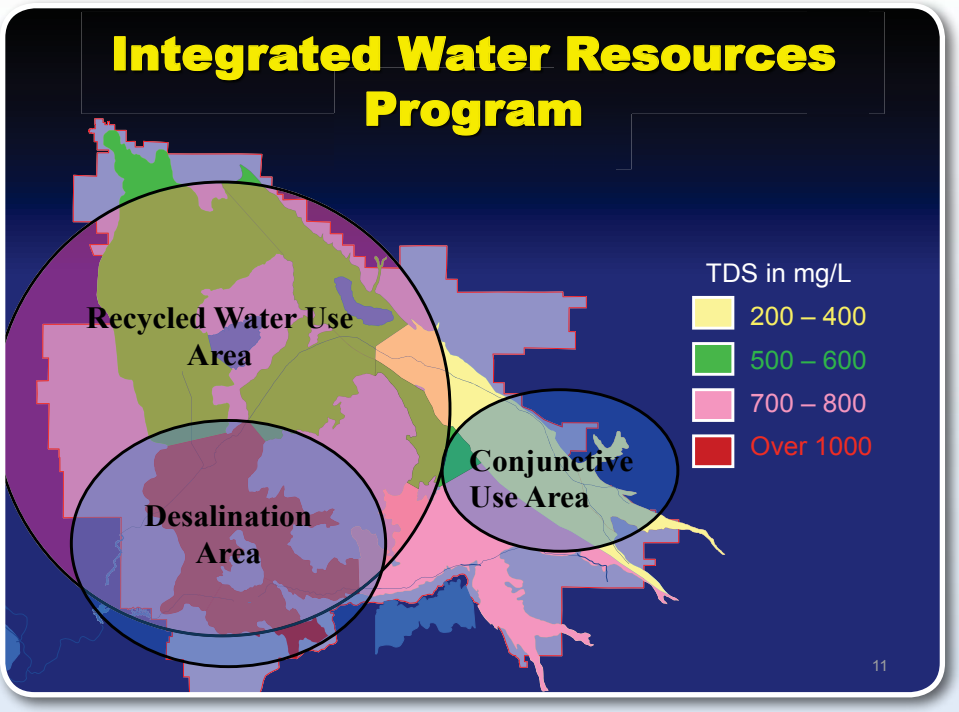


Brian Lockwood: Groundwater levels below sea level, Pajaro Valley.

Summary of GRA's Workshop on The Role of Models and Data in Implementing SGMA – *Continued*

Thomas Harter, Hagan Endowed Chair for Water Management and Policy of UC Davis, presented *Use of Models to Assess Stream-Aquifer Interaction*. Thomas provided an overview of modeling approaches to assess stream-aquifer interaction. He discussed four types of tools useful for understanding the stream-aquifer connection: water budgets, stream hydrographs, analytical (spreadsheet) stream-depletion functions, and numerical modeling. The fundamental basis of understanding large-scale stream-aquifer interaction comes from understanding the water balance of a basin, with streams and groundwater as separate entities. Stream losses and gains can be measured to understand large-scale stream-aquifer interactions. Water budgets that include an aquifer-stream flux term can be constructed as seasonal or annual averages, or for specific water-year types. Stream hydrographs—particularly in the summer—can be useful to determine the contribution of groundwater to streamflow (baseflow) after precipitation-runoff ceases, and after accounting for snow-melt or reservoir releases (both important water stores contributing to streamflow). Thomas continued by illustrating the dynamic delay that pumping at some distance from the stream has before it actually begins to capture streamflow. For idealized conditions, analytical tools called stream-depletion functions, which can be spreadsheet-based, are available to quantify these dynamic effects and predict capture of streamflow due to pumping. Numerical modeling tools afford more accuracy and better conceptual representation of the stream-aquifer interaction. Thomas showed several examples of such applications, including the idea of creating "capture maps," showing the long-term fraction of streamflow captured at any well location, from existing numerical models.



Behrooz Mortazavi: Definition of areas within Eastern Municipal Water District.

Keynote Speaker – Behrooz Mortazavi, Water Resources Engineers Inc., and GRA's 2016 David Keith Todd Distinguished Lecturer for Southern California: *Role of Groundwater in Integrated Water Resources Management*

Behrooz demonstrated, using a case study from the Eastern Municipal Water District (EMWD) in the San Jacinto watershed, various aspects of integrated water resources management. Recognizing that there are three areas within EMWD with differing groundwater salinity and surface-water availability, it was decided through an integrated resources planning process to manage each area accordingly. They focused on conjunctive use in the area with lowest salinity and greatest surface-water availability. The area with highest salinity was designated the desalination area, where they use desalters to treat groundwater for use, and concentrate the brine for disposal via a brine line. In between is the recycled water use area, where municipal wastewater and water from desalters is treated and used for irrigation and groundwater recharge activities.

The process of developing this integrated plan involved developing an extensive monitoring program that includes groundwater levels and quality in about 250 wells throughout the basin. They also sealed over 100 open, abandoned wells as part of the monitoring program. A GIS-enabled, cloud-based data base was used to provide data to all stakeholders to foster a common understanding and informed decision making. A groundwater model was also developed for similar purposes.

Behrooz also discussed the process of securing water rights, and ways of encouraging water conservation. EMWD took an allocation-based approach to determine a rate structure, such that water is priced lower within the allocation and higher for above-allocation usage. This approach has proven effective within the EMWD.

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Summary of GRA's Workshop on The Role of Models and Data in Implementing SGMA – *Continued*

Getting More out of a Model

Moderated by ***Jon Traum****, USGS*

Brian Wagner of the USGS presented *Groundwater Management in the Upper Klamath Basin, Oregon and California: Using Simulation-Optimization Techniques to Identify Sustainable Groundwater Management Strategies*. This study links groundwater simulation with optimization to identify sustainable groundwater management practices in the upper Klamath Basin of Oregon and California. The decision model was developed within the framework of the Klamath Basin Restoration Agreement (KBRA) and evaluates groundwater-management alternatives to: (1) identify groundwater-pumping patterns that, to the extent possible, meet supplemental irrigation demand expected under the KBRA; (2) limit the effects of pumping on groundwater-dependent ecosystems; (3) ensure that drawdown caused by managed pumping does not exceed limits allowed by water law; and (4) ensure that groundwater pumping does not adversely affect agricultural drain flows that supply downstream irrigators and wildlife refuges. The results indicate that groundwater pumping is limited primarily by drawdown restrictions defined by Oregon water law, and that the effect of managed pumping on groundwater-dependent ecosystems is minimal.

Rob Gailey of R.M. Gailey Consulting Hydrogeology presented *Hydro-Economic Considerations for Sustainable Groundwater Management*. In addition to hydrology, elements critical for the sustainable management of groundwater include aspects of economics, engineering, finance, law and politics. Economic analysis will play a significant role, and can be combined with hydrogeologic analysis to create useful management formulations. Important considerations with regard to groundwater are: (1) that it exists as a common-pool resource with open access, (2) the magnitude of pumping and scarcity costs, (3) demands (individual, aggregate and hardening), (4) the potential value of markets in counteracting the negative effects of regulation, and (5) pumping taxes. Rob's presentation addressed these points within the general context of California's SGMA.

Ali Taghavi of RMC presented *Analysis of Groundwater Sustainability Opportunities in Central Valley, CA*. Ali posited that with the passage of the SGMA, it is much more relevant that the state agencies use groundwater available in storage as part of the overall water storage computation, along with snow pack and surface-water reservoirs, in forecasting annual water supply availability. Basin-scale models, such as C2VSim, are well-suited for high-level assessment of such forecasting, and for development of strategies to achieve sustainable groundwater management in a basin. The fine-grid version of C2VSim has been used for analysis of historical conditions throughout the Central Valley for the period 1922–2009. The model was used to assess the practical changes in land use, cropping pattern, and groundwater use that would result in reduced pumping and a partially sustainable groundwater system with minimum impacts on the agricultural industry. On the supply side, the model was used to evaluate the potential capture of wintertime excess streamflows from the major tributary watersheds for recharge on suitable agricultural lands with dormant crops. Together, reduced groundwater pumping and off-season recharge on agricultural lands can be an effective strategy to achieve groundwater sustainability at the basin scale.

Metrics for Assessing Impacts of Groundwater Pumping

SGMA Concern	Metric of Sustainability	Source of Limits
Groundwater Levels	Drawdowns for a variety of time scales – seasonal to decadal	Oregon water law; varying limits for CA
Groundwater Storage		
Surface-Water Depletion	Reduction in discharge to streams, lakes, drains	Aquatic habitat - KBRA
		Drains – Varying limits
Groundwater Quality	Not Considered	
Land Subsidence		
Seawater Intrusion		

Brian Wagner: Metrics are an important aspect of any water management plan.

Leveraging Existing Resources and Assessing Uncertainty

Moderated by ***Rob Gailey****, R.M. Gailey Consulting Hydrogeologist*

Derrik Williams of HydroMetrics WRI opened with a presentation on *Using Regional Models to Develop GSA-Scale Models*. The context was development of a model for the Kings Basin using the IWFM code with information derived from the larger-scale CVHM

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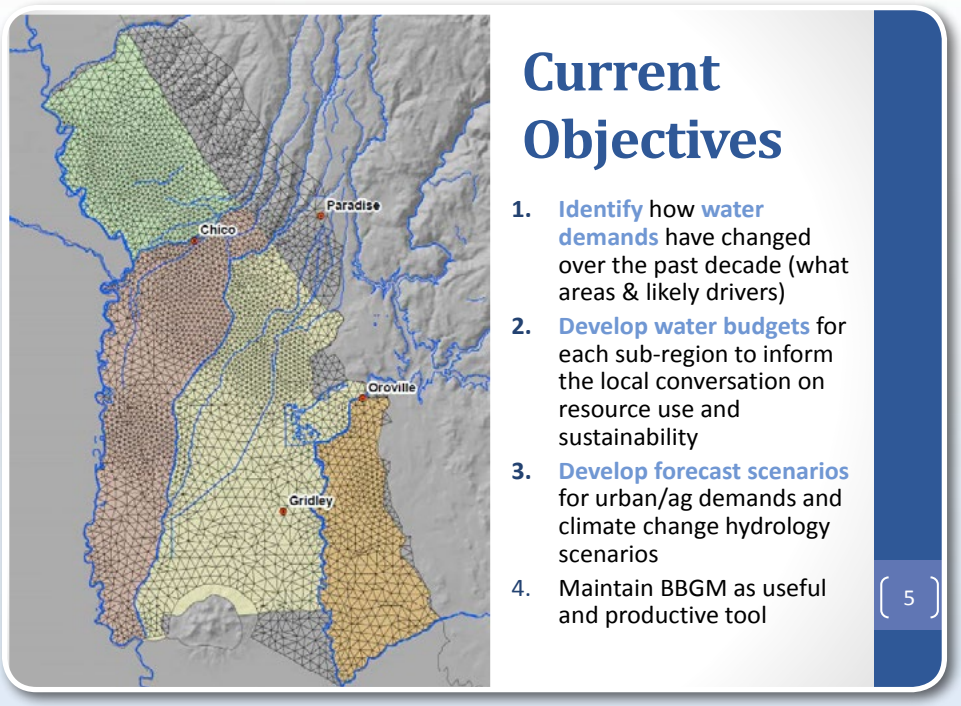
Summary of GRA's Workshop on The Role of Models and Data in Implementing SGMA – *Continued*

and C2VSim models. Approaches for land-use simulation in the two models were compared and contrasted. Details related to working with sediment textural data from CVHM were discussed, as were the availability of water-level and pumpage data from some wells. Caution was suggested when evaluating boundary-flow information available from the models as there are notable differences in estimated water budgets between the two models. On a related note, Derrik stated in conclusion that there is a difference between extracting data used to create an existing model and adopting results from the model as if they were data.

Christina Buck of Butte County Department of Water and Resource Conservation discussed *Updating and Improving Existing Local Models to Support the SGMA Process*. Her presentation explained how modeling is being used to foster understanding of groundwater processes in the Butte Basin. The history of model development, desired applications and modeling objectives were first summarized. Then work to generate insights relevant to the current drought (changes in agricultural water demand, local water budgets and forecast scenarios) was explained. Conclusions included the value of modeling for organizing and integrating data, and the need for models to evolve as new information becomes available.

Tracy Nishikawa of the USGS followed with *Assessing Predictive Uncertainty and SGMA Undesirable Effects: Antelope Valley Case Study*. The focus of this work was on evaluating chronic lowering of groundwater levels and land subsidence. Extension of previous modeling work and calibration of a new model were described. This work indicated that mountain-front recharge was significantly lower than assumed in the recent basin adjudication. The model was then used to evaluate three management scenarios (status quo, redistribution of pumping and implementation of artificial recharge). The three talks in this session generated significant audience participation during the discussion that closed the session.



Christina Buck: Current objectives of Butte Basin Groundwater Model.

Keynote Speaker – Larry French, Texas Water Development Board (TWDB): *Texas Groundwater Management – Working with Statewide Data Networks and Regional Models*

Larry began with a description of the aquifers in Texas, which are primarily carbonate formations, and therefore differ from the major aquifers in California; however, the primary groundwater issues are much the same: chronic overdraft, loss of storage, land subsidence, etc. Groundwater management in Texas is also a local responsibility, but "desired future conditions" are the goal, as opposed to sustainability. About 50 groundwater availability models (GAMs) models have been developed by the state, and 24 of them are currently used to determine the "modeled available groundwater" for a given area with a given desired future condition. This information is provided by the TWDB to local entities for their water management plans.

There are about 130,000 wells and springs in the TWDB database, a subset of which are monitored regularly and used for assessment of past and current hydrologic conditions and model calibration.

Future directions include assessing brackish groundwater as a source, aquifer storage and recovery, and groundwater-surface water interactions.

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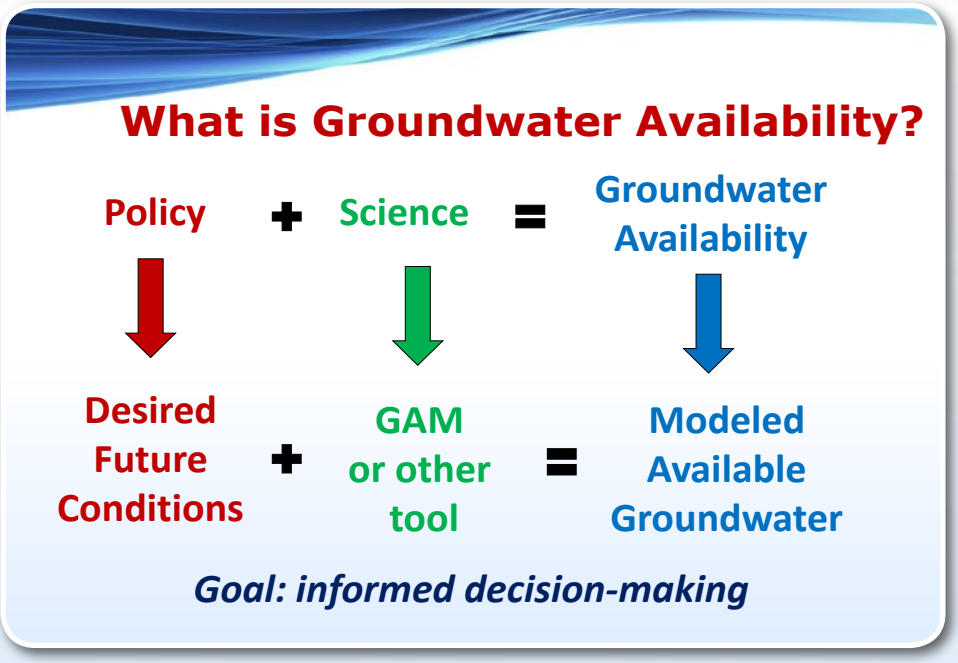
Summary of GRA's Workshop on The Role of Models and Data in Implementing SGMA – *Continued*



Larry French: Groundwater availability, Texas style.

Surface-Water Availability, Reliability, and Potential Use

Moderated by Sam ***Boland-Brien****, SWRCB*

Alex Hall of UCLA presented *A Climate Change Perspective on Surface Water Availability in California*. The application of global climate models (GCMs) to policy-relevant scales is currently challenging due to the spatial resolution of current GCM information. Alex outlined two projects where a hybrid technique was used to downscale the full CMIP5 GCM ensemble. The projects provide high-spatial-resolution predictions for climate variables (temperature, precipitation, snowpack, runoff) analyzed over 2041–2060 and 2081–2100 for the Los Angeles and Sierra Nevada regions. The results demonstrate that under "business as usual" scenarios, a greater share of precipitation will occur as rainfall. Results also show that other downscaling techniques miss significant variations of warming over varying elevations, which indicate greater future snow losses than previously projected.

Lee Bergfeld of MBK Engineers presented *Surface Water Availability*. Although the integration of water management has been brought to the forefront by SGMA, California has in the past had to respond to long-term groundwater declines. Historical responses involved construction of the large-scale State Water Project (SWP) and Central Valley Project (CVP). Future projects of this magnitude are unlikely, but data indicate there is still water available for appropriation, albeit with more constraints than in the past. Information on how to develop new rights was presented, including the data and modeling requirements associated with new appropriations.

Erik Reyes of the Department of Water Resources' Bay Delta Office presented *State Water Project Operations and Water Supply Reliability Modeling*. The SWP and CVP both rely on CalSim, a long-term planning model that represents SWP and CVP operations. The model is used to provide estimates of delivery capability and reliability, and to simulate conditions and constraints in the Sacramento River, San Joaquin River, and the Delta. CalSim is used to help allocate the limited supplies of the SWP/CVP projects based on system constraints by using mixed-integer linear programming. The model can also be used to evaluate potential water-supply impacts throughout the state using comparative analysis, which will be valuable as agencies with imported supplies develop future water-supply projections.

Helen Dahlke of UC Davis presented *Storm Water/Flood Flows for On-Farm Groundwater Recharge*. An important aspect of planning agricultural groundwater-banking activities is an adequate understanding of potential water availability. Historic streamflow records from 93 stream gauges within the Central Valley were analyzed over differing time periods to assess the magnitude, duration, frequency, and timing of flood flows that may provide opportunities for agricultural groundwater banking. The analysis assumed flows above the 90th percentile were available; data were presented that indicated varying this assumption did not significantly affect the results. The flood-flow availability analysis indicates that flood flows are often available, particularly in above-normal and wet years. Trends in volume and duration for flood flows are generally decreasing across the state. Future work will compare the flood flows against water-rights and conveyance-capacity data.

Wrapping It Up: Points of Agreement and Issues Needing More Thought

Moderator: ***Murray Einarson****, Haley & Aldrich*

The final session of the day included more thought-provoking comments from four invited panelists, followed by reflections and discussion amongst all event participants.

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Summary of GRA's Workshop on The Role of Models and Data in Implementing SGMA – *Continued*

Eric Averett of Kern Groundwater Authority shared his experiences in helping to create a new water sustainability agency in Kern County, the Kern Groundwater Authority. Comprising 19 different water agencies, the Kern Groundwater Authority intends to be the GSA to manage groundwater in the region. Eric discussed reasons why his group is in favor of just one GSA per groundwater basin in order to avoid competing models and conflict between agencies. He also stressed the importance of collaboration amongst member agencies in order to meet the rigorous deadlines of SGMA.

Graham Fogg of UC Davis reflected on the case study he presented earlier in the day from the Coachella Valley in Southern California. That project—which was completed nearly 20 years ago—incorporated sound information regarding the subsurface geology and key boundary conditions. Modeling tools were rudimentary then compared to the codes and automated calibration methods, like PEST, that are available today. Yet, the numerical model his team developed for the Coachella Valley is still robust and has stood the test of time. Graham explained that the key to success in simulating groundwater flow and availability is a robust data set and conceptual site model (CSM). Graham continued to share his thoughts on the importance of understanding the physical constraints of groundwater models, including the role of regional stratigraphic units. Yet, some model parameters are arguably of even more fundamental importance than the hydraulic conductivity distribution. In particular, accurate estimates of water fluxes are extremely valuable. Given that most overdrafted groundwater basins are dominantly agricultural, there is a need for information regarding historic ET, surface-water deliveries, recharge and extraction rates. If sufficient head measurements are available, models can be effectively calibrated using a combination of head and flux values.

Paul Gosselin of Butte County described the modeling challenges associated with managing groundwater sustainably in Butte County. Paul explained that Butte County overlies four high- or medium-priority groundwater basins. There is significant interbasin flow, so modeling programs need to be initiated soon to avoid potential conflicts.

Richard Howitt of UC Davis discussed the importance of combining economic variables with groundwater modeling. He noted that the true forcing functions in groundwater management all have economic components. For example, deeper water tables increase pumping costs and can cause shallow wells to go dry, which then have to be deepened or re-drilled. Increases in water costs result in changes in crop patterns, which, in turn, affect recharge rates and buildup of salinity in shallow soil. Changes in surface-water flows impact ecosystems, which affect fisheries. Richard advocates the use of the Statewide Agricultural Production (SWAP) model, which integrates hydrologic and agricultural variables into an economic optimization model that is used for policy analysis and planning. Richard ended his presentation noting that the Orange County Water District (OCWD) is a shining example of how groundwater can be managed sustainably. OCWD is a non-adjudicated groundwater basin that has provided high-quality water at a fair price to its customers for decades.

Following the short presentations described above, the audience had an opportunity to query the speakers and other presenters on a wide range of topics. There was a lot of discussion regarding the coupling of hydrologic simulations with economic aspects. Several in the audience commented on the need for updating and improving conceptual models of the subsurface in key parts of California (many remarked that updates to the Bulletin 118 series publications would be very helpful). There were several comments and questions regarding the value of having common data sets for key boundary conditions (e.g., predictions of anticipated future temperatures and precipitation) to assist in the development of models that incorporate flow between groundwater basins and subbasins. DWR representatives noted that DWR intends to make such data sets available to the public, but noted that providing such data does not preclude GSAs from using alternative data sets if warranted.

Summary of GRA's Sustainable Groundwater Management—Time for a Change, Focused on the *New Groundwater Sustainability Plans: Raising the Bar on Groundwater Management*

By Tim Parker, Parker Groundwater Managment

The Sustainable Groundwater Management Act (SGMA), signed into law September 16, 2014 and effective January 1, 2015, changes groundwater management in the state, 100 years after surface water was legislatively addressed. GRA held the *New Groundwater Sustainability Plans: Raising the Bar on Groundwater Management* workshop on September 2, 2015, in Modesto, California, to bring together groundwater technical, agricultural, legal, and regulatory experts in an open forum to discuss ways to start the dialogue on planning to meet the requirements for groundwater sustainability plans (GSPs).

Defining groundwater sustainability was the keynote topic, and attendees heard how definitions and tools can be applied to help understand and solve the management challenges in the future. Attendees learned about the latest developments on regulations for basin and subbasin boundary changes from the California Department of Water Resources (DWR), and received an update on the current process and next steps DWR will take for SGMA GSP regulations development. The State Water Resources Control Board (Water Board) also provided information how water quality and data programs integrate with SGMA and their data coordination efforts with DWR.

Attendees also heard from academic, research, public agency and industry practitioners about tools and techniques for estimating sustainable yield, and developing and managing approaches to meet SGMA mandates. The need for different types of data and models was discussed in detail, including when a model is needed, and the local and state role in groundwater modeling. Finally, several successfully managed local agencies provided information on how they will meet SGMA mandates.

More Detailed Information Follows

Tim Parker, Parker Groundwater Management, GRA Director and Workshop Chair, kicked off the workshop by introducing the topic of the SGMA and its requirements. The SGMA requires that 127 high- and medium-priority basins form Groundwater Sustainability Agencies (GSAs) by June 30, 2017. These GSAs must consider the interests of all beneficial uses and users of groundwater, as well as other GSPs. The SGMA mandates that all critically overdrafted basins develop GSPs by January 31, 2020, and all other high- and medium-priority basins develop GSPs by January 31, 2022. The DWR, which has a heavy SGMA-related workload and is making excellent progress in meeting SGMA mandates, is developing regulations for the new GSPs.

William Alley, Ph. D., Science and Technology Director for the National Ground Water Association, and former Chief of the Office of Groundwater, U.S. Geological Survey (USGS), provided the keynote on Sustainable Yield. Alley started off by discussing the definition of sustainability, contrasting the USGS version with the SGMA, and concluding that sustainability is not really a scientific construct, but rather a management definition; it is the end result of public acceptance of the tradeoffs of development, and is based on science provided by groundwater professionals. The USGS Circular 1186 defines sustainability as "development and use of groundwater resources to meet current and future beneficial uses without causing unacceptable environmental or socioeconomic consequences." The SGMA defines sustainability as operating a basin in such a way as not to cause "undesirable results" that are considered "significant and unreasonable," such as chronic depletion of groundwater, seawater intrusion, or land subsidence. Sustainability is really in the eye of the beholder, which may be a contrast when considering, for example, an ecological versus an economic perspective. Alley highlighted the need to consider multiple management practices in defining sustainability, including managed aquifer recharge, increased use of recycled water, and conjunctive use of surface water and groundwater.

Regarding the measurement of sustainability in practice, water budgets are essential behind the scenes, but should not be considered an end in themselves. Of significant importance to water budget estimates should be the measurement and trend analysis of surface water-groundwater interaction with groundwater gradients and saturated thickness; land subsidence and groundwater-level trends; water quality in the context of flow systems; and pumping costs in relation to hydraulic heads. Finally, there is water use, the most important aspect that we really don't know in most basins. Alley provided an example of the difficulty of sorting out the differences between the effects of drought and demand on the Colorado River basin, where storage losses appear to exceed increased

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Summary of GRA's Sustainable Groundwater Management – Time for a Change – *Continued*

pumping demands, which begs the question of how much is related to increased pumping demands versus the effects on baseflow from the drought.

Alley also contrasted SGMA in California with the 1980 Arizona Groundwater Management Act and Active Management Area goals. The urban-focused Phoenix-Tucson-Prescott AMAs have a safe-yield goal of 2025 and seek to balance withdrawals with recharge; the riparian-focused Santa Cruz AMA goal is to maintain safe yield and prevent long-term groundwater-level declines; and the agriculturally-focused Pinal AMA strives to extend the life of the agricultural economy, as long as feasible, to preserve water supplies for future non-AG uses. Also in Arizona, the first nationally recognized riparian area, the Upper San Pedro River Basin, has concerns about streamflow depletion; it approaches this by managing the cone of depression, versus the riparian system. A final example of sustainable management comes from Australia, driven by a 10-year drought, which resulted in licensing and metering of pumpage, recognition of surface water and groundwater as a "whole water cycle," development of water markets and trading, relatively adaptable water policies, the ability to share shortages, and joint water management by States and the Commonwealth. A final thought by Alley was to stress the importance of integrated and long-term monitoring where the combined water-level, water-quality, streamflow, pumpage, and climate networks are continually optimized, and conceptual and flow models are continually updated over time with new data (Figure 1).

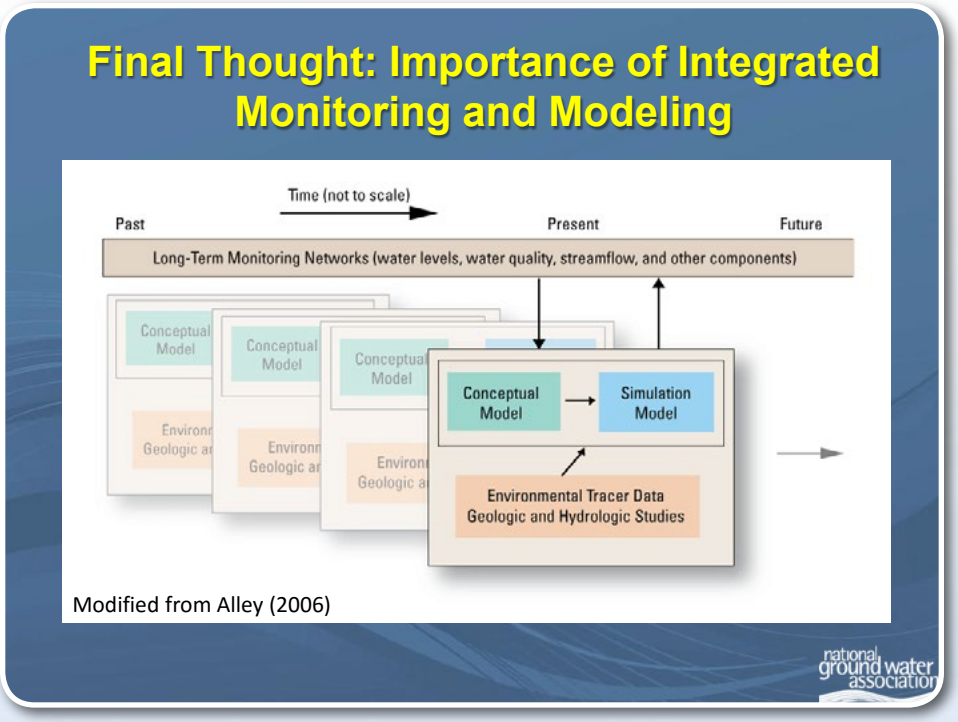

Figure 1. The importance of integrated monitoring and modeling.

Bill Alley

(left to right) Erik Ekdahl, Trevor Joseph, Juliet Christian-Smith

Panel 1: SGMA – Time to Raise the Bar on Groundwater Management

*Moderated by **Tim Parker**, Parker Groundwater Management*

Trevor Joseph, Supervising Engineering Geologist, California Department of Water Resources; **Juliet Christian-Smith**, Climate Scientist, Union of Concerned Scientists; and **Erik Ekdahl**, Groundwater Management Program Manager, State Water Resources Control Board, participated in the panel. Trevor Joseph kicked off the session by discussing DWR's overall schedule of SGMA deliverables. Basin boundary emergency regulations are due to be promulgated by the end of 2015 and the new groundwater sustainability plan and alternative plan regulations are planned to be released in draft form in early 2016 and due to be promulgated in June, 2016. There are ten topic papers being developed, with input from a number of advisory

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Summary of GRA's Sustainable Groundwater Management – Time for a Change – *Continued*

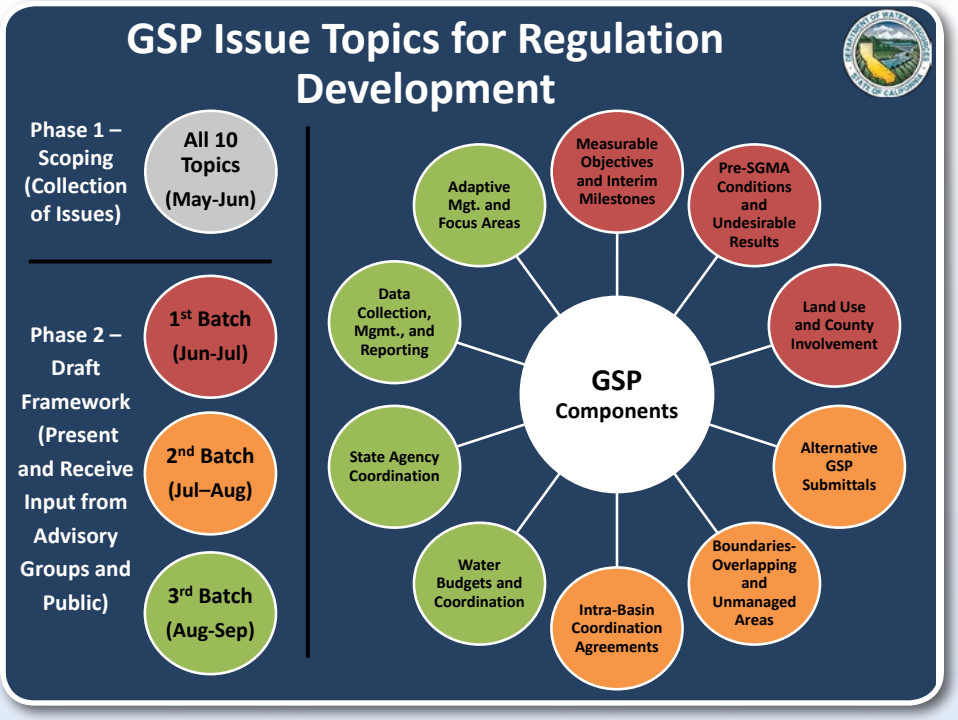

Figure 2. Issue topics for groundwater sustainability plan regulation development.

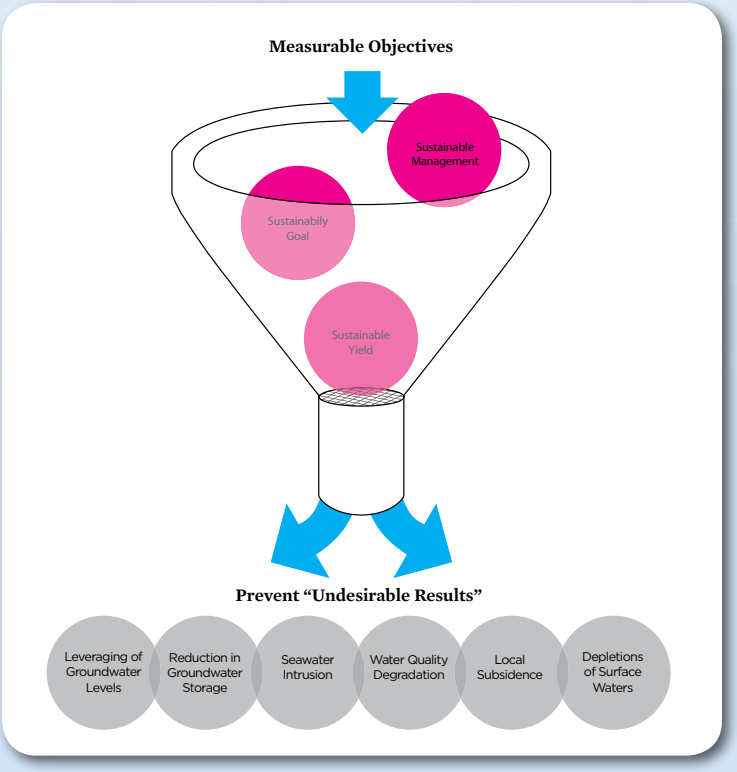

Figure 3. Concept of groundwater sustainability in the SGMA.

groups, to aid in scoping the draft GSP regulations (Figure 2); these topic papers are available here on the DWR website. A key comment from DWR is that GSAs should not overlap, and that overlapping GSAs will need to be corrected. One of the key, and challenging, differences between the AB3030 groundwater management plans and the new GSPs is the requirement to develop measurable objectives.

Juliet Christian-Smith covered the recently published Union of Concerned Scientists' "Measuring What Matters," which provides a good overview of how to set measurable objectives to achieve sustainable groundwater management. The SGMA directs GSAs to set measurable objectives that will avoid what the act refers to as "undesirable results" (such as the chronic lowering of groundwater levels) (Figure 3). Effective measurable objectives must define clear baselines, set quantitative thresholds, develop protective triggers, incorporate regular measurement and monitoring, account for uncertainty, and adapt to changing conditions and knowledge. Juliet suggested recommendations, including developing a common state framework for setting thresholds and milestones, identifying existing data sources and basin conditions, requiring consistent assumptions to develop sustainable yield, and developing common metrics and consistent data management and reporting protocols.

Erik Ekdahl discussed the Water Board's water-quality roles and SGMA implementation. Existing water-quality law and regulations include Porter Cologne (Water Code §13000 et. seq.), Basin Plans, Anti-Degradation Policy (Resolution 68-16), Irrigated Lands Regulatory Program (ILRP), Dairy Program, Drinking Water Policy (Resolution 88-63), Water Code §2100, and the Recycled Water Policy. Erik discussed how SGMA water-quality authorities were really intended to address prob-

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Summary of GRA's Sustainable Groundwater Management – Time for a Change – *Continued*

lems driven by overdraft at the basin scale, and were not intended to regulate pre-existing water-quality issues that can be addressed by existing authorities (e.g., discharges), although GSAs can use new authorities to address pre-existing water-quality challenges. The Water Board continues to act as the primary water-quality control entities through existing Porter Cologne and Water Code powers and authorities; SGMA requires GSAs to understand current water-quality issues and to ensure that their actions do not negatively affect water quality in the basin (Water Code 10727.2). With the possible exception of seawater intrusion, degradation of water quality, which is an undesirable result defined in the SGMA, is ambiguous and site-specific. Erik concluded by observing that we are early in the process, there are conflicting stakeholder goals concerning water-quality integration into SGMA, future regulations will reflect DWR's best approach for maintaining water quality while achieving sustainability, and that the Water Board's authority extends beyond water quality. More information is here on the Water Board's website.

Panel 2: Science, Tools and Technology for Water Budgets – Minimum and Adequate Monitoring and Modeling

Moderated by ***Rob Swartz****, Sacramento Groundwater Authority*

This panel included presentations by **Graham Fogg**, Professor, University of California Davis; **Steve Phillips**, Hydrologist, U.S. Geological Survey; and **Ali Taghavi**, Vice President, RMC Water and Environment. Graham Fogg led off the session by discussing some of the challenges regarding the role of models and SGMA data infrastructure needs, including estimating water budgets, and dealing with cross-boundary fluxes between neighboring GSAs; he suggests that basin-scale, calibrated groundwater models can help greatly with these problems. Graham discussed a number of myths, beginning with (1) the model is only as good as the underlying data; however, groundwater models seeded with sufficient data and properly calibrated can be better than the underlying data and the best and most powerful tools for calculating water budgets. Myth (2) is that since groundwater management is best done locally, groundwater models are best when local; actually, models that encompass entire groundwater systems (e.g., Central Valley, Salinas Valley, etc.) will be the best investments, because artificially-drawn non-physical boundaries, such as county lines, lead to more uncertainty and less efficient water management. Myth (3) is that the most troublesome unknowns in groundwater models are water levels and aquifer parameters, whereas the main drivers are instead the biggest water-budget terms—pumpage and recharge. Myth (4) is that groundwater models are groundwater models; actually, they are integrated hydrologic models encompassing interconnected groundwater, surface water and agricultural water processes. Myths (3) & (4) suggest that, at the statewide level, the highest data priority should be placed on agricultural land use and river data that most strongly reduce the uncertainty in recharge and pumpage estimates. Myth (5) is that it typically takes 3–4 years to build and calibrate a model, and then you just apply it; however, a groundwater model should be considered a major initial and ongoing information infrastructure investment, comparable in importance to hard infrastructure such as dams and pipelines. Myths (6) & (7) are that groundwater modeling is expensive, and that all GSAs need to build models. Except for relatively small basins, model-building by GSAs is too expensive and a regional model of the entire groundwater system is what is needed. California needs to invest in developing basinwide models to support GSAs, especially in the Central Valley, and models need to be more intensively calibrated over multiple decades of groundwater and streamflow response.

(left to right) Graham Fogg, Rob Swartz, Steve Phillips, Bill Alley and Ali Taghavi

Steve Phillips discussed how to overcome deficiencies in existing models. A key focus is to reduce the model uncertainty by the inclusion of more, and different, measurements and information, including the physical properties of the aquifer system, physical aspects of the landscape, components of the water budget, and indicators of system state (things to calibrate to). Notably, models can be improved significantly by incorporating information from well logs, including well location, lithology and well-capacity data; and land use, crop and irrigation information. Taking advantage of model code enhancements as they improve, including tools like the Farm Process for simulating different land-use demands and processes associated with irrigated

Continued on the following page…

Summary of GRA's Sustainable Groundwater Management – Time for a Change – *Continued*

agriculture; advanced tools for quantifying uncertainty; and tools for including different types of data in calibration.

Ali Taghavi focused his presentation on the statewide status of models and water budgets, and the question of what level of water budget is needed to meet SGMA requirements; data-based or model based. Data-based approaches may be sufficient, but would not provide the long-term picture that may be needed to support regional sustainability planning. A comprehensive water budget includes information from multiple systems, including the climatic, land-surface, stream & canal, and groundwater systems. Basin-scale models synchronized with local data via collaboration can be a robust tool for water-budget estimation and sustainability planning; however, local-scale models are needed to meet local/regional project-level planning. A flexible framework of data exchange protocols needs to be developed to facilitate data movement between basin- and local-scale models. C2VSim and CVHM enhancement will benefit from local and regional collaboration and sharing of data and information.

Lunch Speaker: Tim Parker, Parker Groundwater Management – SGMA and Adjudication Reform

Tim Parker provided an update on adjudication reform, which is being spearheaded by the Legislature, ACWA, and Farm Bureau with the support of the Administration. Senate Bill 226 (Pavley) provides provisions to harmonize the SGMA with adjudications to ensure the SGMA processes, such as GSA formation and GSP preparation, will not be interfered with. AB1390 (Alejo) provides provisions to help streamline adjudication processes to reduce the time and cost of groundwater litigation. More information is available here.

(left to right) Ali Taghavi, Dan McManus, Sam Boland-Brien, Lance Eckhart, Tara Moran, and Allen Christensen

Panel 3: SGMA – Integrating State, Federal and Local Data Programs

*Moderated by **Ali Taghavi**, RMC Water and Environment*

Dan McManus, Supervising Engineering Geologist, DWR; **Sam Boland-Brien**, Water Resources Control Engineer, SWRCB; **Lance Eckhart**, Senior Hydrogeologist, Mojave Water Agency; **Tara Moran**, Sustainable Groundwater Program Lead, Stanford Water in the West; and **Allen Christensen**, Hydrologist, USGS, participated in the panel to discuss approaches and plans to integrate state, federal and local data programs. Dan McManus focused his presentation on linkages between the SGMA, and objectives in DWR's Sustainable Groundwater Management Plan, to work they have planned. DWR's SGM Program has five main objectives: (1) develop a framework for SGM, (2) Provide statewide technical assistance, (3) provide statewide planning assistance, (4) assist state and GSA alignment and provide financial assistance, and (5) provide interregional assistance. Key actions regarding data collection under framework development include development of comprehensive basin water budgets, updating basin prioritization and identifying basins subject to critical conditions of overdraft. Key actions regarding data collection, under state technical assistance, include development of a groundwater management information system, data collection and CASGEM. Key actions regarding data collection under statewide planning include updating Bulletin 118 and integrating groundwater information into the state water plan. DWR's integrated data-management-framework project includes data collection by DWR, data exchange by DWR, water-budget methods and analysis by DWR, and data reporting by local agencies.

Sam Boland-Brien discussed how the Water Board will support raising the bar under the SGMA with multiple opportunities to leverage resources and processes that will be driven by SGMA mandates. The Water Board's implementation role is enforcement, as compared to DWR as the regulator and the GSAs as implementers. For probationary basins, the Water Board will have data-collection and storage needs for name and address, name of basin, location of extraction, capacity, monthly extraction volumes, purpose and place of use, and year of initiation. The Water Board and DWR have shared responsibilities, with overlapping data needs; the Water Board will respond to long-term overdraft, probationary GSP review, deficiency identification and interim plan development, and is in the process of developing criteria for a database to support extraction reporting and enforcement. Recognizing the differing timelines between their mandates and DWR's, the Water Board is in frequent contact with, and coordinating with,

Continued on the following page…

Summary of GRA's Sustainable Groundwater Management – Time for a Change – *Continued*

DWR to identify opportunities to integrate multi-agency data collection and utilization.

Lance Eckhart discussed Mojave Water Agency's data program, focusing on the groundwater monitoring. MWA works collaboratively with their partner agencies to collect and manage data, with key wells for the basin, USGS cooperative wells, Groundwater Ambient Monitoring and Assessment Program wells, Title-22 water-quality monitoring wells and water discharge requirements. MWA maintains, and makes available to their partners, the groundwater data management system.

Tara Moran gave an overview of the groundwater data projects in the works at Stanford Woods Institute for the Environment, Water in the West, Sustainable Groundwater Program. Water in the West is doing a retrospective analysis of groundwater data and management arrangements in California with the goal of using lessons learned to inform SGMA implementation activities. They observe a local agency during SGMA implementation in order to develop an understanding of the processes involved, and the role of data and data dissemination. There is also a groundwater data survey being conducted to learn about current groundwater data, including collection, use and sharing practices, in order to better understand current data management practices, anticipate challenges during SGMA implementation, and to inform the case studies and a data workshop series.

Allen Christensen discussed the variety of USGS data and modeling programs in California. The USGS has developed a number of models that cover many coastal and desert basins, as well as the Central Valley, with a variety of features and periods simulated. Examples include the Santa Rosa Plain coupled surface water–groundwater GSFLOW model and Antelope Valley MODFLOW model to evaluate sustainable yield and management options. Additionally, USGS has developed methods and tools to evaluate water quality, including the well-bore flow and depth-dependent sampling methodology. Finally, the National Water Information System (NWIS) database was discussed in terms of the variety of data available, and recent enhancements in accessibility.

(left to right) Rob Swartz, Lance Eckhart, Adam Hutchinson, Vanessa De La Piedra

Panel 4: Existing Alternative Plans and Approaches

*Moderator – **Lance Eckhart**, Mojave Water Agency*

Lance Eckhart kicked off the session, which included **Adam Hutchinson**, Recharge Manager, Orange County Water District; **Rob Swartz**, Senior Project Manager, Sacramento Groundwater Authority; and **Vanessa De La Piedra**, Groundwater Unit Manager, Santa Clara Valley Water District. Lance described the Mojave Water Agency as having a complex mix of high-, medium-, low- and very-low-priority basins in their jurisdictional area; the adjudicated boundary of the Mojave Basin encompasses about 3,400 square miles. Most of the adjudicated area is in balance, but some areas are declining.

Adam Hutchinson explained that Orange County Water District was established by the Legislature in 1933 and is a leader in the water industry through its water reuse and recharge/replenishment programs. Currently OCWD says they are managing groundwater effectively as-is, and would prefer not to take on the role of a GSA, as additional powers are not currently needed to maintain groundwater sustainability, and change could upset the current management system, which is working well. One issue that OCWD has identified with the SGMA is that their jurisdictional boundary does not quite fully cover the entire basin, and fringe areas exist that have minimal activity, but are accounted for in management; so the question becomes whether or not these fringe areas need to be addressed, and if so, how?

Rob Swartz explained that the Sacramento Groundwater Authority (SGA) was established in 1998 to manage the groundwater basin under north Sacramento County under a joint powers agreement using the police powers of 3 cities and a county, and the board includes 14 water suppliers and 2 independent pumping groups. At the time of formation, the area was experiencing overdraft and water-quality degradation. The SGA established an average sustainable pumping target in the central SGA area, amounting to roughly a 10-percent reduction, which public agencies met by implementing conjunctive use or reducing demands. The 2014 Groundwater Management Plan update set measurable objectives and upper and lower action thresholds to mitigate impacts from users of groundwater. Rob summarized by saying that locals can work together to come up with

Continued on the following page…

Summary of GRA's Sustainable Groundwater Management – Time for a Change – *Continued*

solutions for sustainability, GSPs aren't that different from GMPs, and it is important to identify a process rather than focus on prescriptive actions to meet management objectives.

Vanessa De La Piedra introduced the Santa Clara Valley Water District by noting that it was formed in 1929 as a result of a push by farmers and business leaders to help mitigate groundwater-level declines, and associated land subsidence and bay land inundation. Recharge projects commenced in the 1920s and 30s and subsidence was effectively halted in the early 1970s. SCVWD has a variety of groundwater protection and monitoring programs, including well permitting and metering to protect water quality and quantify pumping; and basin assessment, including groundwater levels, water-quality and subsidence monitoring, and groundwater modeling. The SGMA potentially affects SCVWD by designating it as an exclusive groundwater management agency with the existing authority unchanged, but provides potential new tools, including well-spacing or operational requirements, the ability to regulate or limit pumping, and flexibility for fees. Next steps for SCVWD include coordination with all stakeholders, and conducting a technical analysis and updating the groundwater management plan in 2016.

Closing Panel: Outcomes and Practical Next Steps

*Moderator **Jim Strandberg**, Chief Engineer, West Yost Associates*

The panelists for this session included **Walt Ward**, Water Resources Manager, Stanislaus County; **Phyllis Stanin**, Vice President, Todd Groundwater; and **Tim Parker**, Principal, Parker Groundwater Management. Summary comments from the closing panel included that water budgets are important, but measurement of water use is vital, particularly in areas where basin status is critical. The new GSPs are not that much different from full-fledged GMPs, with the exception of the required measurable objectives and associated quantifiable thresholds and actions, along with a 50-year planning horizon. For models, acknowledge that they are an investment that is needed in many areas, but not all; the state should provide assistance with basin-wide models in the Central Valley; and much-improved calibration is needed, as is an accounting of model uncertainty. A flexible framework of data standards is essential, and this should be developed jointly by DWR and the Water Board, working with the groundwater industry. An example of a flexible data management framework can be found on the website for the National Groundwater Monitoring Network, Subcommittee on Groundwater, Advisory Committee on Water Information, Department of Interior.

(left to right) Jim Strandberg, Tim Parker, Phyllis Stanin, Walt Ward

GRA would like to extend our sincere thanks for the generous support of the following organizations to help make this event a success:

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Groundwater Resources Association of California
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How to Fund Groundwater Sustainability Symposium & Annual Legislative Symposium

MARCH 29-30, 2016 – SACRAMENTO, CA

How to Fund Groundwater Sustainability Symposium – March 29, 2016

This symposium will focus on three areas related to paying for development and implementation of groundwater projects and Sustainable Groundwater Management Act of 2014 (SGMA)-related activities;

- obtaining outside funding
- developing the agency contribution, or "match", and
- Generating revenue to implement your Groundwater Sustainability Plan (GSP).

With the passage of Proposition 1, water resources funding has received new attention. Speakers from State and Federal programs will identify how to find funding sources, apply for, and implement projects using grant funds.

Experts will discuss the various grant programs, how to meet grant criteria, and what successful grant funded projects have looked like. Agency funding for the development of GSAs and GSPs will also be covered, as well as different vehicles for funding including green-bonds, mechanisms for assessment and collecting fees for GSA (and recent relevant Prop 218 happenings), joint-agency cost-sharing, and successful pump-tax programs.

Questions?
Contact Chris Petersen at 916.631.4597

NOTE: Speakers are not yet confirmed and subject to change. Draft agendas to be posted soon.

Annual Legislative Symposium – March 30, 2016

After suffering another year of historic drought and a State of Emergency declared by Governor Brown, California remains poised in 2016 for the extension of Emergency Drought Regulations promulgated by the State Water Resources Control Board. But will 2016 also be a year of finding and finalizing solutions for long term groundwater sustainability? Join us for a dialogue on this and other subjects with California's most influential Legislators and Administration Officials.

California Water Action Plan 2016 Update; SGMA updates including Groundwater Sustainability Agency formation progress and challenges, regulations for evaluating and implementing Groundwater Sustainability Plans, Alternative Plans and coordination agreements; California Water Fix update; identifying water available for groundwater replenishment; Propositions 218 and 26 updates; and much more!

This year's invited speakers will include Senate and Assembly Water Committee Chairs Pavley and Levine, Assembly Speaker Anthony Rendon, Senate President Pro Tem Kevin de Leon, Senators Hertzberg, Stone and Wolk and Assembly Members Bigelow and Eggman, and Administration Officials from the Governor's office, DWR and SWRCB.

Presented by Groundwater Resources Association of California in Conjunction with California Groundwater Coalition.

Questions?
Call Rosanna Carvacho at 916.594.9700

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If you are interested in exhibiting your organization's services or products, or being an event co-sponsor, use our online registration form. For additional information regarding sponsorship and advertising opportunities, see GRA's Ad Kit.

Dates & Details

GRA EVENTS & KEY DATES

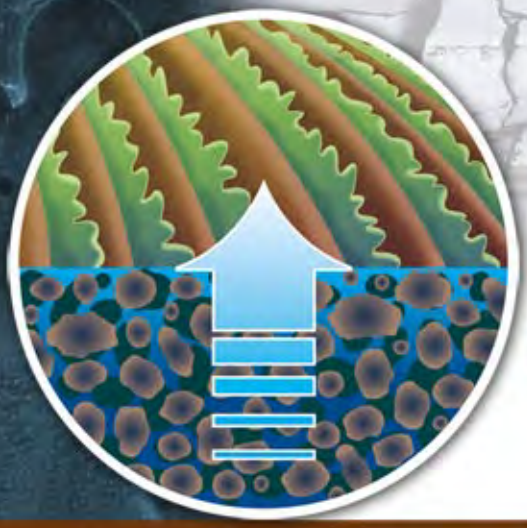
(Please visit www.grac.org for detailed information, updates, and registration unless noted)

GRA Legislative Symposium/ Funding for Groundwater Projects and Groundwater Sustainability Agencies Symposium
Mar. 29-30, 2016 | Sacramento, CA

GRA 25th Annual Meeting
Sept. 28-29, 2016 | Concord, CA

GRA Symposium
Oil, Gas and Groundwater in California
Nov. 2-3, 2016 | Bakersfield, CA

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



Toward Sustainable Groundwater in Agriculture

2nd International Conference Linking Science and Policy

June 28-30, 2016

Hyatt Regency at the San Francisco Airport • Burlingame, CA

Sponsored by the Robert M. Hagan Endowed Chair

This three-day conference will provide scientists, policymakers, stakeholders, governmental officials, and consultants with the latest scientific, management, legal and policy advances for sustaining groundwater in agricultural regions around the world.

Additional Groundwater Workshops set for June 27

Program Highlights:

Groundwater is the lifeline for many agricultural regions and a cornerstone of global food production. It constitutes nearly half the world's drinking water and much of the world's irrigation water supply. Drought, overuse, groundwater salinity, nonpoint source pollution, energy policy and climate change create water quality and supply conflicts. Attend this conference and hear from top speakers about ways to address these issues and better manage vital resources to ensure a sustainable future – in California, the United States, Canada, Australia and Europe, but also in Asia, Latin America and Africa.

Confirmed speakers include:

- **Karen Ross**, *Secretary of the California Department of Food and Agriculture*
- **Gordon Burns**, *Undersecretary of California Environmental Protection Agency*
- **Bill Alley**, *Science and Technology Director for the National Groundwater Association and former USGS Groundwater Chief*
- **Lester Snow**, *Executive Director of the Water Foundation*

This conference builds upon research and presentations from the 2010 International Groundwater Conference. Visit **http://ag-groundwater.org** to learn more.

Sponsorship opportunities and exhibit space are available. Contact Beth Stern at bstern@watereducation.org

Register online at www.watereducation.org/internationalgroundwater2016

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Wells and Words

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

Part 3 – Yield-Depression Curves for Evaluating Well Development Effectiveness, or Whether to Rehabilitate a Well

An informal or formal step-drawdown (step-dd) pumping test (also called a variable discharge [Q] test) provides the paired data sets (Q, s) for the yield-depression (y-d) curve, where "s" represents the drawdown. Ideally, the methodology for the step-dd test should be implemented with pumping and recovery cycles[1] for each step (i.e., pump at Q_1 for elapsed time t_1, then stop pumping for t_1 to recover; pump at Q_2 for t_1, then stop for t_1; and so forth). Because of the significant costs of this cyclical methodology, the step-dd test is usually conducted without recovery periods between the steps (i.e., pump at Q_1 for t_1; increase discharge to Q_2 for t_1; etc.). Therefore, interpretation of the y-d curve sans recovery periods (without corrections) must be done with the awareness that the measured dds for each step may be influenced by projected dds from previous steps.

Typically, these projected dds amount to small corrections that are dependent on the slope of the time-dd line, the elapsed time, and, ultimately, the aquifer parameters. The corrections can be estimated using the Hantush-Biershenk (H-B) method discussed in detail in Kruseman and de Ridder[2] (KdR). This graphical method uses semi-logarithmic graph paper (elapsed time of pumping on the log-scale and dd on the arithmetic) to project the dd from step to step. However, the H-B method is not easily applied during well-development programs, which can otherwise provide valuable well hydraulic information on y-d curves.

The y-d curve incorporates the combined effects on dd in the pumping well caused by formation-loss (fm-loss) and well-loss. Fm-loss (aquifer-loss[3]) is the dd associated with the laminar flow of groundwater through the aquifer toward the pumping well in response to the change in hydraulic head (i.e., dd) at the pumping well. The laminar flow toward the pumping well encounters a resistance (hydraulic conductivity) represented by the systematic array of dds that radiate from the pumping well; the greatest dd is located at the pumping well, and dd decreases with distance from the well. This pumping response manifests as a cone of depression, which expands according to Darcy's Law and the Well function. In essence, the fm-loss is the hydraulic-head loss measured at the interface between the aquifer and edge of the boring[4].

The well-loss is the additional decline in hydraulic head in a well below that measured in the adjacent aquifer; it is created by turbulent flow and by frictional head losses in the well screen and the filter pack[5]. Sometimes called the "skin effect," this head loss is derived from the bore-hole damage zone, incomplete development of the filter pack, an improperly-sized filter pack, and physical constraints on the transmitting capacities of the filter pack and the well screen.

A method to evaluate the proportion of fm-loss (B) and well-loss (C) for a pumping well was first proposed by Jacob[6] and later modified to a more general formula by Rorabaugh[7]:

$$s = BQ + CQ^2, \text{ or } s = BQ + CQ^n$$

where, B and C are constants in ft/gpm and ft/gpm^2, respectively;

s = drawdown observed in the pumping well in feet (ft);

Q = discharge of the well in gallons per minute (gpm);

BQ = linear fm-loss + linear well-loss coefficient (a function of the effective borehole radius and the elapsed time of pumping);

CQ^2 = non-linear well-loss coefficient due to turbulent flow near the well; and

n varies between 1.5 and 3.5.

Re-arranging the equation:

$$\left[\frac{s}{Q}\right] = B + CQ = \text{specific drawdown} = \text{inverse of specific capacity} = \left[\frac{Q}{s}\right]^{-1}$$

Coefficients B and C can now be estimated by using a graphical method of plotting Q (x-axis) versus specific-dd (y-axis) on arithmetic graph paper[1,8]. Note that the specific-dd is the inverse of our jolly good friend the specific capacity. This equation defines a straight line where B is the intercept at Q = 0, and C is the slope of the line [Δ(s/Q) ÷ ΔQ].

Figure 1 shows a comparison of plots for Well 23[9]: part 1a is the y-d curve analysis and part 1b is the H-B method. The y-d curves were discussed in the first two articles of this series, and are the easiest field method for evaluating the effectiveness of well development programs. Question: what will be the drawdown at 2,250 gpm (blue dotted vertical line) for Well 23? The y-d curve can be used to predict that the dd for the well would be about 66 ft (blue dotted horizontal line). The H-B method can also be used, but each time this question arises for a different Q, the specific-dd (0.0296 ft/gpm from the projection of the blue dotted horizontal line) must be multiplied by 2,250 gpm, which in this case would be about 66.6 ft. Note the scatter of red data points in part 1b, which contrast to the systematic alignment of the red data points in part 1a; is this scatter useful information?

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Wells and Words – *Continued*

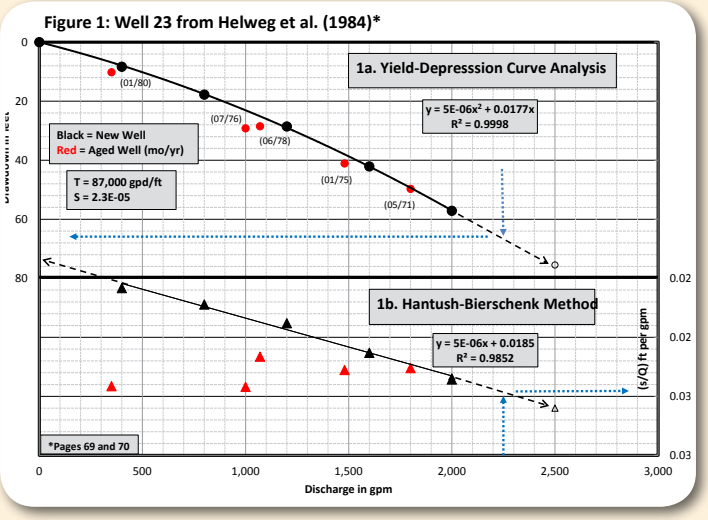

Figure 1: Well 23 from Helweg et al. (1984)*

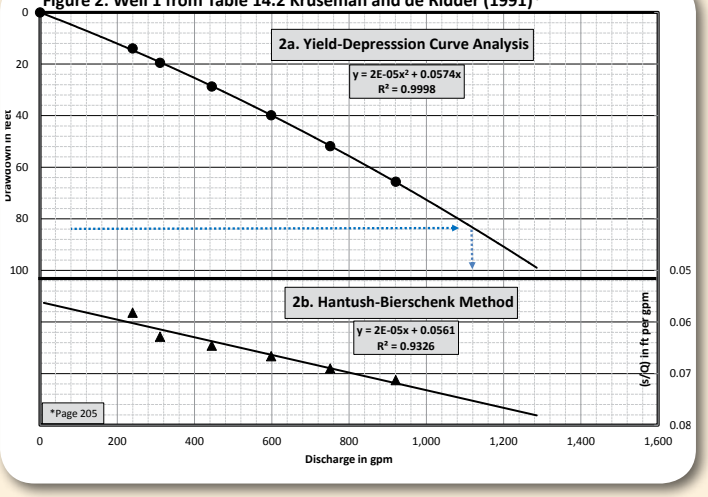

Figure 2: Well 1 from Table 14.2 Kruseman and de Ridder (1991)*

Figure 2 shows a comparison of plots for data from KdR on page 205: part 2a is the y-d analysis and part 2b is the H-B method. Question: what would the discharge be at 84 ft of dd? The y-d curve can be used to predict that the discharge for the well would be about 1,120 gpm; note that the projection includes both existing fm- and well-losses. The H-B method cannot be graphically solved, because the discharge is unknown on both the x- and y-axis. However, it can be solved by using the best-fit equation of the line:

$$\frac{s}{Q} = 0.00002Q + 0.0561; \text{ re-arranging yields}$$

$$s = 0.00002Q^2 + 0.0561Q;$$

let s = 84 ft in this example, and

$$0 = 0.00002Q^2 + 0.0561Q - 84$$

The quadratic formula can solve this equation, where a = 0.00002; b = 0.0561; and c = -84:

$$Q = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Calculations show that Q = 1,080 gpm. What a nightmare calculation!

In summary, computing B and C may be important in some cases; for example, to determine whether a well-development program should be implemented or extended to increase the efficiency and reliability of the well and pumping plant. However, the additional calculations required for the H-B method to determine various paired data sets (Q, s) are cumbersome and are not easily used by mechanical or electrical engineers (let alone many well owners) for the purpose of designing and selecting a permanent pump. The y-d method provides the engineer the flexibility to choose different operating parameters (Q, s) for a given application without burdensome calculations.

[1] Hantush, M.S., 1964, Hydraulics of Wells in: V.T. Chow (editor), *Advances in Hydroscience*, Volume 1, pp. 281-432, Academic Press, New York.

[2] Kruseman, G.P. and N.A. de Ridder, 1991, *Analysis and Evaluation of Pumping Test Data (2nd edition)*, Pub. 47, International Institute for Land Reclamation and Improvement, Wageningen, the Netherlands, 377 p.

[3] Poehls, D.J. and G.J. Smith, 2009, *Encyclopedic Dictionary of Hydrogeology*, Academic Press, Amsterdam, 517 p.

[4] Roscoe Moss, 1990, *Handbook of Ground Water Development*, John Wiley & Sons, New York, 493 p.

[5] American Geological Institute (AGI), 1998, *Glossary of Hydrology*, AGI, Alexandria, VA, 248 p.

[6] Jacob, C.E., 1947, *Drawdown test to determine effective radius of artesian well*, Transactions of the American Society of Civil Engineers, Volume 112, Paper 2321, pp. 1047-1064.

[7] Rorabaugh, M.I., 1953, Graphical and theoretical analysis of step-drawdown test of artesian well, Proceedings of the American Society of Civil Engineers, Volume 79, separate no. 362, 23 p.

[8] Bierschenk, William H., 1963, Determining Well Efficiency by Multiple Step-Drawdown Tests, International Assoc. of Science Hydrology Publication 64, pp. 493-507.

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

The Federal Corner

By Jamie Marincola, U.S. EPA

EPA Releases Final Regulatory Determinations for Contaminants on the Third Drinking Water Contaminant Candidate List

U.S. EPA reduces human health risks by studying the presence of selected unregulated contaminants in drinking water every five years, and then determining whether to regulate the unregulated contaminants. EPA has made a final regulatory determination not to issue a national primary-drinking-water regulation for dimethoate, 1,3-dinitrobenzene, terbufos and terbufos sulfone, because they are not occurring, or occur infrequently in drinking water. EPA also deferred a final regulatory determination for strontium. Read more here.

Groundwater Study Assists in Crucial Sustainable Water-Management in Borrego Valley, California

A new study completed by the U.S. Geological Survey, in cooperation with the Borrego Water District, will help water planners in the Borrego Valley, California better understand and manage the groundwater resources that the area relies on for drinking water, agriculture and recreation. USGS scientists collected new data, and analyzed decades of historic data, from the Borrego Valley to evaluate the potential hydrologic effects of future development and quantify the limits of the Valley's groundwater resources. The results of the study are featured here.

EPA Announces $22 Million Settlement for Cleanup of Cooper Drum Superfund Site in South Gate, Los Angeles County

U.S. EPA and U.S. Department of Justice today announced that a group of 40 parties has agreed to conduct the cleanup of the Cooper Drum site in South Gate, 10 miles southeast of downtown Los Angeles. The settlement requires an estimated $15 million to construct the additional groundwater treatment system needed, including wells, piping and treatment costs, plus $7 million to reimburse EPA for its past cleanup actions at the Superfund site. For more information on the site, please visit this link.

Commercializing Passive Sampling Technology to Enhance the Risk Analysis Process

A team of researchers at North Carolina State University, which is funded under U.S. EPA's Superfund Research Program, has developed a new passive sampling technology that can provide better estimates of chronic exposure to bioavailable chemicals present in water. It is called a non-selective passive sampling device (ns-PSD). This technology also gives practitioners information related to the ability to uptake a chemical in animals or humans, as well as time-weighted averages of surface-water contaminant concentrations. In the end, it allows a better prediction of exposure rates and the development of more complete assessments of human health risk. To learn more, click here.

New USGS Report on Snowpack, Rainfall, and Reservoirs in Buffering California Against Drought

The USGS recently released information on how snowpack, rain, and reservoirs are used to buffer the California drought. Although California has almost 1,300 reservoirs, only 200 are considered "storage reservoirs," and the larger ones are critical to the Central Valley and State Water Project facilities. Storage reservoirs capture winter precipitation for use in California's dry summer months. In addition to water stored in reservoirs, California also depends on water stored as snowpack to augment the state's water supply as it melts during the summer. The information includes monthly totals of water stored in 12 major reservoirs and 148 smaller reservoirs, and estimated statewide snowpack from January 1970 through April 2015. The report is available here.

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

Dissolved Organic Matter (DOM): What is it and Why Should We Care?

By Bart Simmons

An earlier column discussed the critical role of dissolved organic matter (DOM) in the behavior of copper in aqueous systems. In San Francisco Bay, greater than 98% of copper is chelated by DOM, which renders the copper non-bioavailable and non-toxic. DOM has similar effects on other metals. It also binds to and changes the surface charges of colloids. Barriers to understanding the role of DOM are its complexity and its variability. Two particular questions regarding DOM are: 1) what is it? and 2) how does it react with environmental contaminants?

DOM consists of a complex, heterogeneous collection of high- to low-molecular-weight species exhibiting different water solubilities and reactivities. However, multidimensional nuclear magnetic resonance (NMR) and GC- GC-MS have identified the major structural groups in fresh water as:

- carboxyl-rich alicyclic molecules (CRAM) in the range of C10 to C17 (alicyclic compounds are aliphatic and cyclic, e.g., cyclohexane)
- heteropolysaccharides
- aromatic compounds
- material derived from linear terpenoids (MDLT); terpenoids have also been identified in marine organic matter.

Terpenoids are modified terpenes, which are naturally-occurring hydrocarbons resulting from the combination of several isoprene units. Terpenoids account for most natural products. It has been suggested that most of freshwater DOM is aliphatic in nature, with CRAM derived from cyclic terpenoids and MDLT derived from linear terpenoids. Historically, aquatic organic matter has been arbitrarily divided into dissolved and particulate organic matter, based on filtration, generally through a 0.45 µm filter. No natural cutoff exists between the >0.45 µm fraction and the <0.45 µm fraction so the distinction is operational. Based on recent advances in the analysis of DOM, many thousands of molecules, most of which have relatively low molecular weight (less than 2,000 Daltons), are known to contribute to the composition of DOM in a given water sample.

However, DOM composition varies among samples as a function of source materials, biogeochemical processes, and hydrology.

DOM plays a critical role in:

- fate and transport of metals
- understanding the fate of manufactured nanoparticles
- carbon sequestration, thus its importance in understanding the effects of climate change.

DOM has the double curse of complexity and variability. However, newer analytical tools are providing some insight into the nature of this common but important environmental substance.

Bart can be reached at bartonps@aol.com.

Do Your Part to Raise Public Awareness of Groundwater

Groundwater Awareness Week March 6-12

By Cliff Treyens, National Ground Water Association

As someone with a stake in groundwater, the National Ground Water Association (NGWA) invites you to help raise public awareness about groundwater during National Groundwater Awareness Week, March 6-12, 2016.

For starters, consider posting information on your websites or social media in which your organization may be involved. We've included links you can use below.

To further help you promote your organization and groundwater awareness in conjunction with Groundwater Awareness Week, consider issuing a news release. You can download a news release using the link in the list of information resources below.

To make it easy to locate news media in your state, download this news media database, then go to the telephone number column. The area codes are in descending numerical order so you can easily pick out media with area codes in your state. Then just copy and paste the corresponding email addresses in order to email a news release, news advisory, an invitation to interview, an announcement, etc.

Remember, about 40 percent of Americans rely on groundwater for all or part of their drinking-water supply—and nearly 40 million Americans get their drinking water from privately owned and maintained water wells.

Some of the following resources can be used as-is; others can be adapted, modified, or customized to your state or locale. It's really up to you. National Groundwater Awareness Week is an opportunity to publicly promote something you care about year-round: groundwater.

- Groundwater Awareness Week logos (click on link, then right click on logo and "save as")
- Flier
- Poster
- Well owner videos
- *Groundwater Is Cool* video
- *Groundwater Careers* video
- State groundwater use data
- NGWA educator resources
- Groundwater Adventurers for kids
- Editorial
- News release
- Radio spots
- Well owner information sheets
- Global groundwater use

Please feel free to contact me with your questions!

Cliff Treyens, Public Awareness Director for National Ground Water Association — Dedicated to Advancing Groundwater Knowledge, Phone 800 551.7379 (614 898.7791), x 554, fax 614 898.7786, www.NGWA.org, www.WellOwner.org

2016 David K. Todd Distinguished Lecturer Series

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

The Winter 2015 *HydroVisions* included biographical introductions of the lecturers for this year. Further details on these lecturers can be found on the GRA website. Look for the lecture schedule to be posted online, to attend an event near you!

Miranda Fram, Ph.D.
(Northern California)
Geochemist
Program Chief,
Groundwater Ambient Monitoring and Assessment Priority Basin Project
United States Geological Survey

Quality of Groundwater Used for Public Drinking Water Supplies in California

Abstract:

Dr. Fram's presentation provides an overview of the GAMA Program Priority Basin Project (GAMA-PBP), and draws on results from more than 10 years of GAMA-PBP studies to illustrate the primary factors affecting groundwater quality in California. GAMA-PBP is a SWRCB program implemented by the USGS and designed to assess the quality of groundwater in aquifers used for drinking water supplies statewide, to help better understand the risks to groundwater resources, and to increase availability of information about groundwater quality to the public. Groundwater provides approximately half of the water used for public and domestic drinking water supplies in California. Assessment of nearly all of the groundwater used for public supply statewide indicated that about 20% has high concentrations for one or more constituents of concern. High concentrations are defined as greater than state and federal maximum contaminant levels set for drinking water standards, or for constituents without MCLs, other human-health based benchmarks. On a statewide basis, trace elements, such as arsenic, manganese, and uranium, were found to be more prevalent at high concentrations than either nitrate or organic compounds. However, different areas of the state had different combinations of constituents prevalent at high concentrations, reflecting three primary factors controlling groundwater quality. (1) Time: Wells may tap mixtures of groundwater with ages ranging from just a few years to several tens of thousands of years, and groundwater of different ages commonly has different chemical compositions. (2) Hydrogeologic conditions: The geochemistry of sediments and rocks through which groundwater percolates determines which constituents are available to dissolve into the water, and groundwater flow patterns affect how these constituents move in the aquifers. (3) Human activities: Anthropogenic contaminants, such as nitrate and organic compounds, may be intentionally or unintentionally introduced to groundwater in agricultural, urban, and industrial environments. Furthermore, groundwater pumping and irrigation may cause changes to hydrogeologic conditions that result in changes in groundwater quality.

Behrooz Mortazavi (Southern California)
Principal
Water Resources Engineering Inc.

Role of Groundwater in Integrated Water Resources Management

Abstract:

Many water agencies and water resources authorities in California and around the world are interested in increasing their supply reliability during critically dry conditions. These entities continuously try to expand use of local resources in an effort to improve water supply reliability in their region. Use of potable groundwater, desalinated groundwater, and storage of surface water or recycled water in the local aquifers are some of the elements that can enhance water supply reliability.

Implementation of these elements requires existence of water rights, and existence of a viable water resources management plan. In addition, water quality variations and geopolitical dynamics play an important role in the structure of these management plans.

This talk reviews political, environmental, and technical challenges for implementing an integrated resources plan. EMWD's local resource planning will be used as a case study to demonstrate how EMWD used its available groundwater resources to implement a successful integrated resources plan in Southern California.

GRA Requests Nominations for the 2016 "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:

To provide recognition to individuals who have demonstrated leadership and continuous dedication in groundwater hydrology.

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 24, 2016**.

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 25th GRA Annual Meeting in Concord, CA, September 28 and 29, 2016.

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:

2015 – Dr. John A. Izbicki

2014 – Dr. David Huntley (1950-2015)

2013 – Dr. Shlomo P. Neuman

2012 – Anne J. Schneider, Esq. (1947-2010)

2011 – Joseph C. Scalmanini, P.E. (1945-2014)

2010 – Dr. John A. Cherry

2009 – Dr. T.N. Narasimhan, P.G. (1935-2011)

2008 – Dr. Perry L. McCarty

2007 – Dr. Herman Bouwer (1927-2013)

2006 – Glenn A. Brown, PG, CEG (1924-2015)

2005 – Dr. Luna B Leopold, P.G. (1915-2006)

2004 – Dr. John D. Bredehoeft

2003 – Rita Schmidt Sudman

2002 – Thomas W. Dibblee, Jr., PG (1911-2004)

2001 – Carl J. Hauge, P.G., CEG

2000 – Dr. Joseph H. Birman, PG, Gp, CEG, CHg (1924-2015)

1999 – Dr. David Keith Todd, P.E. (1923-2006)

1998 – Eugene E. Luhdorff, Jr., P.E. (1930-2010)

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:

2015 – California Department of Water Resources for its significant contributions to local agencies to advance groundwater planning, management, and conjunctive use with Regional Partnerships, Integrated Regional Water Management, and Drought Grant programs

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

2013 – Santa Clara Valley Water District for its 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 her leadership in the enactment of the comprehensive, statewide groundwater level monitoring legislation in California

2009 – U.S. Geological Survey, California Water Science Center for its 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 that became operational last January

Continued on the following page…

GRA Requests Nominations for the 2016 "Lifetime Achievement" and "Kevin J. Neese" Awards – *Continued*

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 its publication in 2003 of its updated Bulletin 118: "California's Groundwater"

2002 – Glenn County Water Advisory Committee for its 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.

A Tribute to Dr. Joseph H. Birman

Dr. Joseph H. "Joe" Birman, Geologist, Professor Emeritus at Occidental College, and Founder and President of Geothermal Surveys, Inc. (GSI/water), passed away December 23, 2015. He was 91. Joe leaves behind his two sons, David and Daniel Birman; his grandchildren, Jessica Johnson and Aaron Birman; and four great-grandchildren. Joe enhanced our industry with a remarkable scientific legacy that spanned more than 60 years of original research and contributions. From mapping the paths of glaciers, to making the case for early civilization in the Persian Gulf, to inventing technology that uses shallow temperature probes to detect the movement of groundwater, Joe has left an indelible mark.

As a Professor of Geology at Occidental College in Los Angeles from 1949 to 1984, Joe inspired hundreds of students to pursue a career in geohydrology. Three past GRA Board members—Brian Lewis, Susan Garcia and Tony Ward—and many GRA members are former students of Joe.

Joe possessed an extraordinary talent for communicating complex scientific topics with energy, insight and humor. At GRA's 1996 Annual Meeting, Joe gave the keynote address, entitled "*Why I Hate Hydrogeology*." While initially taken aback by its title, those in attendance quickly realized that this was a very interesting and well-articulated thesis—that the geologist should remember that other disciplines can enhance and refine, but never replace, the portion of geological understanding that only the geologist can provide.

Throughout his career, Joe published numerous articles in trade journals for various entities, including the Geological Society of America, California Division of Mines and Geology, American Society of Civil Engineers, and American Institute of Hydrology. Joe also provided contributions to the Handbook of Groundwater Development and AEG's Engineering Geology Practice in Southern California.

As Founder and President of Gsi/water, Joe oversaw projects in the western United States, the Gulf Coast, Mexico, South America, the Middle East and even an island in the Indian Ocean. His work included geologic and geohydrologic investigations, groundwater resource exploration and development, dam leakage detection and monitoring, brine resources exploration, and geothermal resources exploration. In addition to his affiliation with many trade organizations, Joe was a licensed geologist in the states of California, Oregon, and Arizona, and a Registered Geophysicist, Certified Engineering Geologist, and Certified Hydrogeologist in California. Joe was also a Certified Groundwater Professional (AGWSE) and Professional Hydrologist (groundwater/American Institute of Hydrology).

For his contributions to our industry, Joe was a recipient of the Life Member Award (NGWA), the Lifetime Achievement Award (GRA), and the Outstanding Educators of America Award (Occidental College). He was also a member of Sigma Xi Honorary Scientific Society, and received research grants from NSF, GSA and Southern California Edison.

In closing, it is worth noting that beyond the strictly terrestrial interests of geology and geohydrology, Joe enjoyed sailing on open waters and flying. It thrilled him to say that he could really experience the lithosphere, hydrosphere and atmosphere. Indeed, he was truly a man of our planet.

Whether you were family, friend, student, colleague, employee or client, knowing Joe put a smile on your face and made you a better human being. He will be deeply missed, but his legacy will continue.

GRA Welcomes the Following New Members

NOVEMBER 2, 2015 – FEBURARY 1, 2016

Herman, Bob	Roscoe Moss Manufacturing Company
Partington, Brian	Water Replenishment District of Southern California
Ortega, Ken	Water Replenishment District of Southern California
Stromberg, Scott	Arctos Environmental
Garcia, Roxanne	Orion Environmental Inc.
Atkinson, Holly	S.S. Papadopulos & Associates, Inc.
Duncan, Ron	Soquel Creek Water District
Zhao, Jin	
Herzog, David	CA Department of Toxic Substances Control
Lopez, Alexander	
Caruthers-Knight, Samantha	ERRG
Nicely, Timothy	GSI Water Solutions
Page, Nathan	GSI Water Solutions
Akbari, Aziz	
Standen, Allan	Allan R Standen LLC
Kassenaar, Dirk	Earthfx Inc.
Collins, Eric	Equant
Hebert, Aaron	Midpeninsula Regional Open Space District
London, Shari	Shell
Frind, Michael	Univ of Waterloo/Frind and Assoc
Frickle, Cynthia	San Mateo County Environmental Health
Chau, Les	Amec Foster Wheeler Environment & Infrastructure, Inc.
Baillie, Matt	Amec Foster Wheeler Environment & Infrastructure, Inc.
Conner, Kenn	Amec Foster Wheeler Environment & Infrastructure, Inc.
Midbust, Jessica	Ecology and Environment Inc.
Callahan, Michael	San Joaquin County Public Works
Hoffman, Lynn	San Joaquin County Public Works
Fulton, Ryan	Davids Engineering, Inc.
Davids, Grant	Davids Engineering, Inc.
Clark, Byron	Davids Engineering, Inc.
Fay, Ryan	Albion Partners
Nassar, Mohamed	Luhdorff & Scalmanini C.E.
Chamberlain, Warren	TRC Solutions
Rohde, Melissa	The Nature Conservancy
Ures, Tina	San Francisco Bay Regional Water Quality Control Board
Cuthbertson, Aaron	California Department of Water Resources
Davis, Jeff	Cardno
Bray, Erin	University of California
Weller, Ryan	CSULB
Wilkin, Claire	WSP | Parsons Brinckerhoff
Bass-Deschenes, Michael	P&D Environmental, Inc.
Nommensen, Roger	Amec Foster Wheeler Environment & Infrastructure, Inc.
Olsen, McKinley	Geosyntec

GRA Extends Sincere Appreciation to the Chairs, Sponsors and Exhibitors of the Role of Models and Data in Implementing SGMA

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UC Water Security and Sustainability Research Initiative

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Wildermuth Environmental, Inc.
GEI Consultants
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2016 Contributors to GRA – Thank You

As of Feburary 2, 2016

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CORPORATE *($250-$499)*

CHARTER *($100-$249)*
Stanley Feenstra
Sally McCraven
Steven Phillips
Iris Priestaf
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SPONSOR *($25-$99)*
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Gary Dickenson
Scott Furnas
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Thomas Harter
Barbara Hennigan
Christopher Johnson
Dirk Kassenaar
Carol Kendall
Ted Koelsch
Taras Kruk
Douglas Mackay
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Dan McManus
Angelica Mercado
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SAVE THE DATE
September 28-29, 2016
GRA's 2016 25th Annual Meeting
REGISTER HERE

Southern California

By Emily Vavricka,
Branch Secretary

On December 10, 2015, the Southern California Branch held its end-of-year Holiday celebration featuring an exclusive field trip to the THUMS Islands, the artificial Islands off the coast of Long Beach engaged in oil drilling operations. The field trip consisted of a tour of Island White, one of the four THUMS Islands, and was led by Bill O'Toole of California Resources Corporation. The tour began with a boat ride to Island White and continued with a walking tour and narrative of the Island's operations. Attendees learned about the history of the Island, how the Islands were constructed, and the various operations and technical aspects of the oil drilling operations. We were surprised to learn of the extensive architectural planning that went into constructing the Islands to both limit noise and conceal the drilling operations by using aesthetic features, such as waterfalls and colored lights. Following the tour, attendees continued the festivities in downtown Long Beach with a dinner and holiday raffle to raise funds for the Southern California Branch Scholastic Fund.

The Branch would again like to thank all GRA Members and Non-members for participating in the Branch's end-of-year celebration and field trip. A special thank-you also goes to Bill O'Toole and California Resources Corporation for hosting the tour and providing a fantastic experience for attendees. The Southern California Branch looks forward to a great 2016 and continuing the Branch's Scholastic Fund in support of geology and engineering students engaged in groundwater studies and research.

Snowpack and California's Water Supply

Snowpack is vital to California's water supply and normally provides one-third of the water used by California's cities and farms each year. In a typical year, the state's snowpack stores 15 million acre-feet of water, more than all the water used by California cities in 2010.

The Department of Water Resources coordinates the California Cooperative Snow Survey Program, which involves more than 50 federal, state, and private agencies that contribute funding and/or data. Snow survey data is collected in the Northern Sierra/Trinity, Central Sierra, and Southern Sierra regions.

A California Water Blog article written by Dr. Jay Lund at the University of California Davis also suggests visiting the following websites for snowpack information:

http://cdec.water.ca.gov/cdecapp/snowapp/sweq.action
http://cdec.water.ca.gov/cgi-progs/snow/PLOT_SWC

Because of climate change, snowpack is projected to decline by 25 to 40 percent by 2050, relative to historical averages. By 2100, estimated reductions of 50 percent to more than 75 percent are projected for the April 1 snowpack. In addition to reductions in snowpack, warmer temperatures from climate change are expected to change streamflow patterns. Since the early 20th century, there has been a decline of 5 to 13 percent in spring runoff for major rivers in Northern California. These observed changes are likely due to a combination of increased air temperatures and changes in winter storms—warmer storm temperatures lead to snowfall only at higher elevations, reducing the amount of snowpack and spring runoff.

Photographed by John Karachewski, Ph.D., at Becker Peak on January 1, 2016.
View of Upper Echo Lake and Desolation Wilderness in Eldorado National Forest.
GPS coordinates of photograph (38°49'56" N 120°3'36" W)
(www.geoscapesphotography.com)