On May 24, 2018, the Groundwater Resources Association of California’s (GRA’s) Contemporary Groundwater Issues Council (see https://www.grac.org/contemporary-groundwater-issues-council/), at its annual workshop at UC Davis, tackled perhaps the most challenging and perplexing issue facing some groundwater sustainability agencies (GSAs): reducing groundwater demand. At the workshop, sponsored for the eighth year by UC Davis’s Robert M. Hagan Endowed Chair for Water Management and Policy, the Council and several GRA Board members heard morning presentations before breaking into small workgroups to brainstorm and discuss creative opportunities to address the challenges of managing groundwater demand reduction. The presenters and their presentations include:

- Ellen Hanak, Senior Fellow and Center Director, Public Policy Institute of California, Water Trading, Water Banking, and Sustainable Groundwater Management;
- Abigail Hart, Agriculture Project Director, The Nature Conservancy (TNC), Diversifying Agricultural Landscapes, co-presenting with Christina Babbitt, Senior Manager California Groundwater Program, Environmental Defense Fund (EDF), Managing Groundwater to Achieve Co-Benefits in California’s San Joaquin Valley;
- Marcus Trotta, Principal Hydrogeologist, Sonoma County Water Agency (Sonoma Water), Considerations for Sustainable Groundwater Management in Sonoma County; and
- Terry Erlewine, Principal Engineer, Provost & Pritchard Consulting Group, Kern Groundwater Authority.

Breakout sessions, facilitated by California State University Sacramento College for Continuing Education, Consensus and Collaboration Program (CSUS CCP), considered: 1) translating overdraft conditions into solutions to achieve sustainability, 2) who are the players and what do they need to bring to the table, and 3) land use management and groundwater sustainability plans.

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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.

Photo: Mount Rainier National Park, Photo Credit Gabriel McHugh

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GRA is Having a Whale of a Year

By Steve Phillips, U.S.G.S.

Ah, another excuse to share some fun, and to use the word “whale!” This summer I vacationed in Iceland and Greenland, joining a tour of the natural and cultural aspects of these countries. Iceland is brand new geologically, as the oldest rocks are a mere 14 million years old; in contrast, rocks in Greenland can exceed 2 billion years in age. It was only 60 million years ago that Greenland, part of the North American plate, separated from the Eurasian plate along the mid-Atlantic Ridge, the spreading center for the Atlantic Ocean. This spreading center cuts through Iceland and is responsible for its volcanic activity; Iceland is also a hot spot, similar to Hawaii.

The highlight of the trip was an extended encounter with several species of whale in the wee hours, between about 10 PM and 2 AM (it was still pretty light during those hours near the Arctic Circle), in deep water between the two countries. Included were Humpback, Fin, Killer, and the rarely seen Northern Bottlenose whale (about 20-25 ft, a toothed whale).

Now I’ll catch you up on what GRA has been up to lately, and where we are heading.

Events

GRA’s first annual Groundwater Sustainability Agency (GSA) Summit, and the associated workshop, was a huge success. GSA representatives were involved in the planning process, and many served as speakers and panelists during this very interactive event that featured short “flash” presentations and as much audience/panelist interaction as we could fit in, which went over very well with the attendees. The presentations from this event are available to all GRA members here—see other member resources available there as well.

The inaugural Western Groundwater Congress will be held on September 25th – 27th. This will be a three-day, quad-track event covering SGMA, contaminants, groundwater replenishment, agricultural issues, and solutions, oil, and gas, groundwater law, and many other topics. No-cost hands-on workshops; poster sessions; and a variety of fun networking opportunities, including wine tasting, the Darcy Dash 5K, and great raffle prizes, will also be provided at this can’t-miss event. Register now to reserve your seat.

Continued on the following page…
Strategic Planning

GRA’s Board of Directors, which currently comprises 16 members, is very much a working board; we do much of the hands-on work, as opposed to directing others. Therefore, we are very effective at planning individual events and other relatively short-term activities, and less effective at long-term planning. In recognition of this general weakness in long-term planning, the previous two GRA Presidents, Ted Johnson and Chris Petersen, led initial efforts to develop a strategic plan. These efforts were helpful and resulted in extensive documentation of long-term goals and associated tactics for achieving them; however, we lacked a good means for tracking progress.

A key goal of mine was to build on past strategic planning efforts, and to better focus our attention on our long-term goals. Therefore, we hired a facilitator to evaluate our existing plan and processes, and to lead us through development of a simple plan and associated tools during the Board’s quarterly meeting in May. The outcome of this process, which included confidential interviews of all Board members and others, and about 10 hours of interaction with the whole Board, was somewhat unexpected. In addition to developing a simplified strategic plan we can work with, we also closely examined our structure, which included 13 committees—and consolidation of those committees was a key recommendation. We are now undergoing implementation of the plan and are anticipating increased efficiencies and integration as a result. I think it is fair to say that the Board is excited about these changes, and is looking forward to even better serving GRA’s members and the broader water community. Please feel free to contact me, or anyone else on the Board, for more information.

As always, we welcome all ideas on future events and directions. If you are not a GRA member, consider becoming one!

Cheers,

Stan Phillips

Call for Submissions

Picture Your Research Featured in HydroVisions

HydroVisions is looking for submissions from students engaged in groundwater research, to highlight in our Student Corner.

Do you know of a student with something to share?
  - Articles
  - Research Papers
  - Summary Blurbs

For further information, please contact:
editor@grac.org, subject “Student Corner”
Ellen Hanak explored the scope of water trading and groundwater banking as key strategies for transitioning from overdraft to groundwater sustainability. She focused on the San Joaquin Valley, site of most of the state’s groundwater shortage and where additional recharge from local streams may suffice to address, at best, one-quarter of the overdraft. Ellen described how trading and banking have similar requirements and constraints. Both need infrastructure to connect the source areas with destinations, and both need certain protections in place to prevent injury to water users in the source area, mitigate economic harm in the source area, create protected “bank accounts” subject to transparent monitoring and fully developed accounting systems, and establish trust among all parties involved. The latter points were echoed repeatedly during the Council’s discussion.

Off-site banking is underdeveloped in the San Joaquin Valley, where Kern County developed the largest storage capacities. Conveyance is part of the issue. San Joaquin Valley GSAs may expand off-site banking opportunities. Conveyance challenges include: 1) the Delta, which provides key linkages for north-south and east-west water trades; 2) the Friant-Kern Canal, which experienced severe capacity limits following subsidence along the Canal during the 2012-2016 drought; and 3) insufficient local conveyance facilities. While surface water trading became popular after the 1987-1992 drought, trading volumes remained flat in recent years. The approval process can be cumbersome and often involves multiple agencies. Short-term leases (1 year) may be easier to obtain than the more important long-term agreements. Ellen suggested critical steps forward include: authorized regional surface water trading permits, preauthorized transfers and expedited off-site banking reviews, and improved information about trading and banking opportunities. Significant future projects, not including infrastructure, must clarify tradeable water rights, establish environmental protection, and determine tradable water budget components.

Meaningful agricultural landscape diversification, including conservation efforts, was the topic of Abigail Hart’s and Christina Babbitt’s coordinated presentation. Abigail and Christina pointed to opportunities for ecosystem habitat expansion as half a million acres of currently irrigated lands are anticipated to lose access to groundwater due to required demand reduction. The EDF, Audubon Society, Point Blue, Sustainable Conservation, and others are coordinating ways to incentivize agricultural land retirements that provide the greatest conservation benefit, especially in the San Joaquin Valley. Public funding is likely a key resource for land retirement where habitat co-benefits are available. Mapping and tools to assess habitat and recharge potential are currently being developed by TNC, EDF, UC Santa Barbara, and others. Programmatic multispecies safe harbor agreements and regional conservation investment strategies could generate demand for funding to landowners to create positive habitat outcomes and attract investors. While conservation alone is not a silver bullet to address land retirement challenges, it could incentivize landowner participation and constitute part of a broader portfolio of alternative land uses, including solar energy generation, to reduce overall water demands.

Marcus Trotta provided insights on Sonoma Water’s wide range of programs to sustain groundwater resources. Integrating groundwater and surface water management has been a key component of the agency’s long-term strategy to build resiliency and maximize benefits across sectors. To address localized pumping depressions, Sonoma Water diversified supplies with additional surface water and the use of recycled water for agricultural irrigation. Groundwater banking during the winter season replenishes groundwater used for irrigation and other purposes; pilot banking projects are also underway to enhance the overall groundwater supply. Capturing stormwater for groundwater recharge is being evaluated, and significant interest exists in winter on-farm recharge in vineyards. Urban water conservation efforts exist in rural areas in response to information, education, and incentives to rural well-owners that promote rainwater harvesting and graywater systems. Conservation efforts achieve the greatest success when they are linked to specific issues relevant to water users. Groundwater resources protection is linked to land use planning through the water resources element in Sonoma County’s General Plan, and local land use authorities are participants in GSAs. Marcus recommends that GSAs consider barriers and challenges in tandem with stakeholder and resource benefits.

Terry Erlewine provided a perspective from “ground zero” about Kern County, one of the counties that will bear the brunt of groundwater pumping cut-backs. In Kern County, ten GSAs are working on five groundwater sustainability plans (GSPs) with initial draft GSPs planned to be completed by late 2018 to allow timely GSP finalization by the end of 2019. Groundwater management actions being considered to address existing overdraft conditions include:

Continued on the following page…
• Additional recharge, although few additional water resources are available
• Fees on groundwater pumping
• GSA purchases of irrigated lands for voluntary fallowing
• Quantifying groundwater allocations; and incentivizing transfers.

Since recharge is not always realistic, Rosedale – Rio Bravo Water Storage District is leading the articulation of other more pragmatic groundwater management options. The District’s strategy involves a cap and trade program that would allow for groundwater transfers to maximize flexibility while reducing overdraft. Part of the District’s plan is to bill for water pumped above the sustainable yield; the District will use the revenues to implement the most cost-effective management action. During the GSP implementation period, initial projects will focus on increasing supplies; subsequent projects will address demand reduction on a voluntary basis. Landowner demand reduction would be the last projects implemented to meet the 20-year GSP groundwater sustainability goal.

The participants in the first breakout session discussed the different actions and tools that are needed or available to accomplish demand reduction. The demand reduction challenges facing GSAs and concerned stakeholders are particularly onerous in basins/subbasins wrestling with overdraft conditions. Under pre-Sustainable Groundwater Management Act (SGMA) circumstances, demand reduction was a tall order; however, the compressed timeline that GSAs face to submit GSPs in less than eighteen months makes water resources management and future sustainability decisions especially difficult. Ideally, GSAs, in basins where prior studies include estimated sustainable yield, can design and leverage management strategies to bring the basin into balance based on an understanding of areas where water resources are available (internal or external to the basin) or depleted. Even with previously completed studies, projects and management actions that involve significant financial commitments will not be easily reconciled and agreed upon by local policy makers and stakeholders in such a short time frame. With the GSP deadline looming, GSAs (such as described by Terry Erlewine) are creating innovative approaches to demand reduction. A variety of strategies alone or in combination may be considered, including (but not limited to):

- Estimate sustainable yield (including climate considerations) and determine future groundwater use by GSAs, landowners, and/or basin-wide users with schemes to determine equitable allocations
- Develop a demand reduction structure based on other variables (e.g., economic) rather than a fixed allocation
- Incentivize lowered water demands or land fallowing
- Encourage shifts in land use to lower water demand

- Reassess water pricing to align water use with actual water value
- Engage stakeholders early in the decision-making process
- Consider geographical/hydrogeologic differences and whether certain management strategies make sense based on basin-specific attributes
- Understand legal issues associated with water allocation schemes
- Plan (within reason) for climate variability.

Successful approaches to reduce groundwater pumping require engaging the right agencies and the broad spectrum of stakeholders potentially impacted by the GSA’s decisions. The
second breakout group focused on non-traditional “players”, including
domestic well users, the petroleum industry, investor-owned agriculture,
and counties. Engaging domestic wells users through county environmen-
tal health programs and other outreach venues and providing them a voice
in the planning process appears promising. Better engagement between
the petroleum industry (where present) and counties and having both
groups participate in groundwater sustainability issues are important to the
success of GSAs in overdrafted basins. Bringing investor-owned agriculture
to the table and partnering with them as active benefactors of GSP goals
was identified as another important opportunity. Engagement with
counties involves several considerations: 1) counties sometimes represent
upstream areas that are important recharge sources; 2) they may already
have existing groundwater plans (AB 3030/SB 1938); 3) they regulate land
use and agricultural land conversions; and 4) they are already engaged
in well permitting. It was suggested that GRA could help by supporting a
legislative bill that would incentivize conservation habitat through lower
taxes and by providing outreach to domestic well users.

The third breakout group considered options for alternative land uses
for retired lands. It was suggested that land use planning is on a very
different (decadal) time schedule from current GSP development, and
land use planning is also implemented at a much finer spatial (parcel)
scale than the GSP. Land use planners have specific requirements for their
general planning process, some of which may contradict GSP goals. Land
use planners need consistent information from water entities, including
population growth and climate information. Regional scale planning,
water resources management approaches, and supply and demand solutions
will be important to avoid patchwork approaches. Opportunities
for GSAs and land use planners to coordinate include during preparation
of a water resources element in county general plans and development of
plans for retired irrigated lands. GSAs may regularly participate at county
Board of Supervisor’s meetings and provide counties with information
that illustrates the potential benefits and limitations of groundwater
management strategies.

Key take-aways from the
Council workshop included:

- It is important to think regionally. This
  will require navigating local political
  power, educating landowners about
  broader basin interests, and working
  collaboratively to achieve sustainability.

- When counties embark on future
  General Plan updates, coordination
  of land use and water resources
  elements will be essential. GSAs can
  help facilitate productive engagement
  and consistent information among
  counties, land use planners, and
  water agencies. GSAs can inform
  county supervisors and others of the
  benefits and limitations of potential
  groundwater management strategies.

- GRA can help develop groundwater
  sustainability-related training materials
  for GSAs and others such as land use
  planners. Outreach and education
  are critical. Venues that facilitate
  exchange of viewpoints and knowledge
  among diverse stakeholders will
  ultimately benefit everyone striving for
  groundwater sustainability. Perspectives
  on different groundwater issues and
  potential solutions are more similar
  than many people believe.

- SGMA and its implementation are
  replete with technical challenges,
  barriers, lack of data, and uncertainty.
  However, some of the largest hurdles
  in the SGMA implementation
  process involve public engagement
  and outreach. Most GSAs are facing
  imperfect data and uncertain
  conditions; therefore, it is important for
  stakeholders to work together to move
  the GSP process forward – beyond the
  GSP submittal deadline in 2020 or
  2022 – to actual GSP implementation
to achieve or maintain sustainability.
California’s past and present water management challenges are inextricably linked to its unique climate. Success in the future will depend on planning for changes to this climate. Groundwater forms an essential part of the total available water supplies and can be critical in mitigating against the impacts of climate change. The Sustainable Groundwater Management Act (SGMA), signed by Governor Brown in 2014, acknowledges this and mandates that the projected effects of climate change be incorporated into sustainable groundwater management and planning.

California’s Climate

Much of California can be characterized as having a Mediterranean type climate, with warm dry summers and cool wet winters. Precipitation in California tends to be highly variable, spatially, and temporally. Most of the rain/snow is concentrated in the north and in the east (along the Sierra Nevada). However, the areas with the highest water demand are in the Central Valley and Southern California, which has led to the development of one of the most highly engineered water conveyance and storage systems in the world. ‘atmospheric rivers’ (like the famed Pineapple Express) - long, narrow regions in the atmosphere that transport concentrated water vapor from the ocean, delivering intense bursts of rainfall or snow on land (Dettinger et al., 2011) are linked to 30% to 50% of the precipitation in the State.

A Changing Climate

California’s climate, like the rest of the planet’s, is changing. Two recent reports by the California Department of Water Resources (DWR) (DWR, 2015) and Office of Environmental Health Hazard Assessment (OEHHA) (OEHHA, 2018) summarize recent trends in key climate change indicators, collected from historical datasets across the state. Over the last century, mean temperatures across the state rose by 1.1 to 2 degrees Fahrenheit (°F), with minimum temperatures (+1.6 to +2.5 °F) rising more than maximum temperatures (+0.4 to 1.6 °F) (Figure 1). 2014 was the hottest year on record, followed by 2015, 2017, and 2016 (OEHHA, 2018). Changes to precipitation patterns include:

1) A higher percentage of rain than snow over recent years (Figure 2) [red bars indicate above mean rain percentage]

2) Earlier snowmelt runoff observed in the Sacramento River System - California’s largest water-supply watershed (Figure 3). Some of the largest glaciers in the Sierra Nevada lost an average of 70 percent of their area, over the last century. Sea level rise is observed at several coastal cities, including San Francisco (7 inches since 1900) and La Jolla (6 inches since 1924) (OEHHA, 2018).

Figures 1-3: Statewide annual average (top) and decadal temperatures (bottom) trends relative to long-term average (1949-2005) (OEHHA, 2018)
These trends in climate change indicators are expected to continue into the future and could potentially intensify (DWR, 2015; DWR, 2018). Global Circulation Models (GCMs) predict a 3 to 6 °F increase in mean temperature by 2070, compared to 1985-1994 (DWR, 2018) (Figure 4). Warmer conditions are expected to lead to more intense dry periods with longer droughts. Most GCMs predict drier conditions in the south and heavier and warmer winter precipitation in the north of the State (DWR, 2018). Precipitation is expected to become more volatile, as higher temperatures lead to more intense, warmer, and wetter atmospheric river events (DWR, 2015). Consistent with historical trends, precipitation is expected to shift from snow to rain, with snowpack in the Sierra Nevada expected to decrease by 48 to 65 percent, compared to the 1960 – 1990 average (DWR, 2015). Sea levels are expected to rise 0 to 2.5 ft by 2050, relative to 2000 levels (DWR, 2015).

Climate Change and Groundwater

Climate change is expected to impact California’s water resources - both above and below ground. Impacts on surface-water resources will be more direct. Higher temperatures will lead to higher evaporative losses from surface-water bodies. More snowmelt runoff as well as more volatile precipitation patterns will lead to ‘flashier’ flows in streams and rivers. Snowpack serves as a natural reservoir for the state’s water, releasing water slowly during spring and early summer. Earlier snowmelt would lead to higher volumes of flows during the flood season, in turn reducing the stored water available to meet peak summer demands. At the same time, higher temperatures are expected to increase water demands further stressing supplies during summer months. Rising sea levels may constrain State Water Project (SWP) and Central Valley Project (CVP) deliveries, due to an increase in salinities and subsequent effects on vulnerable ecosystems in the Sacramento–San Joaquin Delta (Delta).

Climate change is expected to impact groundwater systems by altering the water budget of the basin, in direct or indirect ways. The timing and magnitude of these changes will depend on the natural and anthropogenic recharge and discharge processes in each groundwater system. Figure 5 (taken from Taylor et al., 2013) summarizes key potential impacts of climate on groundwater through natural and human-induced processes. Climate change impacts on groundwater systems may be categorized as follows: 1) changes to the natural hydrologic variables (consisting of temperature, precipitation, and unimpaired streamflows) in the basin; 2) changes to surface-water operations (consisting of imported water deliveries, reservoir releases, or inter-basin water transfers); and 3) changes to groundwater demands/extractions and land-use practices (Taylor et al., 2013) – as illustrated in Figure 5. With shallow systems, higher temperatures may lead to increased groundwater losses due to evapotranspiration. An increase or decrease in net precipitation and the timing and duration of precipitation events would increase or decrease and effect net groundwater recharge. Higher intensity, shorter duration rainfall and ‘flashier’ streamflows,
could lead to more water exiting the basin as runoff leading to less groundwater recharge. In some areas, more snowmelt may increase net groundwater recharge, essentially shifting storage from the snowpack to the groundwater aquifer. It is important to note, that for groundwater systems with confined aquifers or a thick vadose zone, it may take several years (even decades) for precipitation and/or streamflow events to translate to recharge in the form of deep percolation.

Reduction in imported water deliveries may cause increased groundwater demands/extractions and reduced return flows from the applied surface water. Higher temperatures and longer droughts would likely lead to more groundwater extraction due to increased agricultural and urban water demands. Future changes in land use and agricultural prac-

ces could significantly impact groundwater recharge and extractions. However, these changes are not easy to predict and may depend on socio-economic factors as well as water-management decisions made within the basin. Rising sea levels and increased groundwater extractions may impair coastal groundwater quality, due to seawater intrusion along the coastline.

Conjunctive use of groundwater and surface water can provide an opportunity to better manage the total available water resources in a more volatile hydro-climatic regime. The SGMA legislation acknowledges this, stating that ‘sustainable groundwater management in California depends upon creating more opportunities for robust conjunctive management of surface water and groundwater resources. Climate change will intensify the need to recalculate and reconcile surface water and groundwater management strategies.’ Managed aquifer recharge (MAR) would allow for the capture and storage of excess surface-water flows (from more intense stormflows or earlier and higher snowmelt runoff) that might be otherwise lost as runoff to the ocean.

Continued on the following page…
Climate Change Datasets and Tools for Groundwater Sustainability Planning

Under SGMA, Groundwater Sustainability Plans (GSPs) need to include projected water budgets for the basin, accounting for impacts of climate change and sea level rise on future hydrology, surface water deliveries, and water demands (Section 354.18(c)(3) of the GSP regulations). Understanding and quantifying climate change impacts will be essential to: long-term planning of groundwater sustainability, assessment of sustainable yield, evaluation of projects and management actions; and adaptive management.

To facilitate this evaluation, the DWR provides guidance (DWR, 2018), tools, and datasets (downloadable from DWR’s SGMA Data Viewer website1) to incorporate climate change into GSPs (DWR, 2018). The data contain necessary climate, hydrology, and water supply variables for the entire state. The datasets are consistent with those provided with the California Water Commission’s Water Storage Investment Program (WSIP), are based on the latest climate data (the Coupled Model Intercomparison Project Phase 5 [CMIP5]), and follow guidance provided by the Climate Change Technical Advisory Group (CCTAG), convened by DWR in 2015.

For these datasets, climate (temperature and precipitation) projections were assembled from 20 GCMs, recommended by the CCTAG as the most appropriate for California water resources and planning. The projections consist of four scenarios:

- **2030 conditions** (near future)
  - central or typical conditions predicted by an aggregate (ensemble) of all 20 GCMs

- **2070 conditions** (late future)
  - central or typical conditions predicted by an aggregate (ensemble) of all 20 GCMs
  - drier with extreme warming conditions predicted by a single GCM2
  - wetter with moderately warm conditions predicted by a single GCM3

There is significant uncertainty in climate change projections of the future. This uncertainty arises from the complexity of the climate system and varying abilities of different GCMs to represent these complexities as well as the uncertainty about future carbon emissions, driven by future societal decisions. The last two scenarios included in the 2070s conditions, are meant to encapsulate this uncertainty by providing two ‘end members’ representing more- and less-stressful future conditions than the central tendency. Groundwater planners should consider the range of these scenarios to improve reliability with respect to uncertainty in climate change projections.

To create these datasets, temperature, and precipitation values from the GCMs were first downscaled (using a statistical downscaling technique) to a 1/16th degree or 6 km grid. These downscaled temperature and precipitation time-series were then used as input to a statewide Variable Infiltration Capacity (VIC4) hydrologic model to generate projections of future streamflows. In turn future streamflow and sea-level rise projections5 were used as inputs to California Water Resources Simulation Model II (CalSim II) and Delta Simulation Model 2 (DSM2) to generate projections of future SWP and CVP performance and Delta conditions. The final dataset consists of:

- Monthly climatological data (i.e., precipitation and reference ET) on a state wide gridded basis
- Monthly hydrological data as point data. This includes VIC routed streamflows at several locations within the Central Valley.
- Central Valley project operations data

The precipitation, reference ET, and unimpaired streamflows are also available as monthly change factor ratios (relative to 1995 baseline conditions). These change factors can be used to alter basin-specific historical data to represent projected future conditions (Figure 6). The

Continued on the following page…
change factors are available for the period from 1915 to 2011 for the VIC climatological and hydrologic data. Note, for watersheds outside the Central Valley, the DWR dataset only contains streamflow change factors, not VIC routed streamflows. CalSim II SWP and CVP time-series data are available on a monthly basis from 1921 to 2003. The projected time series may be used with a spreadsheet-based- or numerical- groundwater model to estimate future water budgets. Given the complex interactions of groundwater with the climate, numerical models (calibrated to historical hydrology) would provide the most robust tools to evaluate climate change impacts on future water budgets.

Apart from the datasets provided by DWR, several other datasets exist for climate change climatological and hydrologic projections. The USGS California Basin Characterization Model (CA-BCM) dataset (Flint and Flint, 2014) provides historical and projected climate and hydrology data at a 270-meter resolution encompassing California6. The BCM approach uses a regional water balance model based on high resolution precipitation and temperature as well as elevation, geology, and soils data to produce output such as precipitation, temperature, snowpack, recharge, runoff, evapotranspiration, and climatic water deficit. Several of these variables (e.g., recharge) may be more directly translatable to groundwater models compared to precipitation projections. The USGS is also conducting a study evaluating conjunctive use of surface water and groundwater in response to climate change in the Central Valley7.

The Bureau of Reclamation (Bureau) conducted several ‘WaterSmart Basin Studies’, evaluating future water supplies and demands as well as identifying water management alternatives to address any potential deficits. These studies can also provide useful information for future climatological and hydrological projections for groundwater planning purposes. Key studies relevant to California include: the Sacramento and San Joaquin Rivers Basin Study; the Los Angeles Basin Study8; the Santa Ana Watershed Basin Study9; and the Southeastern California Regional Basin Study10.

Note that, climate change datasets (from DWR or elsewhere) need to be used with caution and prudence. When developing inputs for predictive numerical models based on the climate change datasets, one must be careful that the scale, variability, and magnitude of future water budget terms are consistent with the conceptual model and hydrogeologic understanding of the basin. For example, precipitation change factors should not be directly applied to recharge for a basin with confined aquifers or a thick vadose zone, as the precipitation signal would tend to get attenuated and lagged before reaching the water table. In such cases, appropriate pre-processing steps must be taken to translate the climate change datasets to appropriately scaled inputs to the numerical model. Note, that the climate change projections provide sub-regional scale information about the impacts of climate change. There may be significantly more variability at the local scale in hydrologic variables, than captured by the climate change projections. Finally, care should be taken not to mix and match climate change datasets, as the methodologies and assumptions inherent to different datasets may be inconsistent making them incompatible.

In conclusion, climate change is a key consideration when planning for sustainable groundwater resources. While groundwater resources are expected to be impacted by climate change, they can prove to be valuable assets in developing resilient and robust water supplies. SGMA lays out this path, “…when properly managed, groundwater resources will help protect communities, farms, and the environment against prolonged dry periods and climate change, preserving water supplies for existing and potential beneficial use.”

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First Annual Western Groundwater Congress  
Tuesday-Thursday, September 25-27, 2018 – Sacramento, CA  

Don’t Miss a Drop!  
Sign up here or text the code WGC2018 to 797979 to receive special discount codes, advance updates, bonus raffle/reception tickets and exclusive prizes at the First Annual Western Groundwater Congress!

New Groundwater-Quality Data Maps  
The USGS, in cooperation with the Groundwater Ambient Monitoring and Assessment Program (GAMA), launched a new web application to view and retrieve groundwater-quality data. These data were collected from wells completed in the public supply aquifer (PSA) since 2004, and wells completed in the domestic supply aquifer (DSA) since 2013.

Application features include:

• **Spatial Analysis**: Groundwater-quality data can be mapped for several constituents with water-quality benchmarks to reveal areas where raw groundwater is poor or suitable for drinking.

• **Trends**: Graphs of water quality parameters over time to see apparent trends.

• **Data Downloads**: Data are available to download by study type, constituent group, and study unit(s). Results are zipped and delivered as four tables: detailed (results) and simple (well and sample information), and their associated ReadMe files.


SOUTHERN CALIFORNIA

By Chris Baker, President

Upcoming meetings:

We plan to host a meeting in September, October, and November. Details are being finalized, but we plan to host Jim Carter from TRC to speak about the Mountain Pass Mine, the David Keith Todd lecture series speaker, and a presentation on PFAS by staff from TestAmerica.

GRA Communications

GRA keeps you informed on member benefits, groundwater news, legislation, and events in a lot of ways, but the primary method is email. If you’re subscribed to the email list and are not receiving messages, try reconfirming your email subscription. If the confirmation doesn’t come through, please contact your IT department, and ensure they whitelist emails from @grac.org.

If you’re not subscribed to our email list, sign up today!

Editor’s Note

As the editor of HydroVisions and a fellow Board Member I recognize the significant contribution made by David Abbott. In this issue of HydroVisions we present his 54th article. Every three months he conceives a new topic, conducts research, and writes a three- to four-page article. Thank you, David, for educating and entertaining us since 2005!

–John McHugh, HydroVisions Editor
Wells and Words
By David W. Abbott, P.G., C.Hg., Consulting Geologist

Client: Why is my domestic bedrock well so deep?

Believe it or not (even in fractured rock [FR] water-bearing formations [WB-Fm]), the installation of a low-yield, reliable, and efficient water supply well can be a challenging and complicated geologic/engineering process with many interconnected and competing factors that could define project success or failure. A partial list of these factors for FR WB-Fm is:

1. The frequency of open fractures and their aperture size usually decrease with depth
2. The effectiveness of the hydraulic connection of the fractures to the ground surface or an overlying aquifer
3. The scale of the permeability of the fractures
4. The extent, development, and orientation of fracture and joint sets
5. The length and placement of well screen intervals and filter/stabilizing pack
6. The drilling method and the relative success of well development
7. The local climatic conditions. This is often the case in crystalline (igneous or metamorphic) bedrock environments for water supply wells.

Typical, probable, and sustainable well yields in FR WB-Fm using 50 feet (ft.) of drawdown range from about 3 to 30 gallons per minute (gpm); yields greater than 100 gpm with 50 ft. of drawdown are the anomaly rather than the norm.

Crystalline rocks are affected and altered by tectonic fracturing, thermal cooling, and by mechanical and chemical weathering. Weathering is the physical disintegration of and chemical decomposition of rocks that produce an in-situ mantle of waste and prepare sediments for transport (erosion). Weathering of crystalline rocks typically produces a continuum of permeability from nearly impermeable to very permeable; most weathered crystalline rocks have low permeability. This permeability continuum varies with depth below the ground surface and depends on the local geologic history, fracture patterns, fracture density, fracture orientation, and outcrop orientations.

Highly-decomposed rock will produce and store more groundwater than a slightly decomposed or un-weathered crystalline rock (which store and transmit small amounts of groundwater principally from fractures). Both weathered and un-weathered crystalline rocks are referred to as FR aquifers. A relatively thin veneer, of soil and unconsolidated alluvium can occur, but it is usually too thin and permeable to permanently store groundwater. Groundwater seeps through this veneer but is removed by lateral interflow along the soil-alluvium and weathered and un-weathered bedrock contacts. If the bedrock is highly decomposed then groundwater may percolate below this contact or can be temporarily stored in the weathered crystalline rocks and leak to the underlying FR aquifer. The maximum effective depth of mechanical and chemical weathering in crystalline rocks is about 100 to 150 feet.

In general, water wells in FR WB-Fm should not exceed depths of about 300 to 400 ft unless there is a good logical and hydrogeological reason. Another way to state this: if a landowner has only budgeted costs for 1,000 ft. of drilling then the statistical odds of completing a successful well are better if two 500 ft. deep wells are installed rather than one 1,000 ft. well. Sometimes, the contractor will (1) drill to depths significantly greater than 400 ft. with the hopes of chasing deeper and elusive fractures; or (2) to create a groundwater storage structure (a so-called sump) below the WB-Fm or fractures to accommodate requirements for the water system demands; or (3) some unscrupulous contractors will drill deeper for financial gain.

Amusingly, the definition of a sump is a pit or reservoir serving as a drain or receptacle for liquids, such as the lower part of the crankcase of an internal-combustion engine, into which liquids, especially lubricants, can drain to form a reservoir; also another name for cesspool; and thirdly, in mining, a depression at the bottom of a shaft where water collects before it is pumped away. In the groundwater industry, sump has morphed into an interval of excess borehole drilled below the interval to be cased or an excess portion of blank casing at the bottom of the well screen. This engineered water storage approach for a well, in some cases, can eliminate the need to construct above ground facilities and a secondary booster pump if the FR aquifer itself cannot meet the total demand of the water system.

Over-excavation is common with wells that tap FR WB-Fm and thin unconsolidated aquifers that are slow to recharge during non-pumping periods. However, the lower portion of the borehole/well can store sufficient water to operate the pump for several hours (and/or to comply with building permit applications from local agencies that may require

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demonstration of the “reliability” of the groundwater source). The dynamic volume of water stored in the sump depends upon the well diameter, the well depth below the static water level (SWL), and the amount of water entering the well from the overlying WB-Fm or fractures during pumping events.

For example, a typical water system demand needed for a single-family house is about 10 gpm for a couple of hours. If the installation and development of a domestic water supply well in a FR WB-Fm produced only about 3 gpm then the system demand (10 gpm) significantly exceeds the reliable yield of the well. However, pumping the well at 3 gpm for 24 hours (hrs.) produces 4,320 gallons (gal.) of water. This amount of water could be stored in an above ground tank or sump to fulfill the system demand for the house; at 10 gpm this stored water would last about 432 minutes (min.) or about 7.2 hrs. An over-sized downhole well pump would need to be installed nearly to the total depth of the well in order to remove this storage and meet system pressure demands. The system demand rates for local building codes for fire protection and codes for rural building permits could also be accommodated with this type of engineered approach.

The recommended drilling method in crystalline rock is usually with direct air rotary with (or without) a downhole hydraulic-accentuated (pneumatic) hammer and preferably drilled without any additives (i.e., soap or engineered drilling fluids). Many small domestic wells are drilled with a 10-inch diameter (ø) drill bit and then cased with 4-inch ø casing with a stabilizing pack to centralize and support the casing. The amount of water stored in the borehole below the SWL is about 0.65 gallon per ft. (gal/ft) for 4-inch ø casing and about 4.1 gal/ft for a 10-inch ø boring (see Table 1); see also Figure 1 showing the relationship for various ø boring/pipes between volume and depth below SWL.

If the well is drilled and cased to about 1,000 ft below the SWL, then 653 gal. of water is stored in the 4-inch ø casing and about 1,028 gal. of water is stored in the annular space between the 4-inch ø casing and 10-inch ø borehole (assume a porosity of 30% for the stabilizing pack and ignoring casing wall thickness). The calculated total storage is about 1,681 gal. Pumping that stored water at 10 gpm would take about 168 min. or about 2.8 hrs. not accounting for some additional increment of recharge water from the over-lying

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FR WB-Fm. An open hole completion is an uncased well or borehole or that portion of the well extending below the depth at which casing has been set. If the well was designed as an open hole completion, the total volume of water in the boring would be about 4,080 gal. which would take 408 min. or about 6.8 hrs. at 10 gpm to extract.

Note, also that a one-hour formal pumping test on a well tapping a FR WB-Fm at 3 gpm is probably not sufficient since it will not provide enough stress to demonstrate the long-term capacity and reliability of the well and allow for good estimates of the “aquifer” parameters. Part of the water that is pumped from the well is derived from storage in the well and the other part is derived from the WB-Fm during pumping. For water-bearing fractures and/or low-yield formations, it may take several hours or more to pump through what is referred to as “casing storage” in order to correctly evaluate the FR WB-Fm or system for reliability and sustainability.

REFERENCES
2 Abbott, David W., Winter 2007, Fractured rock aquifers – positive correlation between well depth and estimated hydraulic conductivity in HydroVisions a publication of the Groundwater Resources Association of CA, Volume 16, No. 4, pp. 4-5.
10 Actual pipe-size dimensions can be derived from the following document: National Association of Steel Pipe Distributors (NASPD), 1996, Tubular Products Manual: A steel pipe and tubing notebook (third edition), published by NASPD, Houston, TX, 251p.
**EPA Orders $21 Million in Cleanup Work at San Fernando Valley Superfund Site.**

The U.S. Environmental Protection Agency (EPA) has finalized three orders with Lockheed Martin Corporation and Honeywell International, Inc. requiring the companies to expand groundwater treatment and conduct additional groundwater contamination studies at the San Fernando Valley Area 1 Superfund site. Since the early 1980s when solvent pollution was first discovered EPA has been working to clean up groundwater contamination in the San Fernando Valley area. Groundwater treatment systems, operating since 1989, are removing TCE, PCE, 1,4-dioxane, and other volatile organic compounds (VOCs) from groundwater in the North Hollywood area. The work is expected to cost more than $21 million. For more information on the San Fernando Valley Superfund Site, including a copy of the Explanation of Significant Differences, visit: www.epa.gov/superfund/sanfernandonorthhollywood.

**USGS Interdisciplinary Science Contributes to Native Fish Ecology Efforts in the Delta.**

With the development of the Central Valley (CVP) and State Water (SWP) projects, the natural flow of the Sacramento-San Joaquin Delta has been reengineered to provide water for California’s growing population and agricultural needs. These changes have drastically reduced natural wetlands, affecting the habitat of native fish species, including the threatened Delta Smelt. To help address the situation, the U.S. Bureau of Reclamation engaged the USGS to help better understand and promote habitats that are conducive to reestablishing the Delta Smelt and other native fish. For the past two years, an interdisciplinary team of scientists from the USGS California Water Science Center (CAWSC), the Water Mission in Menlo Park, and other USGS offices collected data on a diverse set of information including: hydrodynamics, water quality, aquatic ecology, and benthic ecology (ecology relating to the bottom of a body of water). To learn more about these efforts, go to: https://ca.water.usgs.gov/highlights/2018/07/interdisciplinary-delta-study.

**Groundwater Statistics for Environmental Project Managers, Sponsored by the Interstate Technology and Regulatory Council, Available Online.**

Statistical techniques may be used throughout the process of cleaning up contaminated groundwater and it is challenging for practitioners, who are not experts in statistics, to interpret, and use statistical techniques. In 2013, ITRC developed the Technical and Regulatory Web-based Guidance on Groundwater Statistics and Monitoring Compliance (http://www.itrcweb.org/gsmc-1/). This associated training was created specifically for environmental project managers who review or use statistical calculations for reports, make recommendations or decisions based on statistics, or need to demonstrate compliance for groundwater projects. The video is 2 hours and 15 minutes and available to watch online here: https://clu-in.org/conf/itrc/GSMC_032718/.

**EPA Finalizes Cleanup Plan for Casmalia Resources Superfund Site in Santa Barbara.**

U.S. EPA announced a comprehensive final cleanup plan for contaminated soil and groundwater at the Casmalia Resources Superfund Site in Santa Barbara County, California. EPA’s final remedy includes: removal of contaminated liquids and soils, engineered capping of waste disposal areas, design and construction of upgraded groundwater collection and treatment systems, natural breakdown of groundwater contaminants at some locations, long-term surface water management, source reduction, land use controls, and ongoing monitoring and maintenance to ensure onsite containment. Construction of the proposed cleanup projects is estimated to take five years and cost approximately $60 million; annual operations and maintenance costs are estimated at $4.1 million per year. For more information about the Casmalia Resources Superfund Site, please visit: https://www.epa.gov/superfund/casmalia.

Jamie Marincola is the California Coordinator 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.
In a New York Times editorial, July 23, 2018, “Flint Kids Were Not ‘Poisoned’” Hernán Gómez, Associate professor at the University of Michigan, and Kim Dietrich, professor at the University of Cincinnati, challenge the perception that children were exposed to abnormally high levels of lead in drinking water.

Lead was recognized as damaging children’s brains through the work of Needleman, who found a correlation between IQ deficits and lead concentration in baby teeth. Since then, the acceptable risk levels have been lowered in a series of regulatory changes.

U.S. EPA issued guidance for Flint residents, including:
1) Running water for several minutes every day (would be a difficult act for water-conserving Californians).
2) Comparing the 90th percentile of lead concentrations in Flint with the Action Level of 15 µg/L (ppb). Using the 90th percentile rather than the mean or the actual distribution of lead levels gives an unorthodox and distorted view of the problem.

“I really believe that we ought to set a goal as a country that, over the next 10 years, that we ought to work with respect to investments in our infrastructure to eradicate lead in our drinking water,” EPA Administrator Scott Pruitt told reporters this week at the agency’s headquarters. Scott Pruitt subsequently left EPA, but the policy will presumably continue.

As a chemist, I object to eradication as a target. Lead, of course, is ubiquitous. With a sufficiently sensitive method lead will be found in any sample taken anywhere. Establishing an unattainable goal is deceptive and disingenuous.

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Call for Nominations for 2019 GRA Directors
Nominations Due Friday, October 5, 2018

GRA is now soliciting nominations for GRA Board of Director candidates. Board member terms are for three years and will commence service January 1, 2019. The Nominations Committee established the following criteria for nominations and selecting candidates for the final ballot that will be presented to GRA membership for voting:

**Minimum Qualifications for Director Nominees**
- Active member of GRA at the time of nomination
- Experience in a groundwater-related field
- Prior role(s) in a GRA Branch, committee or other GRA activity, or like experience with a similar organization.

**Nominations Guidelines and Procedures**
- Directors and members of GRA may nominate themselves or another member as a prospective candidate to run for the Board
- Nominations must be submitted in writing to GRA and accompanied by:
  - A statement from the nominee addressing the following questions:
    - Why are you interested in serving on the GRA Board of Directors?
    - What qualifications and experience do you have for serving as a Board member?
    - What specific skills or expertise do you bring to GRA and the GRA Board (e.g., leadership skills, fundraising, financial management, etc.)?
    - What experience do you have serving on similar Boards?
    - What level of time commitment can you make to GRA?
  - Current curriculum vitae
  - A letter of recommendation from a current Director or Regular Member
- The Nominations Committee will review all nominations, evaluate the nominees based upon their response to the above questions and their qualifications, and will conduct interviews, if deemed necessary
- The Nominations Committee will recommend a slate of nominees to the GRA Board of Directors for approval
- The approved slate of nominees will be presented to GRA membership in ballot form in accordance with GRA Bylaws.

To nominate yourself, or to nominate someone else, please complete the online nomination form.

**Statement of Inclusivity**

GRA seeks to foster a community that encourages understanding, appreciation and acceptance of all persons involved in GRA membership and activities. GRA believes that broad representation and participation on the Board adds significant value to the association and that GRA’s relevance and effectiveness are enhanced by embracing diverse backgrounds.

Nominations must be received no later than October 5, 2018.

Should you have any questions or need additional information, please contact Sarah Erck, GRA Administrative Director at (916) 446-3626, or Chris Petersen, Nominations Committee Chair, at (916) 631-4597.
GRA Welcomes the Following New Members

MAY 2 - AUGUST 2, 2018

Abdel Alfahham
Alexander Leff
Amy Malik
Andy Rodgers
Ashley Gibson
Bill Rice
Brooke Rumley
Casper Mejer
Chris Perri
Chuck Baughman
Ciroos Liaghat
Claudia Mack
Courtney Davis
Craig Locke
Cynthia Oppenheimer
David Terry
Diana Engle
Ellis Wallenberg
Emily Haugen
Erik Ringelberg
Frances Sayler
Gary Petersen
Gene Ratcliffe
Glenn Shephard
Hugh McManus
Jacob Wilcox
James Workman
Jane Doe
Jim McCord
John Poulson
Joy Dias
Justin Lashley
Kathryn Dominic
Ken Sansone
Kevin Almestad
Lauren Wallace
Lorena Benitez
Lynn Groundwater
Mark Nicholls
Matt Cohen
Megan Vaughan
Moises Santillan
Namsik Park
Nicholas Newcomb
Nick Osman
Paul Armendariz
Peter Brown
Piret Harmon
Reni Keane-Dengel
Richard Meyerhoff
Rob Rush
Rob Schumann
Robert Lilly
Robert Scott
Ruth Stiles
Ryan Molhoek
Scott Redelfs
Sercan Ceyhan
Shobha Gopal
Simon Jankowski
Spencer Harris
Thomas Gallagher
Thomas Grovhoug
Thomas Krazan
Tiffani Fong
Touraj Tayebi
Zachary Roy

Dates & Details
GRA EVENTS & KEY DATES

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

First Annual Western Groundwater Congress
September 25-27 | Sacramento, CA

Groundwater Sustainability Bootcamp – A Short Course
February 5-6, 2019 | Davis, CA

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

Special Thanks to Our Event Chairs, Sponsors and Exhibitors

First Annual Groundwater Sustainability Agency Summit

Chair:
Tim Parker

Administrative Director:
Sarah Erck

Co-Sponsors:
Aqua Shares, Inc.
GHD

Reception Sponsor:
The Nature Conservancy

Member Exhibitors:
Cascade Drilling & Technical Services
Montage For AG
Pumpsight
Skytem
Wellntel

Non-Member Exhibitor:
Wildermuth Environments, Inc.
Haley & Aldrich, Inc.

Thank You to Our Contributors

Special thanks goes to David Abbott for his donation to GRA’s Scholastic Fund in the amount of $369.33.
The San Joaquin River is the second longest in California and its watershed includes wilderness areas and national parks in the rugged and scenic central Sierra Nevada. Rainbow Falls is located along the Middle Fork of the San Joaquin River in Devils Postpile National Monument. The stretch of the river is unusual because its headwaters are located east of the Sierra Nevada crest, before it cuts across the mountains and flows southwestward into the Central Valley and ultimately into the Delta at the head of San Francisco Bay.

At Rainbow Falls, the river drops 101 feet over a cliff of rhyodacite that differs in composition from the nearby and renowned columnar basalts of Devils Postpile. The rhyodacite is locally massive or poorly jointed near the top of the falls, whereas sub-horizontal thinly-spaced platy joints become more abundant near the base of the cliff.

As the Middle Fork cascaded over the falls, its water eroded into the weaker platy rock at the base of the cliff and undercut the harder massive rock above, causing it to collapse and cave in. The cliff has thus retreated 500 feet or more upstream to the present location of Rainbow Falls since the last glaciation.

Mammoth Mountain forms the distant peaks in the background. Mammoth Mountain consists of about 12 overlapping rhyodacite and dacite domes and lies in the southwestern corner of the Long Valley Caldera. Mammoth Mountain reaches a height of 11,059 feet and is home to a large ski area.

Photographed in Devils Postpile National Monument. GPS coordinates of the photograph are 37.601513 and -119.084582. Information for visiting the park is available at: https://www.nps.gov/depo/index.htm.