Program

Water and Rocks
the Foundations of Life

2014 AIPG and AHS National Conference

September 13-16, 2014
Prescott, AZ
Platinum Sponsor

Salt River Project

Gold Sponsor

Clear Creek Associates

Silver Sponsors

Central Arizona Project
Montgomery & Associates
Resolution Copper
U.S. Geological Survey
The Wright Group

2014 Exhibitors

• ACZ Laboratories, Inc.
  • AHS Foundation
• AMEC Environment & Infrastructure, Inc.
  • American Geosciences Institute (AGI)
  • Bill Johnson Equipment Company
  • Bureau of Reclamation
  • Central Arizona Project
  • Clear Creek Associates
• Directed Technologies Drilling, Inc.
• Directional Technologies, Inc.
  • Geotems, Inc.
  • Golder Associates
  • Hach Hydromet
  • Hose Solutions, Inc.
• hydroGEOPHYSICS, Inc.
• Inflatable Packers International, LLC
• Montgomery & Associates
• National Exploration Wells and Pumps
• Resolution Copper Company
• Roscoe Moss Company
  • Salt River Project
  • Stewart Brothers Drilling
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## Welcome to Prescott, Arizona!

### 2014 Exhibitors (continued)

- U.S. Geological Survey
- Verdad Group, LLC
- The Wright Group
- Yellow Jacket Drilling
- Zonge International, Inc.

### Reception Sponsor

- AIPG Northeast Section

### Event Sponsors

- First Bank
- GeoSystems Analysis, Inc.

### Product Sponsors

- Aspen Laser & Technologies
- Rockware, Inc.
On behalf of AIPG, welcome to Prescott Arizona, site of this year’s AIPG National Conference titled Water & Rocks, the Foundations of Life. AIPG has once again joined with the Arizona Hydrological Society in organizing this meeting of geologists and water professionals, a reprise of our combined meeting in 2008 in Flagstaff, Arizona. This year’s theme is apt given the on-going 15-year drought that we in the west have been suffering. Geologists and water professionals are at the forefront of finding long-term solutions to this and future potential droughts through use of ever improving technologies and tools to help us understand how best to utilize the limited quantities of both surface water and groundwater and how best to convey water information to the public. Besides water that we personally use in our daily lives, many of our industries depend greatly on sustainable, long-term supplies. Without that, life in the west would be much more difficult.

Many geologists in Arizona directly or indirectly work in and around the many copper mines that occur in Arizona. New innovations in mining techniques and environmental stewardship are leading to a much improved environment for mine development in the state. Mining companies are investing in mine improvements, mine expansions, and new mines. These are exciting times for geologists and hydrogeologists in Arizona!

We hope that you will also have an opportunity to join us for one or more of the numerous exciting field trips that have been planned as part of this conference. We are privileged to have leading experts in a variety of fields lend their knowledge and experience to you as they lead you through key areas of our state. Please take advantage of this opportunity for self-improvement.

Finally, my favorite part of any national conference is the opportunity to socialize and meet fellow geologists from around the country and speak with sponsoring vendors. We share much in common, but face different challenges and can therefore share valuable information together. Don’t be shy! Get out and introduce yourself to your fellow professionals.

Again, Welcome to Arizona and enjoy the conference!

Doug Bartlett, CPG-8433  
AIPG Arizona Section President 2014  
Co-Chairman AIPG/AHS Conference
On behalf of the Arizona Hydrological Society (AHS), I would like to welcome all of you to the 2014 AIPG/AHS National Conference entitled Water & Rocks - the Foundations of Life at the Prescott Resort & Conference Center (PRCC) in Prescott, Arizona. AHS is pleased to be partnering with AIPG in what promises to be a very interesting and exciting meeting in Northern Arizona, a land of diverse geology and geological wonders. In addition, Prescott, Arizona, is a wonderful Northern Arizona city, rich in history and old west culture.

I would like to echo the sentiments of my AIPG counterpart Doug Bartlett related to drought issues and how water professionals and geologists are searching for ways to mitigate these challenges. The 2014 conference is appropriately named as it has the two key elements that drive Arizona. Water and Rocks, are two of the most important things that keep Arizona’s economy moving. Water is so precious, and without it Arizona would be a much different place. Water drives our ever-growing population and fuels our economy. As for the rocks, well look around and you will see that there are not many places more famous than Arizona when it comes to rocks. I am so energized every time this conference comes around. It is a time to get reacquainted with old associates, and meet some new ones. And I am continually encouraged when I see new faces and students from the Universities as well as recent graduates. Partnering with AIPG offers the opportunity for more new faces and provides a tremendous strength to the overall program. Welcome AIPG members!

I also think of all the folks that have put a great deal of their personal time into putting this conference together. I would encourage you all to seek out and say “Thanks for all the hard work” to all of our conference planners. Many of these folks are unpaid volunteers and they assemble the conference programs together for the love the organizations and the desire to present an outstanding technical program, as well as some fantastic field trips that showcase some of the projects and natural wonders that Arizona has to offer. Finally, I would be remiss if I did not mention our sponsors. Please stop by and say hello to our vendors and sponsors because without them these type of events would never happen.

I welcome you all and hope your stay is enjoyable and educational. My hope is that you make some new friends, see some of Arizona’s outstanding geology, have a great time and well, maybe even learn a little along the way.

Mike Hulst, RG
2014 AHS President
<table>
<thead>
<tr>
<th>Event</th>
<th>Saturday September 13</th>
<th>Sunday September 14</th>
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</thead>
<tbody>
<tr>
<td><strong>AIPG Executive Committee Meeting</strong></td>
<td>Breakfast <em>(open to all registrants)</em></td>
<td>6:30 am-8:30 am Prescott/Chino</td>
</tr>
<tr>
<td>8:00 am-12:00 Noon Prescott/Chino <em>(open to all AIPG registrants)</em></td>
<td>Registration</td>
<td>7:30 am-8:00 pm Foyer</td>
</tr>
<tr>
<td><strong>AIPG Advisory Board Meeting</strong></td>
<td>Purchased Field Trips</td>
<td>See page 6 for Details</td>
</tr>
<tr>
<td>1:00 pm-3:30 pm Prescott/Chino <em>(open to all AIPG registrants)</em></td>
<td>Exhibitor and Poster Set-Up</td>
<td>10:00 am-4:00 pm</td>
</tr>
<tr>
<td><strong>AIPG 2014/2015 Joint Executive Committee Meeting &amp; Business Meeting</strong></td>
<td>Foundation of the AIPG Meeting</td>
<td>4:00 pm-6:00 pm Jerome</td>
</tr>
<tr>
<td>3:30 pm-4:00 pm Prescott/Chino <em>(open to all AIPG registrants)</em></td>
<td>AHS Foundation Meeting</td>
<td>5:00 pm-6:30 pm Copper Basin</td>
</tr>
<tr>
<td><strong>Foundation of the AIPG</strong></td>
<td>Reception <em>(open to all registrants)</em></td>
<td>6:30 pm-8:00 pm Foyer</td>
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<tr>
<td><strong>AHS Foundation Meeting</strong></td>
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<td><strong>Front Cover Photo</strong></td>
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<tr>
<td>Granite Dells at Watson Lake in Prescott</td>
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<td>Photo by Franz Rosenberger</td>
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<tr>
<td>Event</td>
<td>Monday September 15</td>
<td>Tuesday September 16</td>
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<tr>
<td><strong>Breakfast</strong> (open to all registrants)</td>
<td>6:30 am-8:30 am Verde</td>
<td>7:00 am-8:30 am Sedona</td>
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<tr>
<td><strong>Registration</strong></td>
<td>7:30 am-5:00 pm Foyer</td>
<td>7:30 am-3:00 pm Foyer</td>
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<tr>
<td><strong>Technical Sessions</strong> (open to all registrants)</td>
<td>8:30 am-5:00 pm (see pg 10 for the detailed schedule)</td>
<td>8:00 am-5:00 pm (see pg 20 for the detailed schedule)</td>
</tr>
<tr>
<td><strong>Exhibits/Posters Open</strong> (open to all registrants)</td>
<td>8:00 am-5:00 pm Foyer</td>
<td>8:00 am-3:30 pm Foyer</td>
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<tr>
<td><strong>Purchased Field Trips</strong></td>
<td>See page 7 for Details</td>
<td>See page 7 for Details</td>
</tr>
<tr>
<td><strong>Morning Break</strong> (open to all registrants)</td>
<td>10:00 am-10:30 am Foyer</td>
<td>9:40 am-10:10 am Foyer</td>
</tr>
<tr>
<td><strong>Lunch</strong> (open to all registrants)</td>
<td>12:00 noon-1:30 pm Clarkdale, Cottonwood, Sedona Keynote Speaker Karl Karlstrom &amp; Laura Crossey University of NM</td>
<td>12:00 noon-1:30 pm Clarkdale, Cottonwood, Sedona Keynote Speaker Stephen J. Reynolds AZ State Univ.</td>
</tr>
<tr>
<td><strong>Afternoon Break</strong> (open to all registrants)</td>
<td>2:50 pm-3:20 pm Foyer</td>
<td>3:10 pm-3:40 pm Foyer</td>
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<tr>
<td><strong>AHS Annual Meeting</strong></td>
<td>5:00 pm-6:00 pm Copper Basin</td>
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<tr>
<td><strong>AIPG or AHS Awards Dinners</strong></td>
<td>AIPG Sedona/Verde</td>
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<td></td>
<td>AHS Clarkdale/ Cottonwood</td>
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6:45 pm-8:30 pm (all welcome with additional fee)
<table>
<thead>
<tr>
<th>Saturday September 13, 2014</th>
<th>Sunday September 14, 2014</th>
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</thead>
<tbody>
<tr>
<td>AIPG Executive Committee Meeting Prescott/Chino 8:00 am-12:00 noon</td>
<td>*Field Trip — Geology of the Grand Canyon and the Trail of Time 6:45 am-6:00 pm</td>
</tr>
<tr>
<td>AIPG Advisory Board Meeting Prescott/Chino 1:00 pm-3:30 pm</td>
<td>Registration Foyer 7:30 am-8:00 pm</td>
</tr>
<tr>
<td>AIPG 2014/2015 Joint Executive Committee Meeting &amp; Business Meeting Prescott/Chino 3:30 pm-4:00 pm</td>
<td>*Field Trip — Prescott Geology and Natural History Hike 8:00 am-5:00 pm</td>
</tr>
<tr>
<td>*Field Trip — Jerome Precambrian Ore Deposits, Young Volcanoes, Red Rocks, and Modern Sinkholes 8:00 am-6:00 pm</td>
<td>*Field Trip — Jerome Precambrian Ore Deposits, Young Volcanoes, Red Rocks, and Modern Sinkholes 8:00 am-6:00 pm</td>
</tr>
<tr>
<td>Exhibitor and Poster Set-up Foyer 10:00 am-4:00 pm</td>
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</tr>
<tr>
<td>Foundation of the AIPG Meeting Jerome <em>(open to all registrants)</em> 4:00 pm-6:00 pm</td>
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</tr>
<tr>
<td>AHS Foundation Meeting Copper Basin 5:00 pm-6:30 pm</td>
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</tr>
<tr>
<td>Reception — Exhibit Area Open Foyer <em>(complimentary for all registrants)</em> 6:30 pm-8:00 pm</td>
<td>Reception — Exhibit Area Open Foyer <em>(complimentary for all registrants)</em> 6:30 pm-8:00 pm</td>
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</tbody>
</table>

*All field trips will depart and return to the Prescott Resort and Conference Center from the Lobby*

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*Goldwater Lake in Prescott Courtesy of the Prescott Office of Tourism*
| **Monday**  
September 15, 2014 | **Tuesday**  
September 16, 2014 |
|-------------------|-------------------|
| *Field Trip — Geology of the Grand Canyon and the Trail of Time  
6:45 am-6:00 pm | *Field Trip — Geology of the Bagdad Copper Mine  
7:00 am-6:00 pm |
| *Field Trip — Glen Canyon Dam Tour and Ancient Landscapes of Northern Arizona  
6:45 am-6:00 pm | Registration  
Foyer  
7:30 am-3:00 pm |
| Registration  
Foyer  
7:30 am-5:00 pm | Technical Sessions (see Technical Session Schedule on pg 20)  
8:00 am-5:00 pm |
| *Field Trip — Sedona Pink Jeep Tour, Page Springs Hatchery, and Oak Creek Winery  
8:00 am-6:00 pm | Exhibits Open —  
Foyer  
8:00 am-3:30 pm |
| Exhibits Open —  
Foyer  
8:00 am-5:00 pm | *Field Trip — Geology of the Prescott Area  
8:00 am-3:00 pm |
| Technical Sessions (see Technical Session Schedule on pg 10)  
8:30 am-5:00 pm | *Field Trip — Geology and Hydrogeology of the Upper Verde River Watershed  
8:00 am-6:00 pm |
| *Field Trip — Natural and Cultural History Tour of the Central Arizona Highlands and Prescott Area  
9:00 am-3:00 pm | *Field Trip — Geology and Hydrogeology of the Upper Verde River Watershed  
8:00 am-6:00 pm |
| AHS Annual Meeting  
Copper Basin  
5:00 pm-6:00 pm | |
| AIPG Awards Dinner  
Sedona/Verde  
6:45 pm-8:30 pm | |
| AHS Awards Dinner  
Clarkdale/Cottonwood  
6:45 pm-8:30 pm | |
1.800.967.4637
PrescottResort.com

1500 Highway 69
Prescott, AZ 86301

All Field Trips
Depart/Return Here
### Plenary Session

- **Welcome**
  AHS President, **Mike Hulst**

- **AIPG President,** **Ray Talkington, CPG**

- **2014 Co-Chairman,** **Doug Bartlett, CPG**

- **Mayor Marlin Kuykendall,** Mayor of Prescott

- **Plenary Speaker**
  **Flagstaff’s Water & Rocks: Past, Present & Future**
  - Bradley M. Hill, R.G., Utilities Director, Hydrologist, City of Flagstaff

### Poster Session - Arizona

**Estimating Groundwater Recharge in Semi-Arid, Ponderosa Pine Forest Using a Precipitation-Sourced Chloride Mass Balance Technique**

Vaden J. Aldridge
Northern Arizona University, Flagstaff, AZ

**Dissolved Solids in Streams of the Conterminous United States**

David Anning
U.S. Geological Survey, Flagstaff, AZ

**A National Assessment of Brackish Groundwater**

David Anning
U.S. Geological Survey, Flagstaff, AZ

**Case Study: The Variance of Water Quality Parameters to Depth in Coupon Bight**

Rachel Bobich, SA
Florida Atlantic University, Boca Raton, FL

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**Poster Presenters will be Available at their Posters Monday During the Morning Break**

**Student Poster Contestants will be Available at their Posters Monday from 10:00 am - 12:00 noon to Answer Judges’ Questions**
An Inquiry of Upper Lake Mary’s Water Quality and the Origin of the Lake Mary Basin  
Rae Byars, SA  
Northern Arizona University, Flagstaff, AZ

Paleomagnetic, Anisotropy of Magnetic Susceptibility, Geochronology and Petrography of the Buena Vista Dike, North-Central New Mexico  
Geno Castillo, SA  
New Mexico Highlands University, Las Vegas, NM

An Estimated Water Budget for the Lower Colorado River Multi-Species Conservation Program at Palo Verde Ecological Reserve  
Arien Chavez  
GeoSystems Analysis/The University of Arizona, Tucson, AZ

Divergent Ridge Features on the Juan de Fuca and Gorda Ridges  
Mary Eaton  
College of Charleston Department of Geology and Environmental Geo, Charleston, SC

Planning for Effluent Use: Capacity Use and Impacts in Tucson, Arizona  
Julie Huigens, SA  
University of Arizona, Tucson, AZ

A Geomorphic and Geochronologic Study of the MIS-5B Diamictite at Palisades Creek, Eastern Grand Canyon, Arizona: Evidence For Emplacement during Regional Wet Events in the Southwestern United States  
Ray Kenny  
Fort Lewis College, Durango, CO

**Student Poster Contest**  
**Results will be Announced Monday Afternoon**
<table>
<thead>
<tr>
<th>Title</th>
<th>Presenter</th>
<th>Institution</th>
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</thead>
<tbody>
<tr>
<td><strong>10</strong>Be, Oxygen Isotopes, and Geomorphology of Late Pleistocene Stone Runs, Tufa, and Scalloped Kaibab Limestone Cliffs: Twin Creek Canyon, Western Grand Canyon, Arizona</td>
<td>Ray Kenny</td>
<td>Fort Lewis College, Durango, CO</td>
</tr>
<tr>
<td>Composite Patterns Typical of Widespread Heavy Rainfall Events in the Phoenix, Arizona Metropolitan Area</td>
<td>Michael McLane</td>
<td>NOAA/National Weather Service, Phoenix, AZ/ Tempe, AZ</td>
</tr>
<tr>
<td>Evaluating the Performance of CMIP5 Climate Projections over the Colorado River Basin</td>
<td>Noe Santos</td>
<td>U.S. Bureau of Reclamation, Boulder City, NV</td>
</tr>
<tr>
<td>Distribution and Identification of Factors Influencing Rates of Manganese Concentrations in Groundwater in Lebanon, Connecticut</td>
<td>Samantha Schwarz</td>
<td>Eastern Connecticut State University, Willimantic, CT</td>
</tr>
<tr>
<td>Naturally-Occurring Metals Concentrations in Michigan Soils: A 2014 Survey</td>
<td>Zachary Spotts, SA</td>
<td>Western Michigan University Department of Geosciences, East Lansing, MI</td>
</tr>
<tr>
<td>Evaluating Erosion Risk Mitigation from Forest Restoration Treatments Using Alluvial Chronology and Hydraulic Modeling</td>
<td>Victoria Stempniewicz</td>
<td>Northern Arizona University, Flagstaff, AZ</td>
</tr>
<tr>
<td>Remote Controlled Monitoring for Mine Closure</td>
<td>Katherine Stoll</td>
<td>University of Arizona, Tucson, AZ</td>
</tr>
<tr>
<td>Investigation of an Oil Shale Fire at Windfall Mountain</td>
<td>Linda Stromquist, MEM</td>
<td>National Park Service, Anchorage, AK</td>
</tr>
<tr>
<td>Time</td>
<td>Session</td>
<td>Title</td>
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<tr>
<td>Monday, Sept 15, 2014 10:00am-10:30am</td>
<td>Poster Session - Arizona (continued)</td>
<td>Using Spectral Reflectance Signatures to Differentiate between Bennett Reef Limestone Beds</td>
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<td>The Virtue of Flux Measurements during Hydraulic Tomographic Surveys</td>
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<td>Deep Groundwater Flow through Interconnected Fracture Networks</td>
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<td>Integrating Science and Communities in Northeastern New Mexico: The Union County Hydrogeology Project</td>
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### Technical Sessions

<table>
<thead>
<tr>
<th>Session 1A - Granite Mountain</th>
<th>10:30am-11:50am</th>
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<tbody>
<tr>
<td><strong>Balancing Cost &amp; Risk in Designs for Large Storms</strong></td>
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<tr>
<td>• Moderator - Mike Geddis, AZ</td>
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<tr>
<td><strong>10:30-10:50</strong></td>
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<tr>
<td><strong>Flooding, Erosion, Seepage and Treatment:</strong> Balancing Risk and Costs in Mine Closure Designs</td>
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<tr>
<td>Stephen Taylor, Picacho Associates, LLC, Phoenix, AZ</td>
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<tr>
<td><strong>10:50-11:10</strong></td>
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<tr>
<td><strong>Probability and Risk Considerations in Sizing Mine Water Ponds</strong></td>
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<tr>
<td>Nathan Haws, MWH Americas, Inc., Tempe, AZ</td>
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<td><strong>11:10-11:30</strong></td>
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<tr>
<td><strong>The NEXRAD Revolution: Scientific Basis for Updating the HMR-49 Statistical Storm Intensities and PMPs</strong></td>
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<tr>
<td>Bill Kappel, Applied Weather Associates, LLC, Monument, CO</td>
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<td><strong>11:30-11:50</strong></td>
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<tr>
<td><strong>A Comparison of Hydrology and Designs Using HMR-49 and 2013 ADWR NEXRAD Guidance</strong></td>
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<td>Alexander Edstrom, MWH Americas, Inc., Tempe, AZ</td>
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<thead>
<tr>
<th>Session 1B - Prescott/Chino</th>
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<tr>
<td><strong>Colorado River</strong></td>
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<tr>
<td>• Moderator - David Anning, AZ</td>
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<tr>
<td><strong>10:30-10:50</strong></td>
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<tr>
<td><strong>Impacts of Climate Uncertainties on Colorado River Water Supply</strong></td>
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<tr>
<td>Andrea Carlson, Central Arizona Project, Phoenix, AZ</td>
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<tr>
<td><strong>10:50-11:10</strong></td>
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<tr>
<td><strong>Colorado Flood Impacts, September 2013: Northern Front Range</strong></td>
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<tr>
<td>William Hoyt, CPG, Earth &amp; Atmospheric Sciences, University of Northern Colorado, Greeley, CO</td>
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<td><strong>11:10-11:30</strong></td>
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<tr>
<td><strong>Irrigation to Support Riparian Habitat Restoration on the Lower Colorado River</strong></td>
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<tr>
<td>Lindsey Hovland, GeoSystems Analysis, Inc., Tucson, AZ</td>
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### Technical Sessions

**Session 1C - Copper Basin**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:30-10:50</td>
<td>Horizontal Environmental Drilling 101 - An Introduction to the Means and Methods for Horizontal Environmental Well Installation</td>
<td>David Bardsley</td>
<td>Directed Technologies Drilling, Inc., Scottsdale, AZ</td>
</tr>
<tr>
<td>11:10-11:30</td>
<td>Directional Drilling for Mine Dewatering: Extending Our Reach</td>
<td>Gwyn Rhys-Evans</td>
<td>Freeport McMoRan Inc., Morenci, AZ</td>
</tr>
<tr>
<td>11:30-11:50</td>
<td>A General Overview of Directionally Drilled Horizontal Remediation Wells and the Benefits in Environmental Remedial Applications</td>
<td>Mike Sequino</td>
<td>Directional Technologies, Inc., Wallingford, CT</td>
</tr>
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**Luncheon Keynote Speaker**

**Karl Karlstrom & Laura Crossey**

University of New Mexico

**Grand Canyon: Resolution of the 140-Year-Long Debate About Its Age, Insights into the Last 12 Million Years of an Incised Aquifer System, and Geoscience Outreach along the Trail of Time**

Clarkdale/Cottonwood/Sedona

12:00 noon - 1:30 pm

*(all registrants welcome!)*
### Session 2A - Granite Mountain

**Monitoring & Evaluating Reclamation Performance**  
• Moderator - **Stephen Taylor, AZ**

1:30-1:50  
**Risk Evaluation of Dam Erodibility**  
Chin Man Mok, GSI Environmental Inc., Orinda, CA

1:50-2:10  
**Reclamation of a Mid-Continent Former Lead Smelter Site**  
David Heidlauf, CPG, ENVIRON International Corporation, Chicago, IL

2:10-2:30  
**AA Leach Pad Cover Design and Long-Term Monitoring Results - A Successful Reclamation Project at a Nevada Gold Mine**  
Mike Milczarek, GeoSytems Analysis, Inc., Tucson, AZ

2:30-2:50  
**Remote Controlled Monitoring for Mine Closure**  
Gail Heath, University of Arizona, Tucson, AZ

### Session 2B - Prescott/Chino

**Geophysics & Ground Water**  
• Moderator - **Frank Getchell, CPG, NJ**

1:30-1:50  
**Remote Sensing and Passive Geophysical Techniques in Clark County, Nevada**  
David Donovan, CPG, AquaPetrus LLC, Las Vegas, NV

1:50-2:10  
**Nuclear Magnetic Resonance - A New Tool for Enhanced Groundwater Supply and Environmental Investigations**  
Bradley Cross, ARCADIS-US, Scottsdale, AZ

2:10-2:30  
**Testing Fracture Connectivity through Visualization and Monitoring in a Granitic Rock Setting Near Roxboro, North Carolina**  
Melinda Chapman, U.S. Geological Survey, Raleigh, NC
Monday, September 15, 2014  1:30pm-2:50pm

Session 2B - Prescott/Chino (continued)

Geophysics & Ground Water
• Moderator - Frank Getchell, CPG, NJ

2:30-2:50
Positive Impacts on Groundwater Resources Subsequent to Wildfires in the Lincoln National Forest in New Mexico
Roger Peery, CPG, John Shomaker & Associates, Inc., Albuquerque, NM

Session 2C - Copper Basin

Engineering Geology
• Moderator - Erin Young, AZ

1:30-1:50
Water Use and Sources for Oil and Natural Gas Activities in Six Western States
Tammy Rauen, Golder Associates Inc., Lakewood, CO

1:50-2:10
Integrated Geotechnical and Geophysical (2-D and 3-D Electrical Resistivity Tomography) Assessment of Failed Railway Line Bridge at Akere, Nigeria
Waliu Adeolu, Geophase Resources Nig Ltd, Ikeja

2:10-2:30
The Burmister System of Soil Classification - History and Application
Robert Stewart, CPG, AIPG, Thornton, CO

2:30-2:50
An Update on Arizona Land Subsidence Using Interferometric Synthetic Aperture Radar (INSAR) Data by the Arizona Department of Water Resources
Brian Conway, Arizona Department of Water Resources, Phoenix, AZ

Silent Auction
Monday at AIPG’s Awards Dinner
(open to all)

*All proceeds go to the Foundation of the AIPG
### Session 3A - Granite Mountain

**Science Smorgasbord**

- **Moderator** - **Michael Tomlinson**, MEM, AZ

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<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker(s)</th>
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<tbody>
<tr>
<td>3:40-4:00</td>
<td>Rare Earth Elements (REE) in Bauxite, Kaolinite, and Terra Rossa Deposits</td>
<td>Mark Cocker, MEM, USGS, Tucson, AZ</td>
</tr>
<tr>
<td>4:00-4:20</td>
<td>Geologists and Site Conceptual Models: VOCS and Sewer Gas in Indoor Air Resulting from Migration from Breached Sewer Conveyance Systems</td>
<td>James A. Jacobs, CPG, Clearwater Group, Pt. Richmond, CA</td>
</tr>
<tr>
<td>4:20-4:40</td>
<td>Integration of Rain Gauge and Doppler Radar Data Using Bayesian Non-Parametric Approach</td>
<td>Chin Man Mok, GSI Environmental Inc., Orinda, CA</td>
</tr>
<tr>
<td>4:40-5:00</td>
<td>Statistical Analysis of Left-Censored Geochemical Data</td>
<td>Michael Tomlinson, MEM, University of Hawaii at Manoa, Flagstaff, AZ</td>
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### Session 3B - Prescott/Chino

**Surface & Ground-Water Quality & Interaction**

- **Moderator** - **Edwin McGavock**, AZ

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<tbody>
<tr>
<td>3:40-4:00</td>
<td>Conceptual Models in Characterizing the Source and Migration of NAPL-Impacted Sediments</td>
<td>Jeffrey Johnson, CPG, NewFields, Houston, TX</td>
</tr>
</tbody>
</table>
### Surface & Ground-Water Quality & Interaction

- **Moderator** - Edwin McGavock, AZ

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<tbody>
<tr>
<td>4:00-4:20</td>
<td>Groundwater under the Direct Influence of Surface Water, City of Charlotte, Michigan - A Case Study</td>
<td>Mark Sweatman, CPG, AMEC Environment &amp; Infrastructure, Novi, MI</td>
</tr>
<tr>
<td>4:20-4:40</td>
<td>Playa Lakes Water Resource Assessment and Implications for Ogallala Aquifer Recharge</td>
<td>Andrew Weinberg, Texas Water Development Board, Austin, TX</td>
</tr>
<tr>
<td>4:40-5:00</td>
<td>The Padre Canyon Evaporites, Coconino County, Arizona</td>
<td>Edwin McGavock, Montgomery &amp; Associates, Tucson, AZ</td>
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### Session 3C - Copper Basin

#### Young Professionals

- **Moderator** - Raymond Talkington, CPG, NH

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>3:40-4:00</td>
<td>The Geologist’s Role in Environmental Site Characterization and Remediation</td>
<td>J. Todd McFarland, CPG, AMEC Environment &amp; Infrastructure, Inc., Nashville, TN</td>
</tr>
<tr>
<td>4:00-4:20</td>
<td>I Didn’t Even Like Soils Class: How I Became Manager of the Geotechnical Engineering Dept.</td>
<td>Keri Nutter, CPG, DOWL HKM, Anchorage, AK</td>
</tr>
<tr>
<td>4:20-5:00</td>
<td>Young Professionals</td>
<td>Raymond Talkington, CPG, 2014 AIPG President, Geosphere Environmental Mgmt, Inc., Exeter, NH</td>
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<tr>
<td>Time</td>
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<td>Presenter(s)</td>
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<tr>
<td>8:00-8:20</td>
<td>Ephemeral Stream-Flow Monitoring Utilizing SRP Flowtography</td>
<td>Lee Ester, SRP Water Measurement, Tempe, AZ</td>
</tr>
<tr>
<td>8:20-8:40</td>
<td>Potential Future Declines in Base Flow to the Upper Verde River Due to Groundwater Extraction from the Big Chino Sub-Basin - An Application of the NARGFM</td>
<td>Peter Kroopnick, CWAG, Prescott, AZ</td>
</tr>
<tr>
<td>8:40-9:00</td>
<td>Groundwater Modeling’s Role in Strategic Water Resources Planning for Clarkdale, Arizona</td>
<td>Laurel Lacher, Lacher Hydrological Consulting, Tucson, AZ</td>
</tr>
</tbody>
</table>
Tuesday, September 16, 2014  8:00am-9:40am
Session 4B - Verde

Santa Cruz River
• Moderator - Evan Canfield, AZ

8:00-8:20
Sediment Transport Study at the Tucson Reach of the Santa Cruz River
Jennifer Duan, University of Arizona, Tucson, AZ

8:20-8:40
A Drier More Variable Hydrologic Future Could Mean Diverse but Sparse Riparian Systems
Thomas Meixner, University of Arizona, Tucson, AZ

8:40-9:00
The Effects of Effluent Discharge and Concentration on Infiltration in the Santa Cruz River
Jacob Prietto, SA, University of Arizona Dept. of Hydrology and Water Resources, Tucson, AZ

9:00-9:20
Changes in the Effluent-Dependent Santa Cruz in Pima County: The 2013 Living River Annual Report
Evan Canfield, Pima County Regional Flood Control, Tucson, AZ

Watson Lake in Prescott
Courtesy of the Prescott Office of Tourism
### Session 4C - Copper Basin
Tuesday, September 16, 2014  8:00am-9:40am

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>8:00-8:20</td>
<td><strong>In Situ Copper Mining</strong></td>
<td>Stephen Twyerould, Excelsior Mining, Phoenix, AZ</td>
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<tr>
<td>8:20-8:40</td>
<td><strong>Alkaline Flush Technology: An In Situ Treatment Method for Mine Impacted Alluvial Aquifers</strong></td>
<td>Madhumitha Raghav, Freeport McMoRan, Oro Valley, AZ</td>
</tr>
<tr>
<td>8:40-9:00</td>
<td><strong>Evaluating the Source of Hypersaline Conditions in an Area of Mining and Oil Production</strong></td>
<td>Jeffrey Johnson, CPG, NewFields, Houston, TX</td>
</tr>
<tr>
<td>9:00-9:20</td>
<td><strong>Solving Mine Water Problems with Peat-Based Sorption Media</strong></td>
<td>Paul Egers, Sovereign Consulting, Lakewood, CO</td>
</tr>
<tr>
<td>9:20-9:40</td>
<td><strong>Edible Oil Injection Event Monitored Using Conductivity Transducers at a Fractured Bedrock Site</strong></td>
<td>Kevin Frysinger, MEM, Environmental Standards, Valley Forge, PA</td>
</tr>
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</table>

### Luncheon Keynote Speaker

**Stephen Reynolds**  
Arizona State University

**Looking at Landscapes: Eye-tracking Studies of Where We Look on Photographs of Geologic Scenery**

Clarkdale/Cottonwood/Sedona  
12:00 noon - 1:30 pm

*(all registrants welcome!)*
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker(s)</th>
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<tbody>
<tr>
<td>10:10-10:30</td>
<td>Hydraulic Tomography: Let Data Tell the Story</td>
<td>Michael Tso, SA, University of Arizona, Tucson, AZ</td>
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</tr>
<tr>
<td>10:30-10:50</td>
<td>Effect of Aquifer Heterogeneities on the Water Residence Time (WRT) and Their Significance</td>
<td>Ravindra Dwivedi, SA, University of Arizona, Tucson, AZ</td>
<td></td>
</tr>
<tr>
<td>10:50-11:10</td>
<td>An Introduction to MODFLOW-USG, an Unstructured Grid Version of MODFLOW</td>
<td>Sorab Panday, GSI Environmental Inc., Herndon, VA</td>
<td></td>
</tr>
<tr>
<td>11:30-11:50</td>
<td>Ethics and Environmental Sampling: Things You May Not Have Considered</td>
<td>Joseph Kraycik, MEM, Environmental Standards, Inc., Valley Forge, PA</td>
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<tr>
<td>10:10-10:30</td>
<td>Patterns and Trends in Municipal Water Demand: Impacts of Changing Tastes, Technologies and Demographics</td>
<td>Gary Woodard, Montgomery &amp; Associates, Tucson, AZ</td>
<td></td>
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<tr>
<td>10:30-10:50</td>
<td>Improved Demand Forecasts through Dynamic Simulation Modeling: The Power of Dashboards, Scenarios, and Monte Carlo Methods</td>
<td>Megan Zivic, EL Montgomery &amp; Associates, Tucson, AZ</td>
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### Session 5B - Verde (continued)

<table>
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<tr>
<th>Time</th>
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<th>Presenter(s)</th>
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<tbody>
<tr>
<td>10:50-11:10</td>
<td><strong>Water Demand Planning: A Municipal Perspective</strong>&lt;br&gt;Addressing the Shortage Needs for STEM Technicians</td>
<td>Mario Castaneda, GateWay Community College, Phoenix, AZ</td>
</tr>
<tr>
<td>11:10-11:30</td>
<td><strong>Anticipating the Future of Water Demand - A New Approach</strong></td>
<td>Ray Quay, Arizona State University, Phoenix, AZ</td>
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### Session 5C - Copper Basin

<table>
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<tr>
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<tbody>
<tr>
<td>10:10-10:30</td>
<td><strong>STEM Careers-Feeding the Pipeline</strong>&lt;br&gt;Addressing the Shortage Needs for STEM Technicians</td>
<td>Kerry Schwartz, University of Arizona, Water Resources Research Center, Tucson, AZ</td>
</tr>
<tr>
<td>10:30-10:50</td>
<td><strong>Building an Online STEM Broadcasting Station</strong></td>
<td>Michael Conway, Arizona Geological Survey, Tucson, AZ</td>
</tr>
<tr>
<td>10:50-11:10</td>
<td><strong>Exploring Earth Science through Explosions, Excavations, and the Environment</strong></td>
<td>Stacey Hundley, MEM, Wright State University, Dayton, OH</td>
</tr>
<tr>
<td>11:10-11:30</td>
<td><strong>The Evolution of the Geoscience Workforce in Times of Demographic Change</strong></td>
<td>Christopher Keane, American Geosciences Institute, Alexandria, VA</td>
</tr>
<tr>
<td>11:30-11:50</td>
<td><strong>Arizona Project WET STEM Programs</strong></td>
<td>Kerry Schwartz, University of Arizona, Water Resources Research Center, Tucson, AZ</td>
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<tr>
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<tr>
<td>1:30-1:50</td>
<td>Hydrogeological Investigation of the Timken Faircrest Steel Plant Construction Dewatering Project Stark County, Canton and Perry Townships, Ohio</td>
<td>Curtis J. Coe, CPG, ODNR Division of Soil and Water Resources, Columbus, OH</td>
</tr>
<tr>
<td>1:50-2:10</td>
<td>Ground Water Investigation of the Carbonate Bedrock Aquifer to Evaluate the Impact of Pumping High-Yielding Irrigation Wells on Local Water Supply Wells in Ottawa County, Harris Township, Ohio</td>
<td>Curtis J. Coe, CPG, ODNR Division of Soil and Water Resources, Columbus, OH</td>
</tr>
<tr>
<td>2:30-2:50</td>
<td>The ADWR Online Groundwater Level Data Portal: A New Tool for Groundwater Level Data Reporting</td>
<td>Frank Corkhill, AZ Department of Water Resources, Phoenix, AZ</td>
</tr>
<tr>
<td>2:50-3:10</td>
<td>Technical, Permitting, and Legal Aspects of Replacement Wells in Arizona’s Active Management Areas</td>
<td>Andrew Scott, Montgomery &amp; Associates, Scottsdale, AZ</td>
</tr>
</tbody>
</table>
## Session 6B - Verde

### Tuesday, September 16, 2014  1:30pm-3:10pm

**Industrial Minerals/Economic Geology**

- **Moderator** - *Nyal Niemuth, AZ*

<table>
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<tbody>
<tr>
<td>1:50</td>
<td>Ancestral Yuba River Placer Gold Deposits - Northern Sierra Nevada Region, California</td>
<td>David Lawler, CPG, Lawler Associates Geoscience, Grass Valley, CA</td>
</tr>
<tr>
<td>2:10</td>
<td>Industrial Mineral Production in the United States - An Increasing Reliance on Imports</td>
<td>William Langer, CPG, Bill Langer Research Geologist LLC., Anthem, AZ</td>
</tr>
<tr>
<td>2:30</td>
<td>Mine Scams</td>
<td>David Lawler, CPG, Berkeley, CA</td>
</tr>
<tr>
<td>2:50</td>
<td>Getting Past Go</td>
<td>Larry Cerrillo, CPG, Ingenuity Enterprises Int’l, Inc., Evergreen, CO</td>
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<tr>
<td>Time</td>
<td>Session Title</td>
<td>Presenter</td>
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<tr>
<td>1:50-2:10</td>
<td>Report of a Hydrogeologic Study in the South Salem Hills, Polk County, Oregon</td>
<td>Nicholas Coffey, Coffey Geoscience LLC, Salem, OR</td>
</tr>
<tr>
<td>2:10-2:30</td>
<td>Use of Long-Term Thermometric and Hydrologic Measurements in Characterizing Surface Water-Groundwater Interactions along the Great Miami River in Dayton, Ohio</td>
<td>Brent Huntsman, CPG, Terran Corporation, Beavercreek, OH</td>
</tr>
<tr>
<td>2:30-2:50</td>
<td>Agua Caliente-The Once and Future Spring</td>
<td>Frank Postillion, Pima County Regional Flood Control District, Tucson, AZ</td>
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</tbody>
</table>
Tuesday, September 16, 2014  3:40pm-5:00pm

Session 7A - Granite Mountain

Water Management

• Moderator - Doug McMillan, AZ

3:40-4:00

An Adaptive Reliability-Based Optimization Framework for Integrated Management of Water Resources
Chin Man Mok, GSI Environmental Inc., Orinda, CA

4:00-4:20

Simplified Model of Bank Failure as a Function of Groundwater / River Stage Dynamics
Brent Travis, WEST Consultants, Inc., Tempe, AZ

4:20-4:40

Impacts of Wildfires on Water Supplies
Daniel Neary, USDA Forest Service, Rocky Mountain Research Station, Flagstaff, AZ

4:40-5:00

Arizona Farms of the Future: The Changing Face of Irrigation & Water Use in Agriculture
Dave Laney, Cardno ATC, Tempe, AZ

5:00

Thank You for Attending!
INTEGRATED GEOTECHNICAL AND GEOPHYSICAL (2-D AND 3-D ELECTRICAL RESISTIVITY TOMOGRAPHY) ASSESSMENT OF FAILED RAILWAY LINE BRIDGE AT AKERE, NIGERIA

Waliu Adeolu, Geophase Resources Nigeria Ltd, Ikeja ad_2will@yahoo.com; Rotimi Akinwale, Geodyx-Plus Solution Nigeria Ltd, Ikeja

The renovation of a proposed railway bridge in Akere, Nigeria, was investigated using integrated geotechnical (standard penetration test [SPT]) and geophysical methods (2-D and 3-D resistivity imaging using multi-electrode system and extracted vertical electrical sounding [VES] techniques). Frequent flooding from the Niger River on overflowing its banks has been washing away the railway section along this section and several engineering foundation precautions taken have proved abortive. Eight traverses of 2-D lines, one 3-D section, and 64 extracted VES data were acquired and interpreted. Inter-electrode spacing of 1 m and inter-traverse spacing of 3 m were adopted for better near-surface resolution. The subsurface layers were characterized by topsoil, clay, clayey sand/sandy clay, weathered/intensely fractured rock, sand, and fresh basement. The eight borehole data acquired earlier were integrated with the 2-D and 3-D resistivity tomography results. A perfect correlation was obtained for the two techniques; however, all the boreholes terminated at shallow depth (5 – 11 m), and did not provide information beyond this depth while the resistivity tomography penetrated to a depth of about 15 – 20 m and revealed the presence of structurally weak materials (clay/fractured basement) inimical to the foundation of the rail line along the traverses. The 2-D and 3-D resistivity tomography shows that the first aquifer is underlain by a clay layer separating the upper aquifer unit from the lower aquifer unit; this was further corroborated by the VES results. The presence of low resistivity subsurface materials composed of clay/clayey sand within a depth range of 10 – 17 m may accelerate failure of piles along the railway line. This layer is inimical to the proposed rail line. The depth to the competent soil material along where the failed (10- to 20-m) piles were installed varies compared to adjacent regions (3 – 6 m). It was therefore recommended that necessary precautions in foundation design to competent layer or to exploit the adjacent shallow competent region be considered. Pile foundation to varying depths within the competent region is recommended and should be socketed and anchored within the basement rock which occurs at varying depths within the investigated area. The integration of geotechnics and invaluable multi-dimensional variation of subsurface distribution provided in the geophysical investigation have provided an insightful and lasting solution to the foundation problems encountered.
A COMPARATIVE RESOURCE ESTIMATION STUDY OF A GRANITOID-HOSTED GOLD DEPOSIT IN GHANA

James Adu, MEM, Freeport McMoran Sierrita Mine, Green Valley, AZ, James_Adu@fmi.com

The prediction of grade and tonnages in complex ore bodies has been the main concern in mineral evaluation and appraisal. Deposits have generally similar characteristics but each individual deposit should be looked at differently and the generalization rule applied with caution. In evaluating the resource potential for deposits, all the available techniques should be used and the appropriate one selected.

This property, located in Ghana, is a mesothermal gold prospect hosted in composite granitoid intrusions that consists of crosscutting diabase, micro-diorite, micro-granodiorite, aplite and granitic pegmatite. These granitoids are hosted in a meta-volcanic unit with a thrust contact to a meta-sediment unit. The gold ore deposit strikes about N50°E with a strike length of about 2.7 kilometer (km) and a width ranging from 30 meter (m) -100 m. The dip ranges from 60° – 75° SE.

Two resource estimation methods, Ordinary Kriging (OK) and Inverse Distance Weighting Square (IDW2), were used to estimate the resource for the deposit. OK is judged to be the best estimation method, yielding an indicated resource of about 51.38 million tons of ore with an average grade of 1.45 grams per ton (g/t), or about 2.4 million ounces (oz) of gold, and a measured resource of about 50.31 million tons of ore with an average grade of 1.79 g/t with about 2.89 million oz of gold. Further grade and tonnage analysis resulted in an optimum indicated resource of 21 million tons with average grade of 2.2 g/t at a cut-off of 1.5 g/t and a measured resource of 24.9 million tons with an average grade of 2.6 g/t at a cut-off of 1.5 g/t.

Generally, there was good correlation between the two methods in well-drilled zones, but further analysis showed that areas where IDW2 gave good estimates compared to those of OK only represent areas that have very limited drill-hole data, with corresponding poor efficiencies. Hence, the OK method of resource estimation for this deposit is recommended, along with further drilling to upgrade the indicated resource to that of a measured resource, and also to help separate the various sample populations to enhance the quality of the resource estimation.
ESTIMATING GROUNDWATER RECHARGE IN SEMI-ARID, PONDEROSA PINE FOREST USING A PRECIPITATION-SOURCED CHLORIDE MASS BALANCE TECHNIQUE

Vaden J. Aldridge, Northern Arizona University, Flagstaff, AZ, vja26@nau.edu; Sharon Masek Lopez, Northern Arizona University, Flagstaff, AZ; Abraham E. Springer, Northern Arizona University, Flagstaff, AZ

Forest fires are increasing in incidence and intensity as climate change-related drought continues to induce stress in forested ecosystems. In semi-arid northern Arizona, a ponderosa pine forest stretches from the south rim of the Grand Canyon, east, along the Mogollon Rim, continuing into New Mexico. Recent large-scale forest fires have prompted research and restoration programs to maintain forest health and sustainability. One such program is the U.S. Forest Service’s Four Forest Restoration Initiative (4FRI) which will thin the forest and return a more frequent fire interval in hopes of reducing the amount of available fuel for fires. The hydrogeological implications of these restoration techniques are poorly understood. Previous studies have documented changes to the surface-water hydrology of watersheds (e.g. evapotranspiration) and predicted, via groundwater models, recharge change after major plant-canopy removal. Due to a deep aquifer system (>400 m), and few well data, an alternative method for groundwater monitoring is required. This study is designed to estimate groundwater recharge using a chloride mass balance (CMB) technique within thinned and unthinned portions of the forest. The CMB method is commonly used to estimate recharge in arid and semi-arid climates. Chloride is a conservative, non-volatile environmental tracer that can be used to estimate groundwater recharge under a mass balance approach. The CMB technique requires collection of precipitation, soil water and surface water samples. These samples will be analyzed for major cations, anions (including chloride), deuterium and oxygen-18 isotopes. These data will provide a preliminary suite of information which will be useful for establishing statistical significance of the CMB method and improved CMB monitoring in the forest. Two watersheds have been chosen for this study to represent ponderosa pine forests; both having undergone some degree of forest-thinning. Samples will be taken in both thinned and unthinned areas of the forest, as well as other cover types such as open “parks” and stream channels, to identify differences in groundwater recharge rates. Results from this study will be useful for forest managers to adapt better forest restoration techniques and provide groundwater monitoring data in this era of drought.
DISSOLVED SOLIDS IN STREAMS OF THE CONTERMINOUS UNITED STATES

David Anning, U.S. Geological Survey, Flagstaff, AZ, dwanning@usgs.gov; Marilyn Flynn, U.S. Geological Survey, Flagstaff, AZ

Studies have shown that excessive dissolved-solids concentrations in water can have adverse effects on the environment and on agricultural, domestic, municipal, and industrial water users. Such effects motivated the U.S. Geological Survey’s National Water Quality Assessment Program to develop a Spatially-Referenced Regression on Watershed Attributes (SPARROW) model to improve the understanding of sources, loads, yields, and concentrations of dissolved solids in streams of the conterminous United States.

Using the SPARROW model, annual dissolved-solids loads from 2,560 water-quality monitoring stations were statistically related to several spatial datasets that are surrogates for dissolved-solids sources and land-to-water delivery processes. Sources in the model included variables representing geologic materials, road de-icers, urban lands, cultivated lands, and pasture lands. Transport of dissolved solids from these sources was modulated by land-to-water delivery variables that represent precipitation, streamflow, soil, vegetation, terrain, population, irrigation, and artificial-drainage characteristics. Model input data such as load estimates, source variables, and transport variables were obtained for the period 1980-2010 and were statistically adjusted to compensate for temporal trends and to represent long-term mean conditions as though occurring in the year 2000.

The nonlinear least-squares estimated SPARROW model was used to predict long-term mean annual conditions for dissolved-solids sources, loads, yields, and concentrations in a digital hydrologic network representing nearly 66,000 stream reaches and their corresponding incremental catchments, which drain the conterminous United States. Nationwide, the median incremental-catchment yield delivered to local streams is 26 metric tons per year per square kilometer [(Mt/yr)/km²]. Ten percent of the incremental catchments yield less than 4 (Mt/yr)/km², and 10 percent yield more than 90 (Mt/yr)/km². Incremental-catchment yields greater than 50 (Mt/yr)/km², mostly occur along the northern part of the West Coast and in a crescent-shaped band south of the Great Lakes. The total amount of dissolved solids delivered to the Nation’s streams is estimated at 272 million Mt annually, of which 194 million Mt (71%) come from geologic sources, 38 million Mt (14%) come from road de-icers, 18 million Mt (7%) come from pasture land, 14 million Mt (5 %) come from urban land, and 8 million Mt (3%) come from cultivated land. Examination of the dissolved solids delivered to individual stream reaches
indicates that the predominant source of dissolved solids is geologic materials in 89 percent of the nation’s catchments, road de-icers in 5 percent of the catchments, pasture land in 3 percent of the catchments, urban land in 2 percent of the catchments, and cultivated land in 1 percent of the catchments.

**ANATIONALASSESSMENTOFBRACKISH GROUNDWATER**


Large-scale development of groundwater with accompanying declines in groundwater levels has led to concerns about the future availability of fresh water to meet drinking-water, agricultural, industrial, and environmental needs. Industry and public drinking-water suppliers are increasingly turning to brackish groundwater to supplement or replace the use of fresh water. Data from the USGS Water Use Program show that brackish or saline groundwater use in the United States has increased from about 1 billion gallons per day in 1995 to 3 billion gallons per day in 2005. Although early investigations estimated that two-thirds of the conterminous United States is underlain by mineralized aquifers, relatively little is known about brackish groundwater. The objective of the USGS National Brackish Groundwater Assessment is to develop a better understanding of the distribution and character of brackish groundwater to support development of the resource and to provide a scientific basis for associated regulatory and policy issues.

**KNOCK OFF BLIND WELLS – AN INNOVATIVE METHOD TO COMPLETE SINGLE ENDED HORIZONTAL ENVIRONMENTAL WELLS**

David Bardsley, Directed Technologies Drilling, Inc., Scottsdale, AZ, david@horizontaldrill.com; Dan Ombalski

**Background/Objectives.** Horizontal well installation technology has been utilized since the late 1980s for a wide variety of monitoring and remediation activities. The installation methodology consists of two types of well configurations. (1) Continuous or double ended wells – wells completed using
methods similar to utility installations having an entry and exit location, with the well materials pulled into the borehole in tension. (2) Single ended or blind wells – wells completed with only an entry location, with the well materials pushed into the borehole in compression. Blind wells have distinct advantages in applications where surface constraints limit the availability of an exit location. However, maintaining an open borehole in certain types of geology (gravels, cobbles, poorly consolidated sands and swelling clays) while pushing well materials into the well bore is risky for the contractor, and that risk is normally transferred to the project as increased cost. Additionally, well materials utilized in the environmental well industry are not designed for the compressive stresses associated with the frictional forces generated from pushing the screen and casing through a curve and into the horizontal borehole. The increased costs and risk of failure have limited blind well installations within the environmental horizontal well industry. A new methodology had to be developed to reduce the risks and costs of blind well construction.

**Approach/Activities.** Early blind well completion methods included the installation of surface casing set and cemented through the curved section of the borehole. The surface casing significantly reduced the friction on the well materials as they were pushed through curved section of the borehole. However issues with borehole stability and friction during the well installation process through the horizontal section still limited the success of blind well completions. One way to reduce the risk of failure during installation of blind wells is to utilize steel or stainless steel well screen and riser casing. The steel well materials are able to withstand the compressive stresses during installation; however this is a significant cost increase over PVC (polyvinyl chloride) and HDPE (high-density polyethylene) well materials. A new method for completing wells in single ended/blind boreholes has been developed using large diameter (5-inch inside diameter) drill pipe. Utilizing this large diameter drill pipe and a specially designed drill bit assembly, 3-inch and 4-inch well screen and casing can be installed inside of the drill pipe. The well materials “lock into” the drill bit, which detaches from the drill pipe and anchors the screen and casing into the end of the borehole. The drill pipe is then pulled from the subsurface, leaving the screen and casing in contact with the formation. This innovated well installation technique is called the “Knock Off” blind well installation method.

**Results/Lessons Learned.** The Knock Off installation method allows for the successful completion of blind horizontal wells by inserting the well screen and casing inside of large diameter drill pipe. The Knock Off method reduces the risk of blind well completions and has an added benefit of reducing the overall well cost because PVC and HDPE well materials can now be used to complete long, single ended wells.
HORIZONTAL ENVIRONMENTAL DRILLING 101: AN INTRODUCTION TO THE MEANS AND METHODS FOR HORIZONTAL ENVIRONMENTAL WELL INSTALLATION

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Horizontal well installation technology has been utilized since the late 1980s for a wide variety of monitoring and remediation activities. Consultants and site owners can be intimidated with the equipment, nomenclature and perceived high cost of these innovative well installation methods. This presentation will provide an overview of the following important aspects of horizontal environmental wells:

• History of horizontal environmental wells
• Applications and advantages of horizontal wells
• Horizontal drilling and well installation nomenclature
• Drilling, installation and development fundamentals
• Drilling Fluids
• Well materials
• Drilling equipment
• Potential problems and challenges to successful installations
• Case studies

The data presented will be useful for both seasoned and relatively new environmental professionals.

GEOBACTER: A CASE SITE

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During re-exploration of the Aqua Fria Mining District in Yavapai County, Arizona, a series of adits and tunnels from several mines were opened dating from the 1880s through the 1970s. In these underground workings, clay-like coatings were noted on the walls, ceiling and floors with striking color variations from a mat gray to bright yellows and greens. For mapping of the workings, the walls were washed off and thin coatings of numerous minerals were found below and in the coatings. These mineral coatings did not extend into any of the rock surfaces, but were only found on open surfaces (fractures, voids, etc.). This prompted a closer inspection of the rock surfaces before washing. The mats under a microscope showed a webbing and cellular textures. Samples were sent off for verification of biological content. The samples were
identified as various Geobacters (metal and sulfide reducing bacterial forms). Since the Geobacter mats were only found on the workings exposed surfaces, their formation occurred after the mining activities stopped. Thickness and extent of the mats did not appear to be related to the age of the workings, but the exposed sulfide content in the wall rock. Elemental sulfur crystals were found, where the sulfide mineral content was mostly pyrite. When moisture contents were more than 50%, numerous iron oxide stringers were observed. Copper sulfates were found in areas with pH values over 4, moisture contents near liquid states, and the presence of chalcopyrite. Copper arsenates were found in association with bornite and arsenopyrite. In bornite rich veins without the arsenopyrite, gold was found in rounded masses on the surface exposures.

Surface mapping and re-examination of azurite and malachite exposures found that most of these exposures were copper arsenates with similar mode of occurrences as observed underground. This presents mineral formation occurring at surface temperatures and pressures and in periods less than 40 years. Also, this makes an initial case for supergene minerals by bacterial actions.

CASE STUDY: THE VARIANCE OF WATER QUALITY PARAMETERS TO DEPTH IN COUPON BIGHT

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Coupon Bight, an aquatic preserve in the eastern portion of Big Pine Key, is located in the middle Florida Keys region. Florida Atlantic University sought to test the aquatic habitat for various water quality parameters of total dissolved solids, salinity, conductivity, pH, and temperature. When obtaining the surface water quality data, a parameter of depth was gathered at each collection test site. Students captured ground control points at above locations using satellite enabled handheld instruments. Florida Atlantic University students then measured the water quality parameters and depth with probes and handheld depth finders. In doing so, students were able to run geographic information system (GIS-) based interpolation techniques on the parameters to see if there were correlations between the surface water quality and depth. Students then preformed statistical analysis to correlate the data parameters with each other and with the variance of depth. The relation of the parameters to themselves yielded results almost iden-
tical in nature. The conductivity, salinity, and total dissolved solids parameters were not only close in measurements, but equal in spatial distribution. The relationship of each parameter to depth was tested with several spatial and interpolation techniques through the use of ESRI’s ArcDesktop®. All were shown to be closely intertwined. The visual representation of the water quality parameters’ dependence to themselves and depth was depicted through vertically exaggerated surfaces with ESRI’s ArcScene®.

CRITICAL AND STRATEGIC MINERALS - STATUS REPORT

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A key issue for the US is the necessity for importing numerous geologic commodities. Critical and strategic minerals were categorized as such by the Department of Defense after WWI because their supply could be easily restricted or stopped by unfriendly nations. The original list included quartz crystals, sheet mica, and chromite. The 21st century economy, however, has caused the expansion of that list to nearly 50 items. Many of the commodities can be found within the US. Unfortunately the climate for mining is unfavorable and the time necessary to permit a new mine discourages activity. Nonetheless, some projects are advancing, more so in Canada and Mexico than in the US proper. Germanium and gallium, used in the electronics industry, are being extracted from zinc ores in Tennessee. Further potential exists for germanium in lignite coals of North Dakota and for gallium in Nevada and Quebec. Several sources of indium are under development in Canada. China, from whom the US sources nearly all of this metal necessary for liquid crystal displays (LCDs) and flat screen technology, has announced they will reduce exports to zero. Among the uses for the extremely rare element tellurium is cutting edge solar cells. Again, China produces the entire world’s primary supply. One project is advancing in Mexico and others are at least searching in the US.

Long used to produce high-strength steel alloys, vanadium has gained notoriety for its use in batteries. Much vanadium is available in Colorado Plateau uranium deposits, but those are not being developed because of the low price of uranium. One primary vanadium deposit shows great promise in Nevada. Manganese is a common metal and new deposits for steel alloys are being developed. In the pure form of electrolytic manganese dioxide (EMD), necessary for Li-ion batteries, it is rare and China produces nearly the entire world’s supply. A promising source of EMD is under development in Arizona. Graphite is another element used in batteries, and the demand is steadily expanding. Worldwide, China produces 2/3
of the natural graphite. Three projects are developing in the US and eight in Canada. Uses of the platinum group metals (PGM) are manifold. In particular, platinum and palladium are needed for pollution control devices and fuel cell technology. The US produces some PGM in Montana and two projects are being pursued in Minnesota. Canada produces some PGM and additional projects are proceeding. The lanthanide elements have received a great deal of publicity recently. While China produces nearly all the rare earth elements (REE), projects are opening in the US, Canada and Australia. Lithium demand continues to soar. Most production comes from brines in South America, but some lithium is produced from brines in Nevada and hard rock (pegmatite spodumene) in North Carolina and a process is under development to extract lithium from clays in Nevada.

Finally, modern industry needs tungsten to operate efficiently. As usual, China dominates world production. While both the US and Canada possess significant tungsten resources, only Canada is pursuing new projects for this metal.

**AN INQUIRY OF UPPER LAKE MARY’S WATER QUALITY AND THE ORIGIN OF THE LAKE MARY BASIN**

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Quaternary faulting in Northern Arizona caused major movement of the underlying basement rocks. This fracturing of the region’s geological skeleton created normal faults and volcanic events in the Lake Mary area near Flagstaff, Arizona, providing a lowland basin that was successfully dammed by the city of Flagstaff in 1941. The reservoir that resulted has played an important part in the city’s history. Seepage loss and mitigating turbidity levels have been ongoing issues with the reservoir, yet it continues to be a viable water source that contributes an average of 30% of the city’s total water supply. Water samples show that most of the turbidity is caused by silty sediments which are carried into the lake by contributing streams. The sediments have a negative ionic charge, which causes the solids to remain suspended in solution rather than clumping together and settling out. Although it is costly to treat highly turbid water, the suspended solids ultimately aid in the coagulation and flocculation of the water during the treatment process and help achieve good water quality. My research on Upper Lake Mary may help others understand surface water processes, water quality standards of surface water, and will provide details on how the highly turbid water can affect the filtration process. I will include a geologic cross-section, pictures, graphs, and tables that will illustrate the formation and water quality of Upper Lake Mary.
CHANGES IN THE EFFLUENT-DEPENDENT SANTA CRUZ IN PIMA COUNTY: THE 2013 LIVING RIVER ANNUAL REPORT

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The lower Santa Cruz River in northwest Tucson and Marana flows year-round and provides the principal wetland habitat in Pima County. The permanent water in this stretch of the river results from the discharge of treated wastewater from two regional wastewater reclamation facilities. Pima County recently completed its largest public works project ever by investing over $600 million to improve effluent quality, a change that is expected to significantly improve the aquatic and riparian environment. To document these changes, Pima County and the Sonoran Institute initiated the Living River Project, which will track and assess a broad range of environmental indicators and communicate this information back to the public. The project began in fall of 2012 with funding from the EPA which will continue through summer 2016. The primary communication tool for sharing information about conditions along the lower Santa Cruz River will be the annual Living River report, a highly accessible and visually pleasing summary of our findings for the general public and decision makers. The first year of that publication documents the baseline conditions from the 2013 water year. This presentation will share our data and conclusions regarding the historical and baseline status of water quality, aquatic life, vegetation, sediment transport and societal conditions along the river. We will also describe some initial observations of dramatic changes in stream channel infiltration rates, wildlife presence and social perception that we have already observed following the treatment plant upgrades.

IMPACTS OF CLIMATE UNCERTAINTIES ON COLORADO RIVER WATER SUPPLY

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In 2007, the specter of ongoing drought in the Colorado River
Basin prompted the Colorado River Basin states and United States to agree to voluntary reductions to Lower Basin water entitlements, in particular to Arizona’s Central Arizona Project. When these guidelines were developed, the long-term forecasts of impacts of the guidelines only employed inflow conditions based on observed hydrology from 1906 – 2005. The guidelines did not encompass the uncertainty of future precipitation from climate change. This work simulates the impacts of four hydrologic scenarios on the Lake Mead levels that trigger shortages established in the 2007 guidelines: resampled natural flow record from 1906 to 2010; climate change precipitation yielded by downscaled general circulation models (GCM); combination of natural flow and climate change flow; and paleo–streamflow recreated using tree ring records from 762 to 2005. Comparison of Lees Ferry flows for the four inflow conditions indicates that although average flows are similar (ranging from 14 and 15 million acre-feet per year), climate change realizes the greatest range in possible flows and paleoclimatological records the lowest flow. The Colorado River Simulation System (CRSS) model developed by the United States Bureau of Reclamation (USBR) projects the basin-wide impacts of the guidelines. CRSS routes Colorado River water through the basin within an object-oriented mass balance framework that incorporates reservoirs, diversions, and upper and lower basin demands into the Law of the River. The median CRSS simulations of natural flow, climate change, and combined scenarios show similar probabilities (approximately 53%) that Lake Mead falls below the initial shortage tier of 1075 during the Guideline period (through 2026). Larger probabilities result using climate change inflows, which drive reservoir elevations lower in Lake Mead. Climate change inflows demonstrate a 43% risk that Lake Mead will be below 1050 in 2026, a 34% chance Lake Mead will fall below 1025, and a 26% probability that Lake Mead will drop below 1000. Climate change drives the lowest 10th percentile of Lake Mead elevations to dead pool. Lower Basin reductions beyond those dictated by the guidelines serve to protect dead-pool Lake Mead elevations. Additional comparisons of the paleo–simulation to the natural flow and climate change hydrology are explored as they affect water shortages to the Lower Basin and specifically Arizona.

GATEWAYCOMMUNITYCOLLEGEWATER RESOURCES TECHNOLOGY PROGRAM: ADDRESSING THE SHORTAGE NEEDS FOR STEM TECHNICIANS

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GateWay Community College Water Resources Technologies Program (WRT) offers Certificate of Completions and Asso-
Associate Degrees on Hydrologic Studies, Water Treatment and Wastewater Treatment. The program has been in existence since 1998 and has gone through several updates to meet the demand for professionals in those areas. The program includes theoretical and practical hands-on training in the monitoring of water quality and quantity as well as in water and industrial wastewater treatment. The WRT program offers online, face-to-face, and hybrid courses to address different student’s needs for training. The program is supported by 15 adjunct faculty professionals. Adjunct faculty is usually hired from a wide variety of professional people already working in the industry that have shown interest in teaching. Adjunct faculty also provides free tutoring to the WRT students through the college Learning Center when they are not teaching courses.

The program has an active Advisory Committee that provides guidance and recommends program changes to meet training needs. This Advisory Committee is made of professionals from different federal, state, county agencies, and municipalities, private industry and consulting companies in the area. The Advisory Committee meets every year to provide feedback on curriculum changes and commit to potential internship opportunities for the WRT students. The WRT program considers the Advisory Committee an essential component for the program success: the committee supports the program in recommending and acquiring the latest field equipment needed for the hands-on training. One of the main WRT program objective is to utilize the latest field equipment that will be used by the students when they incorporate into the job market place.

The WRT program has been training hydrological technicians since 2000 that meet the requirements of the United States Geological Survey (USGS). The GateWay-USGS agreement allows for an USGS-paid summer internship to experience the career. Upon a successful completion of the internship and the associate degree program, the student is then considered for full-time non-competitive employment by the USGS. In addition, the WRT program has worked with several state agencies to provide paid/volunteer opportunities for WRT students. These internship/volunteer jobs provide an opportunity to the WRT students to experience the career and to actively promote the WRT program throughout the valley. The program is also working with municipalities in Arizona to address the water and wastewater operator shortage in these areas. These agreements provide internships (or voluntary work) opportunities to the WRT students that are paid directly by the municipalities or by the program.

The program has developed a partnership with the Arizona Project WET (Water Education for Teachers) to promote STEM (science, technology, engineering, and mathematics) activities throughout Arizona. Project WET’s Water Investigations Program (WIP) supports teachers in implementing a four-unit
curriculum focused on water resources, conservation, water in the environment, and communicating science learning. WRT students will participate as Mentor Scientists and receive professional development covering all aspects of water in Arizona. The WRT students will get additional STEM skills that college and high school students alike need to master to be effective in today’s workforce and world.

PALEOMAGNETIC, ANISOTROPY OF MAGNETIC SUSCEPTIBILITY, GEOCHRONOLOGY AND PETROGRAPHY OF THE BUENA VISTA DIKE, NORTH-CENTRAL NEW MEXICO

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The Buena Vista dike, located in north-central New Mexico, crops out on the eastern side of the Sangre de Cristo Mountains, near the transition zone between the Rocky Mountains and the Great Plains. This dike intrudes the Cretaceous Benton Group, which consists of the Niobrara Formation overlying the Benton Formation, Carlisle Shale, Greenhorn Limestone, Garneros Shale, and Dakota Sandstone comprising the Las Vegas Sub-basin. Source rocks that are immature can be positioned within the oil porthole sufficiently from the thermal effects of igneous intrusions. Fractures are developed in the course of thermal cooling after emplacement, or latterly during brittle tectonic deformation. This can provide some secondary permeability and porosity, which provides pathways for migration of fluid through barriers that are impermeable.

Located in Cuu Long Basin, which is off the shore of Vietnam, there are five major oil fields produced from granite (Nguyen and Hung 2003). Their production has been between 100 and 1400 million barrels from each individual field reserve. The source rocks in this area are from upper Oligocene. The recorded oil columns range from 1000 – 1500 meters (3281 – 4921 feet) (Shepherd 2009). This study will employ paleomagnetic, anisotropy of magnetic susceptibility, gravity / magnetic surveys, and geochronology to determine, the time of emplacement, the primary flow direction to assess source area. Petrography will be utilized to characterize the composition and infer melt regions and igneous differentiation processes. This research will give insight if the Buena Vista dike can influence hydrocarbon migration pathways.
GETTING PAST GO

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Regardless of your endeavor—mining, oil and gas, water, housing, roads, lumbering, raising llamas or raising cane, you most likely cannot get past go until all real and perceived stakeholders are happy. You may have acquired all the requisite permits, licenses and bonds, but the local municipal or county regulator bolstered by the Not in My Backyard or NIMBY minions can cause you interminable and costly delays. It goes without saying that conflict is inevitable. One of the cards you can play is the ADR or Alternative Dispute Resolution card; preferably viewed as collaborative problem solving. Employing one or more of ADR tools early-on in your proposed project will save considerable time and money as you approach “GO”. For those familiar with “partnering”, collaborative processes may be viewed as similar. Prior to engaging in any process, understanding the causes that precipitate conflict helps in preparing solutions. Underlying most all conflict are cultural and generational differences. This is true whether in regard to personal relationships, workplace, group, community, or national relationships. The conflicts most frequently encountered in the mineral/energy industry relate to those associated with communities. Three of the many processes that help mitigate these conflicts include: collaborative problem solving, shared vision planning, and future search conferencing.

TESTING FRACTURE CONNECTIVITY THROUGH VISUALIZATION AND MONITORING IN A GRANITIC ROCK SETTING NEAR ROXBORO, NORTH CAROLINA

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As part of the investigation of contaminant distribution and migration at a granitic fractured bedrock Superfund site near Roxboro, North Carolina, more than 1,500 subsurface fracture orientations determined from optical televiewer images of 17 open borehole wells were visualized in three dimensions to evaluate potential interconnectivity. Vertical flow near fractures was measured using heat-pulse flowmeter logging methods and hydraulic properties were modeled using the FLASH modeling program (Day-Lewis and others, 2011).
From the FLASH modeling results, colors and radial length of fractures shown in the visualization software were highlighted for the more transmissive fracture zones. Further monitoring of continuous water levels recorded at one-minute intervals during the drilling of five additional bedrock wells in the area indicated connection between fractures within 100-300 feet distance along orientations of 30 and 120 degree strike azimuths. Three-dimensional visualization of fracture orientations between the 4 wells that showed a response during drilling activities of two new wells indicated a potential connection of a subset of fracture zones which had measured strike azimuth orientations of 7-19 degrees and 135-180 degrees amongst two to three wells. The former orientation corresponds to mapped granite joint strike azimuths of 3 and 12 degrees in the area. The well distribution pattern of one set of water-level response data was orthogonal. Water-level change measured in observation wells during the well drilling activities ranged from 0.5 to more than 23 feet. Delay in response ranged from 1.75 to 5.5 hours. Yields for the new wells drilled was 0.75 to 4 gallons per minute and modeled transmissivities in two of the observation wells that responded was about 2 feet squared per day. Data collected as part of this project and report links can be found online at http://nc.water.usgs.gov/projects/roxboro/.

FINDINGS FROM FIELD INVESTIGATIONS OF NINE REGOLITH-FRACTURED CRYSTALLINE BEDROCK RESEARCH STATIONS IN THE PIEDMONT AND BLUE RIDGE PHYSIOGRAPHIC PROVINCES OF NORTH CAROLINA

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Nine regolith-fractured bedrock aquifer groundwater research stations were constructed along topographic transects in the Piedmont and Blue Ridge Physiographic Provinces of North Carolina from 2000 through 2008. Each research station contains wells completed in each of the three parts of the groundwater system: the shallow regolith, intermediate transition zone, and deeper fractured bedrock. Each research station was constructed with a well cluster located in a local groundwater recharge area (topographic high or slope location (or both)) and a groundwater discharge location (topographic low, near a stream/creek or lake).

A common study approach to all of the eleven research station investigations included: (1) geologic core collection and description of the regolith, transition zone, bedrock lithology and fractures; (2) groundwater-level monitoring; and (3)
groundwater-quality sampling. Additionally, detailed borehole geophysical logs and images were collected at nine research stations. At six research stations, groundwater age-dating samples were collected from wells completed in both shallow and deep parts of the groundwater system in both recharge and discharge areas.

Findings from investigations at the eleven research stations include information about thickness of the weathered regolith, as well as characteristics of the transition zone and bedrock fractures in variable geologic settings. Groundwater system characteristics and processes at both recharge and discharge areas along flow paths were studied, including the measurement of vertical gradients, groundwater-quality fluctuations during recharge events, the timing of seasonal recharge in the regolith from temperature monitoring, and estimation of recharge dates for all three parts of the groundwater system.

AN ESTIMATED WATER BUDGET FOR THE LOWER COLORADO RIVER MULTI-SPECIES CONSERVATION PROGRAM AT PALO VERDE ECOLOGICAL RESERVE

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For the Lower Colorado River Multi-Species Conservation Program, the US Bureau of Reclamation will revegetate over 17,300 acres of historic floodplain with riparian vegetation to mitigate the effects of river management on native species habitat. This project was intended to develop a water budget for a portion of a riparian habitat creation area, Palo Verde Ecological Reserve, approximately 5 miles north of Blythe, California, along the Lower Colorado River. A soil moisture and irrigation monitoring pilot study was completed in July 2013 at a 78-acre phase of the site using an automated, in situ monitoring network. Data collected from two intensively monitored irrigation checks (approximately 7 acres each) representative of coarse (sandy) and relatively fine (loam) soils at the ecological reserve were used to construct a preliminary water budget. Surface soil moisture content rapidly changed due to irrigation, drainage and evapotranspiration, whereas water content at depth, especially in finer-textured soils, was relatively constant. Irrigation was applied in excess of actual evapotranspiration. Rapid changes in groundwater elevation during and after irrigation indicated high percolation in sandy areas. The background groundwater gradient indicated that
percolated water returned to the Colorado River mainstem. By accounting for water loss due to percolation below the root zone and evapotranspiration, more detailed water budgets may provide support in planning habitat creation projects, modeling long-term irrigation needs, and determining actual consumptive use (evapotranspiration) of irrigated habitat restoration areas.

**RARE EARTH ELEMENTS (REE) IN BAUXITE, KAOLINITE, AND TERRA ROSSA DEPOSITS**

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Rare earth elements (REE) are critical for modern consumer electronics, green energy and advanced weapons systems. Although REE-bearing minerals are widespread, economic concentrations of REE are limited. REE in primary, hard rock deposits are often difficult and expensive to mine and process, in part because of their unique mineralogy. In contrast, extreme lateritic weathering may liberate REE from primary minerals and enrich REE as fine-grained secondary phosphates and oxides, and adsorbed on bauxite, kaolinite, and iron and manganese oxides. Because laterites are usually soft, near surface deposits, and the REE are adsorbed on clays or as fine-grained minerals, the REE in laterite deposits are commonly less expensive to mine and process than in primary deposits. Most of the mined residual deposits are associated with laterized granites (southeast China) or carbonatites (Australia).

REE are depleted near the surface in all lateritic REE deposits and increase downwards. Depths below the weathering surface to the top of the supergene enrichment of REE range from 0.5 m to 3 m.

REE geochemical and mineralogical data are compiled for worldwide karst-type bauxite, kaolinite, and terra rossa deposits to document their REE composition. Generally, karst-type bauxite deposits which are developed in carbonate stratigraphic sequences have mean total REE (TREE) in the range of 280 to 620 ppm. Mean light REE (LREE) values are mainly in the range of 260 to 540 ppm and mean heavy REE (HREE) values are in the range of 20 to 110 ppm. Some bauxite deposits in Turkey and Italy have LREE of 870 and 910 ppm, respectively. Metallurgical processing of bauxite ores may further concentrate REE in the waste material known as red mud. REE values from red mud from bauxite operations in Jamaica range from 1,900 to 4,500 ppm, and up to 12,000 ppm lanthanum is reported from red muds in Suriname. High levels of scandium (up to 0.17 percent), niobium (up to 0.91 percent), and zircon (up to 1.86 percent) are also reported for red mud. In a ka-
olinite derived from basalt in China, the LREE concentrations range up to 9,220 ppm, HREE up to 1,490 ppm, and TREE to 9,960 ppm. REE values of most kaolin deposits are unknown. A terra rossa deposit had TREE values up to 1,900 ppm.

HYDROGEOLOGICAL INVESTIGATION OF THE TIMKEN FAIRCREST STEEL PLANT CONSTRUCTION DEWATERING PROJECT STARK COUNTY, CANTON AND PERRY TOWNSHIPS, OHIO

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Timken Corporation (Timken) began upgrading and remodeling of the Timken Faircrest Steel Plant (TFSP) located southwest of Canton, during the summer of 2012. Part of the remodeling involved the installation of a vertical steel pipe caster that would be installed 89 feet below the land surface. Timken had done a geotechnical investigation of the subsurface for the vertical caster foundation engineering design. However, Timken did not include a hydrogeological impact assessment to determine how the construction dewatering would affect the ground water levels in local domestic water supply wells in the surrounding area.

During the excavation of the foundation, the contractor encountered ground water. Timken installed six (6) dewatering wells around the excavation. Shortly after the dewatering operation started in August 2012, local residents complained to the Stark County Health Department (SCHD) that they were having problems with their wells. In response to the request by the SCHD for assistance, the Ohio Department of Natural Resources – Division of Soil and Water Resources (ODNR-DSWR), met with Timken to assess the site hydrogeological characteristics near the dewatering operations. The ODNR-DSWR designed and implemented a long-term monitoring program to determine the extent of the cone of depression created by Timken dewatering operations.

The ground water impact assessment was accomplished during August and September of 2012. It was concluded that the cone of depression had migrated beyond Timken’s property boundary. The main area affected was to the south and east of the TFSP. The September 2012 monitoring data was used to define the approximate geographic extent of the impacted area. Timken used the inferred impact area to sort through the complaint list compiled by the SCHD. In total, Timken responded to 77 complaints from local homeowners. Timken’s response was as follows:
Eighteen (18) complaints were outside the inferred impact area.

Nineteen (19) complaints included residents that wanted to get their name on the complaint list as a precautionary measure, in case problems developed later.

Six (6) complaints were related to the water pumping and storage system and not caused by the Timken construction dewatering operations.

Thirty-four (34) wells were replaced because there was a legitimate problem that could be traced back to the Timken construction dewatering operations. In this case, Timken contracted with a local well driller to install new wells and pumps to replace the older shallower wells. The old wells were sealed in accordance with SCHD requirements.

One (1) homeowner was connected to the public water system that was available on the street.

Long-term monitoring data confirmed that ground water levels in the area were impacted by the Timken dewatering operation, but as of September 2013 the ground water levels in the area had returned to normal. At this time, it has been concluded that Timken has taken the precautionary steps necessary to protect the public health and safety. There does not appear to be any long-term impacts to the ground water supplies available from either the glacial or bedrock aquifer systems in the area.

**GROUND WATER INVESTIGATION OF THE CARBONATE BEDROCK AQUIFER TO EVALUATE THE IMPACT OF PUMPING HIGH-YIELDING IRRIGATION WELLS ON LOCAL WATER SUPPLY WELLS IN OTTAWA COUNTY, HARRIS TOWNSHIP, OHIO**

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A ground water investigation of the carbonate bedrock aquifer was initiated in May 2011 by the Ohio Department of Natural Resources Division of Soil and Water Resources (ODN-DSWR) at the request of local home owners in Ottawa County, Harris Township, Ohio. The purpose of the investigation was to evaluate the impact of high-yielding irrigation wells on ground water levels in the nearby domestic water supply wells.

Previous work completed in this area confirms that the carbonate bedrock aquifer of northwestern Ohio contains a number of flow zones. The well completion diagram for the
Luckey homestead farm well shows the extent to which the flow zones occur in the subsurface. Drilling data shows that the carbonate bedrock aquifer is anisotropic and heterogeneous in its configuration. This leads to the identification of a number of concerns that need to be considered before long-term pumping rates can be accurately calculated and the data used to design water supply systems.

Pumping test data shows that the transmissivity of the aquifer is not uniform throughout the aquifer. It can vary both in the vertical and horizontal directions and may vary over short distances within the carbonate bedrock aquifer when there are significant variations in permeability as well as fracturing. This helps to explain major changes in yield over short distances in both the vertical and horizontal directions.

Field data obtained for this project shows that the pumping of the high-yielding water wells can have an impact on the local water supply wells. The degree of impact depends on the location of the water well relative to the pumping center and the pumping rate. It also depends on the flow zone from which the water well produces. A deeper high-yielding well can impact water supply wells completed in the upper flow zone in the carbonate bedrock aquifer.

To fully define the hydraulic conditions for each of the high-yielding wells, it is recommended that each high-yielding well owner undertake a hydrogeological assessment to evaluate the impacts from pumping these wells on the surrounding water supply wells.

Based on the results of the hydrogeological assessment, the owner of the high-yielding well should prepare a report that fully defines the aquifer characteristics along with a ground water pumping and monitoring plan to show how the operator will prevent dewatering of nearby domestic water supply wells. A mitigation plan should be developed in the event that local domestic water supply wells are affected by pumping of the high-yielding water well.

In accordance with 1521.16 Ohio Revised Code, each high-yielding water supply well owner must register their facility and report the ground water usage to the ODNR-DSWR as appropriate.
REPORT OF A HYDROGEOLOGIC STUDY IN THE SOUTH SALEM HILLS, POLK COUNTY, OREGON

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The Orchard Heights area in West Salem Oregon contains the southeastern most exposures of Miocene flood basalts known as the Columbia River Basalt Group (CRBG). The CRBG flowed across Washington and Oregon for an estimated 15,000 years; each flow separated in time by up to 2000 years. During the intervening periods soil formed and subsequent flows resulted in interflow breccias which carry groundwater. A pair of wells penetrating approximately fifteen feet of permeable rock were evaluated through pumping tests. Transmissivity and storage coefficients were obtained from the analyses of these data. A preliminary evaluation of geologic structure was based on outcrops and well logs using a pyroclastic marker bed known as the Vantage Interbed.

AN UPDATE ON ARIZONA LAND SUBSIDENCE USING INTERFEROMETRIC SYNTHETIC APERTURE RADAR (INSAR) DATA BY THE ARIZONA DEPARTMENT OF WATER RESOURCES

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The Arizona Department of Water Resources (ADWR) land subsidence monitoring program has been greatly enhanced by the use of Interferometric Synthetic Aperture Radar (InSAR). ADWR’s InSAR program started in 2002 with the awarding of a three year NASA Earth Science grant, allowing ADWR the opportunity to develop the program.

In 2005, ADWR began collecting and processing monthly SAR data from the European and Canadian Space Agency SAR satellites, producing time-series interferograms for the greater Phoenix and Tucson metropolitan areas. Since 2005 the program has developed important partnerships with numerous Federal, State, County, and Local Agencies, Water Districts and Water Companies who provide annual contributions to help support the data collection costs. These partnerships have provided ADWR the necessary resources to expand the data collection area for the InSAR program to include numerous groundwater basins in south-central and southern Arizona in Maricopa, Pinal, Pima, La Paz, and Cochise Counties.
Through these efforts ADWR has collected more than $1 million of InSAR data covering more than 50,000 square miles in Arizona. ADWR has identified more than 25 individual land subsidence features that cover more than 1,200 square miles and has determined the spatial extent, deformation rates, and time-series history of each land subsidence feature with the InSAR data. The process of collecting, processing, and interpreting InSAR data has resulted in ADWR producing a total of 200 land subsidence maps for all the land subsidence features covering different time periods.

Engineers, hydrologists, geologists, GIS professionals, and scientists involved in the fields of water resources, structural engineering, geological engineering, hydrological engineering, land planning, floodplain management, and surveying greatly benefit from the InSAR data to identify and evaluate areas of land subsidence, uplift, earth fissures, faults, and many other geologic features.

BUILDING AN ONLINE STEM BROADCASTING STATION


The K-12 education community sorely needs quality online STEM (science, technology, engineering, and mathematics) products to engage and educate school children. The Arizona Experience website (www.arizonaexperience.org) uses interactive and multimedia tools to create a dynamic online environment that teaches aspects of Arizona’s past, present, and future in a STEM context. Administered by the Arizona Geological Survey (AZGS), a significant part of the site is devoted to teaching STEM subjects. All site material, including lesson plans, games, videos ranging from personal stories to 5-minute documentary-style films, and interactive features, promotes comprehension of today’s technology platforms.

Online broadcasting of STEM-related products can be a powerful vehicle for engaging the K-12 community. Over the past two years, AZGS has experimented with monthly online broadcasting of the Arizona Mining Review; a 30-minute program, via Livestream, a low-cost video streaming service. The Mining Review targets Arizona’s mining community and provides news, interviews, and discussions about mining and mineral resources issues relevant to Arizona, the nation’s second largest non-fuel mining state.

Our goal is to couple our experience building videos for Ari-
zona’s K-12 community with this online broadcasting venue to develop a STEM online broadcasting station to build and disseminate products for K-12 science education. Our expertise in Earth science systems and leveraging strong ties to others in the geosciences, e.g., American Geosciences Institute, provides rich material for a showcase of the processes that shape the Arizona landscape as our first efforts. We’ll work closely with K-12 teachers and the Arizona Department of Education to provide quality products that meet common core standards and contribute to a fresh and relevant classroom experience.

THE ADWR ONLINE GROUNDWATER LEVEL DATA PORTAL: A NEW TOOL FOR GROUNDWATERLEVELDATEREPORTING

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The Arizona Department of Water Resources has developed an on-line data portal to facilitate the entry of groundwater level data into the ADWR Groundwater Site Inventory (GWSI) database. This application allows approved entities to submit water levels for various reporting requirements and share water level data with the public. At this time, the water level portal only accepts water level data for GWSI wells. The GWSI database consists of over 233,000 individual water level measurements from over 43,000 individual well locations throughout the state. Measurements in the database date from as early as 1891. Currently, ADWR field staff conduct annual, manual groundwater level measurements at about 2,500 well sites throughout the state. ADWR also maintains a statewide network of about 120 wells equipped with automated water level monitoring equipment:

https://gisweb.azwater.gov/waterresourcedata/GWSI.aspx

The next enhancement to the portal will incorporate wells that have a 55-registration (well registry) number. The WELLS-55 database contains information on most wells in the state; however, not all wells have been registered. Therefore, some unregistered wells may be in GWSI but have not been registered. Likewise many registered wells have not been field verified and are not included in GWSI. Currently, over 21,000 wells have been matched or have a database ID in both GWSI and WELLS-55. Future well matching activities will focus on determining which registered wells that have water level reporting requirements need to be included in the GWSI database, and also which GWSI wells need to be registered. Once the portal enhancements and well matching are complete the portal will be linked to programs that have groundwater level reporting requirements, such as Annual Groundwater Withdrawal...
Reports from Designated Water providers in AMAs, Underground Storage Facilities, Community Water Systems, Well Driller Reports, etc.

Eventually the portal should serve as an efficient tool to facilitate required and voluntary groundwater level reporting. Data submitted through the portal will supplement ADWR’s own water level data collection program. However, the source of all water level data will always be clearly indicated in the database so that potential users will be able to determine what level of confidence they may wish to assign to any particular measurements.

NUCLEAR MAGNETIC RESONANCE - A NEW TOOL FOR ENHANCED GROUNDWATER SUPPLY AND ENVIRONMENTAL INVESTIGATIONS

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Nuclear magnetic resonance (NMR) logging tools have been widely used in the oil industry since the 1960s and have improved in the last two decades. NMR provides estimates of bulk porosity and fluid content, quantification of bound versus mobile fluids, and semi-quantitative estimates of hydraulic conductivity. Although the size and cost of oil-field tools historically limited their use for environmental applications, smaller and more economical NMR logging tools are now available for detecting and characterizing the formation water content and hydraulic conductivity as part of groundwater supply and environmental investigations. It can be used in direct-push mode or can be lowered into existing PVC wells. Using the tool in existing wells is a safe alternative compared to drilling new boreholes. In either mode, NMR can provide useful hydrostratigraphic information if historical drilling logs are unavailable or limited in geologic detail, and can help refine the overall conceptual site model.

NMR investigations at two sites in Texas and one site in New Mexico demonstrate the viability of this technology as a site characterization tool for environmental investigations. NMR measurements were compared to data from lithologic logs and prior field hydraulic tests. Use of NMR detected vadose zone water, including previously unidentified perched groundwater zones, and provided hydrostratigraphic details that could not be gleaned from historical well drilling logs.
NMR also produced hydraulic conductivity estimates similar to those from conventional hydraulic tests, but the improved vertical resolution from NMR provided additional information regarding the vertical heterogeneity of the formation along the entire length of the well or borehole.

REMOTE SENSING AND PASSIVE GEOPHYSICAL TECHNIQUES IN CLARK COUNTY, NEVADA

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Due to the similarities between the hydrogeological conditions and many of the same issues related to water management, many of the techniques that have been successfully applied in Nevada may be applicable to Arizona.

In 2008-2011, the Clark County Building Department contracted with Optim to collect 10,700 Reflection Microtremor (ReMi) 600-foot seismic lines that cover most of the metropolitan area of Las Vegas and other outlying communities such as Moapa, Laughlin, Jean, Primm, and Coyote Spring. The County completed their goal of characterizing seismic susceptibility of the top 100 feet and the results are posted at http://gisgate.co.clark.nv.us/openweb/. The research question of the authors is: What additional geologic information can be inferred from the data, either through reprocessing, cross correlation of drill hole data or additional data collection?

The research question came about because of the strong and obvious spatial correlation between the well-cemented alluvial fans and finer grained basin fill deposits and the seismic susceptibility categories of National Earthquake Hazards Reductions Program (NEHRP) http://www.seis.utah.edu/urban/nehrp.shtml. That is, the “soil” descriptions did not quite match; however, the boundary of the seismic categories closely matched previously mapped geologic mapping units. The ReMi data also provided information about the nature of the alluvium at depth that seemed to correlate with previously defined geologic units described in Donovan, 1996 (http://aquaterranova.files.wordpress.com/2012/05/djd-col-completed-thesis.pdf).

Similar correlations were observed when InSar was first used in Las Vegas Valley in the late 1990’s, when the aquifer system was greatly stressed; however subsequent data collection reveals less information due to the reduction in stress.

Water management and civil planning are most successful
when based on the local hydrogeological conditions. Remotely sensed data provides an inexpensive means of analyzing large areas; however, the key is providing information about the subsurface conditions. Passive systems provide techniques to observe the subsurface without disturbance to the overlying ecological community or existing development. Cultural “noise” is often a hindrance in geophysical data collection; however ReMi uses this “noise” as a source for the energy (seismic) signal.

SEDIMENT TRANSPORT STUDY AT THE TUCSON REACH OF THE SANTA CRUZ RIVER

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Sediment transport in the Tucson reach of Santa Cruz River in Arizona has been studied through field monitoring of cross sections, samples of bed sediments, measurements of flow and sediment load (e.g., bed load, suspended load), and sediment transport modeling. The field survey has collected flow, sediment transport, and cross sectional data since March 2012. Flow data were compared with USGS gage records at Cortaro Road and Trio Road, and indicated possible irrigation return flows from the agricultural field in Marana. Bed load transport rate is low throughout the year. High turbidity and large bed load transport were found immediately after storm events.

Sediment transport at base flow was simulated for the reach from Roger Road to the Trico Road using the US Army Corps of Engineers’ Hydrologic Engineering Center’s River Analysis System (HEC-RAS) sediment transport module. To verify the HEC-RAS model’s results, another sediment transport model based on unsteady flow and multiple grain sized sediment transport, the US Bureau of Reclamation’s Sedimentation and River Hydraulics – One Dimension (SRH1D), is also used. Both HEC-RAS and SRH1D showed the reach from Sweetwater to Ina Road will experience moderate degradation, from Ina Road to Twin Peaks Road will have severe erosion, from Twin Peaks Road to Tangerine Road will be deposition, and from Tangerine Road to Trico Road will be relatively stable. Since there are differences between two modeling results, it perhaps necessary to explore the reasons of those different results. No bank erosion is calculated, which is likely to occur based on our field observation.
EFFECT OF AQUIFER HETEROGENEITIES ON THE WATER RESIDENCE TIME (WRT) AND THEIR SIGNIFICANCE

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Groundwater is a valuable resource in the southwestern United States. There are a variety of risks associated with maintaining this valuable resource. Our lack of understanding of mountain-block recharge processes and hydraulic connections between recharging water and spring flows at process-scale as well as the scale-dependent nature of the processes involved accentuates the risk to these groundwater resources. This risk increases under projected climate-change impacts such as an increase in mean surface air temperature and intense and short-duration storm events.

To augment our understanding of the recharge processes and their connections to spring flows, we have employed the water residence time (WRT) concept. Our approach for WRT considers the effects of both saturated and unsaturated zones holistically, in opposition to the traditional approach which considers only the saturated groundwater flow. This holistic version of WRT combines the variably saturated flow equation with the equation for the mean WRT.

Using the developed flow and water-age model, we are able to shed light on how aquifer heterogeneities affect water residence time using a conceptualized one-dimensional heterogeneous porous media. Such variability in WRT can be related to various water-mediated hydrogeochemical reactions in the subsurface. The results of our research will show our preliminary understanding of the nexus between the hydrology, geochemistry, and microbiology of the subsurface.

DIVERGENT RIDGE FEATURES ON THE JUAN DE FUCA AND GORDA RIDGES

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Geomorphological features of the Juan de Fuca and Gorda Ridges, and the Blanco and Mendocino Fracture Zones were
observed using multibeam data, to relate them to the seismic activity associated with the diverging plate boundaries of the Northeast Pacific Ocean. These ridges and fracture zones comprise the divergent plate boundary of the eastern edge of the Pacific Plate and the western edges of the Juan de Fuca and Gorda Plates. Both of these eastern plates are being subducted beneath the western edge of the North American Plate. Fault and ridge orientations are used to compare the direction of seafloor spreading, and indicate that both the Juan de Fuca Plate and Gorda Plate are spreading in a southeastern direction. Younger ridges from the Gorda Ridge system mapped in the study run parallel to the boundary; however older ridges do not show the same orientation, indicating a change in spreading direction.

A COMPARISON OF HYDROLOGY AND DESIGNS USING HMR-49 AND 2013 ADWR NEXRAD GUIDANCE

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Design of mine facilities (e.g. leach heaps and tailings facilities), for both operation and closure, often require that the facility is designed to withstand the Probable Maximum Flood (PMF). The size and distribution of the specified PMF can have considerable impact on the type, engineering, and cost of the hydraulic facilities required to contain the storm flows. This paper provides examples of the differences in total rainfall, rainfall distribution and consequent facility sizing based on using Hydrometeorological Report No. 49 (HMR-49) and the 2013 Arizona Department of Water Resources Probable Maximum Precipitation guidance, which incorporates the Next-Generation Radar (NEXRAD) data to provide more accurate design storms.

SOLVING MINE WATER PROBLEMS WITH PEAT-BASED SORPTION MEDIA

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Mine water often contains elevated levels of trace metals that must be removed prior to discharge. Conventional technolo-
gies exist but generally are labor intensive and expensive. Peat-based sorption material can be a less expensive alternative and is easily deployed in either “semi-active” or passive treatment designs. APTsorb™, a hardened granular material produced by American Peat Technologies from natural reed sedge peat, is a uniform material with a hydraulic conductivity of around 1 cm/sec, and metal removal capacity ranging from 1 -15% on a dry weight basis. It has been used successfully to remove suspended and dissolved copper from the Soudan iron mine in Minnesota and suspended and dissolved Pb, Zn and Cd from a base metal mine in North America.

Since 2009, water discharging from the Soudan mine has been treated with a commercial ion exchange resin system that includes flow equalization tanks, bag and cartridge filters, a break tank, a carbon tank and several ion exchange tanks. Although effective, the system’s high cost, inefficient removal of suspended material and substantial maintenance have been ongoing and troublesome issues.

In November 2012, a pilot test began using a single tank of APTsorb media. Mine water was pumped through the media without any pretreatment. The media has successfully treated over 16 million gallons (> 30,000 bed volumes) with an average removal of 75% suspended and 60% dissolved copper. Backwash is required at about 4000 bed volumes, but with a combination of air sparging and high flow backwash, the suspended material is effectively removed from the bed. The single tank of APTsorb™ media produced equivalent copper removal to the first 5 components of the existing treatment system; reducing estimated O&M costs by about a factor of 6, from around $130,000 to $21,000.

A pilot test was initiated at a base metal mine in North America in October 2013. The pilot was designed to model both a “semi-active” (pressurized tank) and passive (biocell) treatment system approach. The original plan was to treat the discharge from the clarification basin, but if the mine discharge could be treated directly, the basin could be eliminated. To accommodate this approach, a pressurized sand filter was installed before both systems.

Input mine water had a pH greater than 7 and contained about 1500 micrograms per liter (µg/L) total lead, with about 90% in the suspended form. Total metals concentration varied with the amount of total suspended solids in the discharge. The sand filter essentially removed all suspended metals, but removal did decrease as the pressure drop over the filter increased. Lead removal in both pilot systems was generally greater than 99%. Excessive solids in the mine discharge contaminated the pressurized tank and affected treatment at 6400 bed volumes. This reduced dissolved metal removal efficiency in the media from 99% to about 85% and caused the discharge to exceed the permit limit of 11 µg/L lead. The bio-
cell was not affected and discharge limits are still being met after 18000 bed volumes.

**EPHEMERAL STREAM-FLOW MONITORING UTILIZING SRP FLOWTOGRAPHY**

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The Salt River Project (SRP) developed unique stream flow monitoring equipment and near real-time photo monitoring that allows electronically collected stage data to be calibrated from time-lapse photographs. The technique is referred to as "Flowtography".

The Big Chino Sub-basin Project, Arizona, utilizes SRP Flowtography to monitor surface-water flows along nine ephemeral stream reaches within the Big Chino Sub-basin of the Verde River Groundwater Basin. The monitoring goal is to collect additional hydrologic data for development of a numerical groundwater flow model and establish a long-term data collection program that will improve the understanding of the hydrologic relationship between groundwater and surface water in the upper Verde River area.

SRP will maintain, collect, process data and photographs from the measuring devices and field cameras, and will conduct direct stream-flow measurements. Eight sites are using the Slope-Area Method applied to a time series of recorded stream depths (stage data) for estimating discharge, while one other site is configured with a pre-manufactured flume. Each of the measurement locations is equipped with industry standard water measurement equipment and instrumentation for recording water depth (stage). Camera equipment at each location was installed and will make it possible for the streams to be photographed and monitored at regular intervals during the study period. Records of the stream-flow depth (stage) are made using a stream-specific system comprised of two strategically positioned pressure transducers with self-contained data logging capabilities. These devices are installed appropriately in the channel width and secured to the channel floor at the beginning (upstream) and end (downstream) of each channel reach being monitored. The two devices are installed within the general area of the stream-flow being monitored. One of the proposed gage locations utilizes a pre-manufactured measurement flume. The flume includes a secure stilling well with a pressure transducer.
EDIBLE OIL INJECTION EVENT MONITORED USING CONDUCTIVITY TRANSUDCERS AT A FRACTURED BEDROCK SITE

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A persistent chlorinated solvent plume was the target of voluntary bioremediation efforts at a fractured bedrock site in southeast Pennsylvania. The history of the plume and the hydrogeologic circumstances associated with designing an in situ bioremediation remedy in this fractured bedrock aquifer are examined. The site is located in the Triassic Age Newark Basin and is underlain by the Brunswick Shale of the Newark Supergroup and surrounded by intrusive diabase dikes and sills. These rocks have low primary porosity and transmit groundwater via fractures and along weathered bedding planes. A remediation event involving injecting a patented soybean oil substrate was undertaken in late August / early September 2012. Approximately 1,870 gallons of diluted substrate solution was injected into the bedrock aquifer through two injection wells located approximately 150 feet apart. To evaluate the aquifer response to the injection, transducers measuring water level, temperature, and conductivity were deployed in down-gradient monitoring wells before, during, and after the injection event. To evaluate the reaction of the aquifer to the amendment, bimonthly samples were collected in down-gradient monitoring wells. An evaluation of the efforts associated with the practical aspects of undertaking a substrate injection program in a fractured bedrock aquifer is discussed.

PURSUING DEVELOPMENT OF A PUBLIC COMMUNITY WATER SUPPLY UNDER LIMITED AQUIFER ACCESS CONDITIONS

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As a potentially favorable option for developing a minimum 2 to 3 million gallon per day (MGD) supplemental Public Community Water Supply, a municipality in the lower Hudson Valley of New York state decided to assess the potential for development of a groundwater source from the aquifer deposits underlying the bed of the nearby Hudson River. Avail-
able hydrogeologic information indicated that these aquifer materials are capable of supporting individual groundwater yields to an appropriately constructed well in excess of one thousand gallons per minute (gpm), and receive recharge on the order of over 150 MGD.

Based on the results of a limited exploration program including the completion of borings and observation wells, it was concluded that the targeted aquifer extended from the shoreline towards the river channel with a sloping and wedge-shaped configuration. As such, it was concluded that the potentially most favorable aquifer materials existed below a thick sequence of clay and silt beneath the channel of the Hudson River. Preliminary short-term test results for temporary river-bed wells indicated that the coarser of these aquifer materials could potentially yield to a well appropriately designed and constructed for the specific formation over 1,000 gpm. The analytical results from groundwater samples collected from the piezometers were generally found to be in compliance with New York drinking water standards.

In order to potentially optimize the yield of the thicker sequence of sand and gravel deposits of the aquifer underlying the Hudson River from the limited portion of shoreline accessible to the municipality, the project team identified the installation of an angle well as the most appropriate option.

Prior to completing an actual well, a series of angle borings/test well were completed using the “sonic” drilling method. This method afforded the collection of relatively continuous and intact formation samples, which preserved the penetrated aquifer stratigraphy. The borings were completed at respective angles of about 25° to 30° from the horizontal and oriented perpendicular and obliquely to the shoreline in order to maximize penetration of the targeted aquifer materials in the direction of the river. The angle borings were converted to temporary test wells and pumped in order to determine approximate aquifer characteristics. The results indicate favorable subsurface conditions that are consistent with previous project team findings. The results are currently being used to design a full scale angle well installation geared to develop a 1 to 2 MGD groundwater supply from the desired aquifer materials under the Hudson River from a shoreline site with significant access limitations.
PROBABILITY AND RISK CONSIDERATIONS IN SIZING MINE WATER PONDS

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Careful management of the water balance is required for mining operations to be sustainable and protective of the environment. Many mine operations in both arid and humid climates use open-water storage ponds to temporarily store water excesses and prevent uncontrolled discharges of mine affected water. Appropriate sizing of water storage ponds should consider both the probabilities and consequences associated with exceeding the pond’s storage capacity (i.e., overtopping failure). The probability of overtopping failures are functions of climate (both short-term and seasonal weather patterns) and operational (power reliability, operator error) parameters. Consequences for failure are driven by water quality, downstream receptors, impacts on mine operations, and regulatory/social requirements. When failure probabilities and consequences are quantified, pond sizing criteria can be established based on understood risk tolerances. In this paper, these concepts are demonstrated using an example based on copper and gold heap leaching operations. The approaches are presented in a generalized form that is applicable to a range of facilities in a range of environmental settings.

IN SITU BIOLOGICAL TREATMENT OF CHROMIUM AT THE TOPOCK COMPRESSOR STATION: COUPLING GEOCHEMISTRY AND SOLUTE TRANSPORT MODELING


The use of in situ methods for the remediation of contaminants in groundwater is on the rise. Such methods can provide a means of achieving site cleanup goals with substantial reductions in remediation timeframe, infrastructure, and cost to the client compared to traditional ex situ (“pump and treat”) approaches. In situ approaches for metals involve altering the local aquifer biogeochemical environment to immobilize the
contaminant, typically through generation of sorption sites, creation of mineral precipitates, and/or manipulation of the redox environment. For each site-specific strategy, these biogeochemical changes must be evaluated for 1) the long-term potential for contaminant sequestration and 2) secondary effects that the biogeochemical alteration may cause, such as reductions in permeability and the release of byproducts. Reactive transport modeling (the coupling of geochemical models and flow/transport models) is an ideal tool for developing better site-specific understanding and predictive capability to design and optimize in situ remedial strategies. However, there are two complicating factors that limit the widespread use of reactive transport modeling for in situ groundwater remediation applications: 1) the need to calibrate the geochemical and flow/transport models using site-specific data, and 2) the increased computational time and complexity for a fully-coupled geochemical reactive transport model. Although the initial desire is often to develop increasingly sophisticated reactive transport models, this added detail must be weighed alongside increased complexity and the availability and need for more sophisticated validation data.

Here, we will discuss the challenges and strategies developed for constructing site-relevant geochemical and solute transport models to describe an in situ groundwater treatment program for chromium at the Topock Compressor Station, located along the Colorado River near Needles, California. The treatment strategy being developed includes injection of dissolved organic carbon to establish reducing conditions, resulting in the immobilization of hexavalent chromium as insoluble trivalent chromium hydroxides, in conjunction with a groundwater recirculation/plume flushing program. Accurate hydrogeochemical models are required to adequately describe and predict long-term treatment performance and secondary effects, such as the generation and attenuation of byproducts (including dissolved arsenic, manganese, and iron), water quality changes (including pH, alkalinity, and TDS), and potential permeability changes. A reactive transport model developed using PHT3D will be discussed, calibrated from bench-scale and pilot-scale testing and aquifer hydrologic characterization. A “hybrid” geochemical/solute transport modeling approach that resulted in substantial reduction in model complexity and computation time will also be discussed.
REMOTE CONTROLLED MONITORING FOR MINE CLOSURE

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Background and project goals:
With an increase in mine closure activities including greater emphasis on reclamation, the industry is faced with a greater need for thorough, inexpensive, and better regulated environmental remediation procedures. Indefinite sampling and monitoring of these sites are necessary even after reclamation has been deemed successful.

The example approach presented in this talk to monitor mine closure is predicated on developing a low cost, integrated, autonomous system that includes networked geophysical, hydrological, and self-calibrating general chemical sensors backed by a secure, integrated web-based data storage and retrieval software system. The solar powered system enables 24/7 remote access to the sensors, data storage units, and control system.

This example approach includes the following attributes:

- Automated data collection, QA review, and reporting
- Remote control of data acquisition systems
- Secure web-based data accessibility
- Complementary multi-sensor monitoring networks
- Critical-event alarm capabilities

Typical hardware may include:

- Resistivity and other geophysical systems
- Advanced subsurface sensors
  - Electrodes
  - Thermocouples
  - Pressure transducers (water and air)
  - Automated sampling ports, water, and air
  - Manual sampling ports, water, and air
- Outflow volume of monitored system
- Automated self-calibrating water/gas chemistry monitoring

The main advantages of an integrated monitoring system are that the sensors are self-calibrating and most collect nearly continuous data, allowing for the flow dynamics to be understood. The remediation system optimization performed with these data reduces the operational cost of the remediation efforts and highlights improvements needed in future designs. The monitoring system can be operated remotely and the data is accessed in a relational database using a secure web page in near-real-time. The capability is an important feature.
in that if the remediated system begins to fail, appropriate action can be taken before catastrophic failure results. Automated monitoring systems produce data at very low costs compared to on-site sampling.

RECLAMATION OF A MID-CONTINENT FORMER LEAD SMELTER SITE

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The mid-continent has a substantial number of former smelter sites in need of remedial closure. These sites typically comprise tens to hundreds of acres, slag disposal areas of varying configurations, residual structures or associated debris, and impacted lowland areas. The State of Illinois is seeking a pragmatic presumptive remedy for these sites that consists of a two-foot soil cap with a six-inch cap protective layer (i.e., a cap consistent with 35 IAC Part 807) over consolidated Bevill-exempt wastes.

ENVIRON International Corporation (ENVIRON) and DeNovo Constructors LLC (DeNovo) have teamed together to design and implement a multi-phase, cost-effective reclamation of one such former smelter site. The project site consists of a 62-acre former lead smelter that operated from the early 1900s through 1950s. The former plant area is situated on an upland plateau and was demolished in place in the early 1960s. Wastewaters and approximately 1.5 million tons of slag generated by the smelter were managed in a 13-acre portion of the site’s bottom lowlands behind a levee.

In addition to slag, initial site investigations identified metals-impacted soils, building debris, and former stack debris across large portions of the site’s upland area, as well as metals-impacted soils/sediments and localized groundwater impacts in a low-pH area of the lowland outfalls. ENVIRON conducted soil and groundwater investigations in 2011/2012 to support Risk Assessments, Feasibility Study, and Remedial Design.

ENVIRON and DeNovo initiated site remedial activities in early 2013. Through a collaborative interagency coordination and permitting process, 12,000 cubic yards of metals-impacted soils/sediments were excavated from the lowland on an expedited basis during a historically dry period. These geotechnically soft materials were mixed with 16,000 cubic yards of building debris and were placed on the slag pile. Lowland backfilling was conducted with crushed limestone to adjust
groundwater pH to mitigate low-level groundwater metals impacts, as well as clay to minimize the potential for levee-area sand boils.

Among other seasonal preparations conducted during 2013, 15,000 cubic yards of clean dredged sediments were hauled to the site from a nearby state park for beneficial reuse in the site remediation process through a collaborative Illinois inter-agency agreement. The reuse of these dredge materials alleviated a material disposition problem for park officials while cost-effectively providing site capping materials.

In April 2014, ENVIRON and DeNovo initiated work on the final phase of site remediation. Approximately 100,000 cubic yards of impacted upland soils and debris are being excavated and consolidated on the slag pile as the caps grading layer. Silty-clay soils mined from the site upland will be used for the cap’s two-foot low permeability layer, which will be compacted wet of optimum moisture content from a modified proctor test with no permeability specifications. The dredged sediments will be beneficially reused and mixed with low-level impacted upland top soils for the cap’s six-inch top soil layer. Wood chip berms are being employed as green remediation friendly erosion control measures. Industrial/Commercial institutional controls will be placed on the site. Implementation of these remedial activities will cost-effectively complete the reclamation of this former lead smelter site by late 2014.

**IRRIGATION TO SUPPORT RIPARIAN HABITAT RESTORATION ON THE LOWER COLORADO RIVER**

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Over the course of the Lower Colorado River Multi-Species Conservation Program, over 2,900 hectares (ha) of historic floodplain will be planted with riparian vegetation to mitigate the effects of river regulation, hydroelectric power generation, and water diversion on habitat for native species. Due to disconnection of the historic floodplain and excessive depth to groundwater, irrigation is typically required to establish vegetation and provide moist or saturated soils to satisfy habitat specifications for avifauna such as the federally endangered Southwestern willow flycatcher. For this program, habitat creation is completed primarily using existing surface irrigation to establish and maintain riparian trees (primarily cottonwood and willows) in former farmland. Irrigation requirements for this novel ecosystem are not well understood, and the distribution of irrigation within restoration sites has not been
A pilot project was completed to use soil physical and hydraulic characterization and automated data acquisition systems to assess irrigation distribution and soil moisture at a 30-ha riparian habitat creation site near Blythe, California (Riverside County) during the 2012 and 2013 avian nesting seasons (approximately March 1 through July 31). This site is subdivided into 10 “checks” receiving surface irrigation.

Higher surface sand content resulted in higher infiltration rates, greater percolation to groundwater, and lower soil moisture between irrigation events. Irrigation sensors showed uneven irrigation distribution, with extensive percolation near the water source (high irrigation duration, sandy soils with high infiltration rates), and little applied water at the far end of the field (less irrigation duration, finer-textured soils). Irrigation efficiency improved with higher flow rates, and lower water volumes were required to irrigate checks with finer-textured soils. Higher flow rates or smaller irrigation checks were recommended to increase irrigation efficiency and decrease the volume of irrigation water required. Soil moisture in the root zone was generally sufficient to support vegetation; on the check or site level, irrigation application met or exceeded estimated evapotranspiration. As a result, soil moisture was typically above field capacity and was rarely depleted to near the permanent wilting point. Thus, a reduction in irrigation frequency would also allow decreased water application at the site without adversely affecting vegetation.

Despite irrigation application in excess of plant water demand, surface soil saturation, which is targeted for creating high-quality avian habitat, was generally only observed during and soon after irrigation. Finer-textured soils retained higher surface soil moisture, despite receiving less irrigation. This result indicates that increasing water application in sandy soil areas is not likely to increase levels of soil saturation in sandy soils; instead, water saved through a reduction in irrigation frequency could be allocated to finer-texture soils where increased irrigation is likely to have a higher impact on soil saturation.

COLORADO FLOOD IMPACTS, SEPTEMBER 2013: NORTHERN FRONT RANGE

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Unusual meteorological conditions during the first week of September 2013 brought copious subtropical moisture into
the Northern Front Range of Colorado. Starting September 11th, historic volumes of rain began to fall, mostly north of Denver up against the steep topography of the foothills. Near Boulder and other areas to the northwest toward Estes Park, steady and sometimes heavy rain ensued for the next two days, producing up to 17 inches of rain (in an area where ~20 inches annually is normal).

The steep topography and narrow canyon stream courses of the Big Thompson River, Lefthand Creek, Little Thompson River, Cache la Poudre River, St. Vrain Creek, Coal Creek, South Boulder Creek, and Sand Creek led to repeated flooding over a time period of two days, decimating virtually all human structures within the 100-year flood line and beyond. In some of these areas a recurrence probability of 1/1000 for any given year is estimated. Holocene and Pleistocene deposits eroded away, excavating fresh Precambrian bedrock in all of those canyons. Whatever was built on those deposits was decimated and removed.

Flood waters collected in the South Platte River headed east across the High Plains and produced historic high water hydrographs through September 18th all the way to the Nebraska state line. The duration and severity of the flooding in the Greeley/Evans and Kersey areas was particularly damaging. Damages and losses attributed to the storm included: $400 million road damage (486 miles; 102 bridges); $3.5 million crop losses (28,535 acres which is ~1% of Colorado’s irrigated land); hundreds of water diversions destroyed and river courses changed; 200 million gallons of untreated sewage released; 14 oil and gas “significant spills” (48,250 gallons, which is 0.02% of the amount of spilled sewage); 39,000 acres of pasture/rangeland damaged; more than 11,000 people displaced but ONLY 8 deaths; more than 19,000 homes damaged; 1,500+ destroyed; and up to $450 million of Federal Aid available, out of ~$2 billion total economic losses (about 22.5% of total). Infrastructure rebuilding and improvements on earlier designs will take many years.

In comparing this flood to earlier historic floods in the Northern Colorado Front Range, the scale of damage for the September 2013 event is much more extensive and expensive; on the other hand, there were only 8 fatalities. Reasons for the much greater damage include proliferation of construction right up to the edge of the 100-year flood line, much more transportation infrastructure damage in the river course, and much higher population density. Reasons for the relatively few deaths in this event include the accuracy of warnings, excellence of emergency response systems, and the public awareness of flood dangers.

Expectations of more severe weather and fire events under climate change scenarios are becoming more commonplace as insurance companies rework their actuarial tables to cover losses.
PLANNING FOR EFFLUENT USE: CAPACITY USE AND IMPACTS IN TUCSON, ARIZONA

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The severity of the current drought has posed a real threat to the state of Arizona including the City of Tucson. It is pertinent to address this matter proactively in order to comply with the need to balance the supply and demand of water, particularly considering urban growth. Part of the solution is to utilize effluent to its full capacity, or maximum amount in relation to potential uses. With reliance on effluent for Tucson’s future water supply, it is important to ensure the quality of water is acceptable for all possible uses. High total dissolved solids are a concern, specifically the problem of increasing salinity in the water system, which renders a portion of the effluent unusable. Additionally, a range of emerging water-quality constituents (pharmaceuticals, other endocrine-disrupting compounds, nanoparticles, etc.) raise major challenges for the sustainable use of effluent. Consequently, maximizing effluent utilization directly impacts society and the environment. Strategic planning by the City of Tucson and Pima County plays a vital role for efficient effluent distribution, policy compliance and adherence to state water quality requirements. In 2006, Pima County embarked on a program to improve quality of anticipated escalation of effluent volume through the Regional Optimization Master Plan, a program for wastewater treatment plants’ upgrades and expansions within county boundaries. Due to the uncertain outcomes of these actions, it is necessary to assess plans for effluent use. The objective of this presentation is to discuss, through review and analysis of public documents by Tucson Water and Pima County Regional Wastewater Reclamation Department, the ways effluent will be appropriated while addressing quality issues and the bearing on community sustainability and water security.

EXPLORING EARTH SCIENCE THROUGH EXPLOSIONS, EXCAVATIONS, AND THE ENVIRONMENT

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Classroom teachers, pre-service teachers, and university professors have the difficult task of teaching science to students
at various academic, cultural, and ability levels. As the Next Generation Science Standards (NGSS) are adopted around our nation, K-12 students will be held to a higher standard in science education. As educators, our goal is to present geologic information in a way that stimulates interest, promotes learning, and encourages a deeper understanding of our Earth. According to the National Research Council (2012) Earth and Space Science (ESS) is interdisciplinary in nature and therefore leads to higher levels of complexity. Earth science covers a diverse range of content, which may be taught in a variety of ways. This presentation focuses on earth science, educational outreach programs created for K-12 students; held throughout the community led by faculty, graduate, and undergraduate students from Wright State University in Dayton, Ohio. These programs are designed to meet earth science curriculum needs as stated in the Ohio Model Curriculum and the NGSS. Topics discussed include volcanoes, fossils, rocks and minerals, and water resources. Hands-on activities for K-12 students will be highlighted, including potential opportunities for educational outreach in your community.

**USE OF LONG-TERM THERMOMETRIC AND HYDROLOGIC MEASUREMENTS IN CHARACTERIZING SURFACE WATER-GROUNDWATER INTERACTIONS ALONG THE GREAT MIAMI RIVER IN DAYTON, OHIO**

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The Great Miami River (GMR) and its major tributaries are significant hydrologic features affecting surface and groundwater environments within metropolitan Dayton. Locally the GMR is the major recharge source of an underlying sole source aquifer. This area is also prone to surface and groundwater flooding to nearby building substructures as a result of seasonal high water events contained within the levees bordering the river. To better define the interrelationship of surface water and groundwater in a representative river segment, a thermometric monitoring program is providing required data to calculate daily flux estimates. A total of eight approximately seven meter deep access tubes are installed as transects along the downstream side of the First Street and Third Street bridge piers to collect temperature readings. Each access tube is fitted with a string of five equally spaced single-channel temperature data loggers (thermistors) to measure temperature profile changes as a result of seasonal temperature and hydraulic variations in the river. Continuous measurements of subsurface temperature, together with river water level and
discharge readings, began in August 2008 for this monitoring program.

Using the measured vertical temperature profiles, seasonal temperature changes, river discharge and water level elevations measured at and near the access tubes, the hydraulic interconnectivity between the shallow aquifer and river bed is characterized. This data is further used to calculate seepage velocity rates, estimate a transect water flux and infer hydraulic conductivity values for the upper portion of the shallow aquifer. Temperature measurements show portions of the GMR can be both gaining and losing due in part to the influence of a large groundwater cone of depression extending from the east side of the river into the downtown Dayton area. Average long-term seepage velocities are bidirectional and vary up to 10 cm/day, although small duration episodic increases in exchange rates were noted during and following some high water events.

Surface/groundwater exchange rates calculated from thermometric measurements were found to be similar to those obtained in the GMR watershed using different thermometric installations, seepage meters and piezometer nests. Variations in aquifer heterogeneity and isotropy at the access tube locations are shown to significantly influence the thermometric responses with respect to depth and time. Preliminary analytical and numerical model results of the long-term thermometric and hydrologic measurements within the monitored river segment suggest a predictable pattern of aquifer recharge.

GEOLOGISTS AND SITE CONCEPTUAL MODELS: VOCS AND SEWER GAS IN INDOOR AIR RESULTING FROM MIGRATION FROM BREACHED SEWER CONVEYANCE SYSTEMS

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Geologists have long developed site conceptual models to describe exposure pathways from contaminant sources to the sensitive receptors. Inflow and infiltration (I&I) of groundwater and stormwater into sanitary sewer pipeline systems is well documented. I&I provides significant excess water to wastewater treatment plants, is a national problem associated with aging wastewater conveyance infrastructures and presents a specific challenge at sewer plants with limited wastewater storage capacity. One case study of I&I of stormwater and shallow groundwater into a coastal northern California
Smoke testing, which has long been used to locate gross breaches where I&I enters sewer pipe systems, is a diagnostic in which pressurized smoke is applied to a leaking pipe network to visually identify the location and extent of system breaches. Other diagnostics, video camera inspection and pressure transducers, have been added to the available assessment tools to document visible breaches. Sewer line breaches include corroded pipe walls, pipe cracks, pipe offsets, non-standard piping construction and pipe-to-pipe or pipe-to-fixture seal failure which can occur anywhere between indoor plumbed fixtures and the sewer plant. I&I represents the net inflow of non-network liquids that are conveyed by gravity or pumps to the treatment plant. Sewer gases and vapors, including volatilization of any permitted or non-permitted discharges into the system, have the potential to migrate in the sewer conveyance system. By engineering design of the sewer system, these gases and vapors are trapped or sealed off from indoor air to eliminate human exposure. However, design failures, such as ineffective vapor seals, dry P-traps, improper plumbing construction or nonfunctioning vent lines, can create potential human exposure risks as a result of the migration of sewer gases and vapors into indoor air.

Such potential human exposure to sewer vapors in indoor air in structures with compromised sewer systems takes on an additional dimension for those properties which are directly overlying volatile organic compound (VOC) -contaminated soil and groundwater or those properties whose sewer network otherwise intercepts soil or groundwater containing volatile organic compounds such as fuel hydrocarbons or chlorinated solvents. The study of indoor air as a recipient of incoming soil vapor contaminants from a compromised sewer conveyance system has not been widely considered or generally included in the standard environmental site conceptual models. The presentation will provide a case study describing the role of breached sewer pipelines and ineffective vapor traps in degrading indoor air quality.

CONCEPTUAL MODELS IN CHARACTERIZING THE SOURCE AND MIGRATION OF NAPL-IMPACTED SEDIMENTS

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Concerns associated with the characterization and remedia-
tion of impacted sediments have increased recently. In the past, PCBs (polychlorinated biphenyls) and dioxins were of particular concern; however, due to recent large oil releases, light non-aqueous phase liquid (NAPL)-impacted sediments are receiving more focus within the environmental industry. This paper discusses the characteristics of NAPL-impacted sediments and how the source and transport of the NAPL influences the nature and character of the contamination. In particular, two discrete conceptual models of NAPL contamination are discussed: (1) Ex situ NAPL emplacement; and (2) In situ NAPL emplacement. These conceptual models describe two fundamentally different conditions as to the relationship of the NAPL to the sediment matrix. Ex situ NAPL emplacement describes the transport of NAPL via groundwater from a land source to sediments below the base of an open water body. Hence, the deposition of the sediment and the emplacement of oil occur at two discrete points in time. In contrast, in situ NAPL emplacement describes the deposition of NAPL through a column of water and incorporation within the sediment matrix. During in situ NAPL emplacement, the deposition of the sediment and oil occurs essentially contemporaneously.

Ex situ NAPL emplacement is characterized by NAPL migrating from an on-shore source via a gradient through permeable sediments or fractures. For NAPLs with a specific gravity less than 1.0 migration generally occurs at the water table. For NAPLs with a specific gravity greater than 1.0, migration will occur along a stratigraphic barrier or within a discrete fracture. As such, the NAPL occurs within permeable sediments that extend to the or under the surface water body. The composition of the NAPL remains relatively unchanged. Because the NAPL movement was induced by a gradient, it may produce a long-term and, potentially significant release to the surface water body.

In situ NAPL emplacement is derived from discharges of NAPL to an open water body from a discrete point source, such as a pipe, vessel, or production well. The NAPL disperses within the surface water body and ultimately is deposited at the sediment/water interface. NAPL deposition occurs through the coalescing of fine particles or oil droplets. This deposition occurs in situ with the other sediments, and as such, the NAPL typically becomes incorporated within the sediment matrix, regardless of particle size. Hence, NAPL entrainment within fine-grain clays and silts commonly occurs. The composition of the NAPL is typically characterized by lower soluble, higher molecular weight hydrocarbons since the more soluble compounds are water-washed upon discharge. Because the NAPL is entrained within the sediment it typically forms micro-droplets or residual films throughout the sediment network and is essentially immobile unless disturbed.

The characteristics of ex situ and in situ NAPL emplacement are documented through data collected from various sites.
EVALUATING THE SOURCE OF HYPERSALINE CONDITIONS IN AN AREA OF MINING AND OIL PRODUCTION

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Historical and active mining operations in an arid environment produced a series of closed surface pits that have been periodically water-filled. The lateral extent of the ponds has varied temporally. Moreover, hypersaline water quality characterized the ponds. Due to oil production in the area, concerns existed as to the source of the elevated dissolved concentrations in the ponded water. In response to the concerns, field investigations were conducted to further characterize the conditions in the ponds and the potential of an anthropogenic source for the elevated dissolved conditions.

Results of the field investigation indicated the pond water contains elevated concentrations of calcium, magnesium, potassium, sodium, chloride, and sulfate. The concentrations of sodium and chloride were particularly elevated averaging 18,900 milligrams per liter (mg/L) and 29,650 mg/L, respectively. By utilizing aerial photographs, the water level changes through time were determined and correlated with precipitation, oil production activity, and mining activity. This analysis indicated water levels in the ponds were directly related to trends in precipitation with low pond levels corresponding to low periods of precipitation and conversely, higher water levels during periods of increased precipitation. Field data also indicated that the concentration of sodium and chloride decreased with increasing water levels. No anthropogenic sources could explain the formation of the ponds or the observed water quality conditions.

The conclusions of the investigation produced a reliable Conceptual Site Model (CSM) that was accepted by the regulatory agency. Specifically, the site data indicated that the hypersaline conditions were derived from the arid climate and fluctuating groundwater conditions. Specifically, soluble compounds are leached from the vadose zone, transported via groundwater to the pits, and collected in the pits as water loss occurs due to the high evaporation rates. This process has been ongoing over a period of at least 40 years. Because the pits were closed, chlorides and other soluble compounds accumulated in the pits and produced the hypersaline conditions.
THE NEXRAD REVOLUTION: SCIENTIFIC BASIS FOR UPDATING THE HMR-49 STATISTICAL STORM INTENSITIES AND PMPS

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Engineers build infrastructure to contain or withstand water flows from both high intensity short duration storms, longer duration 24 hour storms and from the probable maximum precipitation (PMP). Credible estimates have to be made for the specified storm sizes. Historically, data based on a geographically sparse set rain gauges have been used. The consequences of selecting unconservative design storm flows are erosion, washouts, floods, and other damage, which can require considerable re-work and/or maintenance costs and economic losses. Conversely, choosing storm flows that are too large can result in high and unnecessary capital costs.

Improved understanding of local weather patterns has led to the development of more realistic site-specific storm estimations, for both short-duration, high-intensity storms and longer duration probable maximum precipitation events. This paper provides a background to the National Oceanic and Atmospheric Association’s efforts in developing design storms and the scientific basis and use of Next-Generation Radar (NEXRAD) II to provide better local prediction for all storm sizes.

GRAND CANYON: RESOLUTION OF THE 140-YEAR-LONG DEBATE ABOUT ITS AGE, INSIGHTS INTO THE LAST 12 MILLION YEARS OF AN INCISED AQUIFER SYSTEM, AND GEOSCIENCE OUTREACH ALONG THE TRAIL OF TIME

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Geoscientists have debated for about 140 years how and when the Grand Canyon formed. “Old Canyon” models posit that an east-flowing 80-70 million year (Ma) old “California”
palaeoriver, then a west-flowing 55-30 Ma old "Arizona" palaeoriver incised Grand Canyon to within 200 meters of its modern depth and hence the Colorado River did not play a significant role in excavating Grand Canyon. “Young Canyon” models have posited that much of the Grand Canyon was carved by the Colorado River in the last 5-6 Ma due to integration of drainage from the Rocky Mountains, across the Colorado Plateau, to the Gulf of California. A recent paper (Karlstrom et al., 2014), using both thermochronologic and geologic data, potentially resolves this debate by recognizing that different segments of Grand Canyon have distinct erosional histories. Thermochronology dates when rocks cooled due to erosion of overlying rock (the Mesozoic section). Cooling paths of rocks from the rim differ from those at the river bottom. Both were deeply buried until 25 Ma and river level rocks were about 30°C hotter and deeper than rim rocks from 70 to 25 Ma. These data falsify the “Old Canyon” model but present the exciting discovery that an “intermediate age canyon” formed 25-15 Ma ago across the Kaibab uplift. The combined data indicate: Marble Canyon has been carved by the Colorado River in the last 5-6 Ma, eastern Grand Canyon was about half carved by East Kaibab paleocanyon to the ~level of the Redwall 25-15 Ma ago, the Hurricane segment was about half carved by ancient rivers that flowed north across the path of modern Grand Canyon from 65 to 50 Ma ago, and western-most Grand Canyon has been carved in the last 5-6 Ma. Thus, integration of the Colorado River took place through partially carved older paleocanyons and the Colorado River and its side canyon tributaries have carved and widened about 75% of the Grand Canyon in the last 5-6 Ma.

Grand Canyon is also a 1.6-km deep incised aquifer system that provides a laboratory for studying groundwater and paleohydrology of this arid region. New geochemical analyses of springs in Grand Canyon show a complex mixing of “upper world” groundwaters derived from surface recharge on the Colorado Plateau with “lower world” fluids that move up along faults and carry very high mineral loads (dissolved salts and toxic metals) and high levels of carbon dioxide and other exotic gases from deep within the Earth (including mantle derived 3He). Quantitative forecasting of the effects of climate change (diminishing surface flows affecting recharge rates) on water quality depends on our understanding of these fault networks and fluid mixing processes. We are developing a robust monitoring and geochemical sampling program for the “indigenous” springs in Grand Canyon to establish a groundwater baseline. Travertines, still forming today around carbonic springs, provide a datable record of how the fault-connected karst aquifer system has episodically been wetter and dryer due to climatic cycles over the last 500,000 years. Farther back in time, geochemical studies of the 12-6 Ma Hualapai Limestone of western Grand Canyon and the ~ 5 Ma Bouse Formation of the Lower Colorado River are providing new insights into the importance of groundwater in promoting downward
integration of the Colorado River through Grand Canyon 5-6 Ma via groundwater sapping processes that connected the once-separate segments and internally drained basins of the Lower Colorado River region (Crossey et al., 2014).

Improved geoscience public education is essential as human societies flourish on our planet of limited resources. The Trail of Time Geoscience Exhibition at Grand Canyon was designed and installed by us (1995 to 2010), with support from the National Science Foundation and Grand Canyon National Park. Winner of the 2011 Award from the National Association of Interpretation, The Trail of Time encourages many of the Park’s 5 million annual visitors to ponder, explore, and understand the magnitude of geologic time and the stories encoded by Grand Canyon rocks, aquifers, and landscapes.

THE EVOLUTION OF THE GEOSCIENCE WORKFORCE IN TIMES OF DEMOGRAPHIC CHANGE

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The geosciences are a dynamic and relatively healthy sector in the United States economy and labor pool. The American Geosciences Institute has tracked geoscience faculty, enrollments, and degrees since 1955 and for the last decade has published biennially a comprehensive look at all factors of the geoscience economy, including labor pool, funding trends, economic indicators, as well as the dynamics in the educational arena. Nearly a decade ago the emerging trend of skilled-labor shortages in the geosciences was identified as a result of the retirement of baby-boomers. We are now in the middle of this transitional process and are witnessing a number of areas where skill shortages are emerging, but also a number of areas where market forces are accommodating for the changing demand. This talk will look at a number of these dynamics, including the trend towards the hiring of bachelor graduates while doctorate recipients struggle to find employment, critical skills deficits in new graduates, challenges to future economic activity as a result of aggressive attrition in the federal geoscience workforce, and a look at some of the emerging educational trends that will impact the geoscience community.
Abstracts

A GEOMORPHIC AND GEOCHRONOLOGIC STUDY OF THE MIS-5B DIAMICTITE AT PALISADES CREEK, EASTERN GRAND CANYON, ARIZONA: EVIDENCE FOR EMBLACEMENT DURING REGIONAL WET EVENTS IN THE SOUTHWESTERN UNITED STATES

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The cosmogenic beryllium 10 isotope ($^{10}$Be) and varnish microlamination (VML) exposure ages were obtained from deeply weathered chert nodules in 0.5-m and smaller Kaibab Limestone clasts embedded in the oldest diamictites adjacent to Palisades Creek (elevation 893-925 m), eastern Grand Canyon, Arizona. Both exposure age methods indicate that the oldest diamictite was emplaced during Marine Isotope State (MIS) 5b. Cosmogenic $^{10}$Be ages range from 86.8-89.0 thousand years (ka) (n = 4) with relatively large errors. Mineral separation, processing/treatment to isolate quartz, and $^{10}$Be was done at the Purdue Rare Isotope Measurement Lab; age was calculated using the CRONUS online calculator (v.2.2) using the constant production rate model and spallation scaling scheme by Lal (1991) and Stone (2000). The more precise VML method yielded a minimum exposure age of 86.8 ka (analyzed by Tanzhuo Liu). The VML method clearly shows that the oldest diamictite varnish unit Wet Period 7 (WP7) was precipitated during a regional wet event. Liu and Broecker (2007) have shown that Holocene wet events recorded in varnish also correspond to large-scale cooling events. Elias (2014) has shown that MIS-5b summer temperatures (southwestern USA) were 5-6ºC cooler than modern values (results from fossil insect assemblages, Ziegler Reservoir, Snowmass, Colorado).

The diamictite: (1) is coarse-grained, matrix-supported, and poorly-sorted (angular- to sub-rounded- clasts, -3 to -10 phi); (2) is well-indurated with an average matrix Schmidt-hammer R-value of 52 (n = 100); (3) is dominated by Paleozoic rocks with subordinate Precambrian clasts; and, (4) lacks quartzite and other Colorado River clasts. Mud-rich layers, typical of debris flows, are mostly absent from exposed outcrops. Basal troughs are locally incised into the Precambrian Dox Formation and indicate deposition under high-energy, fluvial conditions (e.g., debris flows, plunge-pool deposits, and/or boulder bars). Paleozoic rock clasts were clearly derived from the “Palisades of the Desert” cliffs, 1-2 km east of the Colorado River; west of the Colorado River (across Butte Fault), Precambrian rocks are exposed (Paleozoic rocks are faulted out and not locally present). Well-indurated diamictite outcrops occur west of the Colorado River in Lava Creek indicating that diamic-
tite discharge volume was sufficiently large for deposition to occur on the adverse side, across the Colorado River. Micro-morphological analysis of the diamictite shows that: (1) micro-cracks are common on 0.5-1.0-mm grains and cut across the grains creating micro-blocks; and, (2) v-notches and discoid percussion marks are present. These mechanically-induced micro-features are consistent with high-energy systems that impart a strong impact force between grains.

Sandstone clasts in the diamictite have bleached aureoles/rinds (up to ~1 cm) suggesting prolonged contact with water. Leaching of iron oxide from the sandstone clasts may have resulted from several processes: (1) increased precipitation (and local pooling of water?) during the climate wet event; (2) infiltration of ponded/rerouted river water from the large-volume debris flow dams/diversions of the Colorado River; and/or, (3) impoundment of water by western Grand Canyon lava dams [volcanic episode (VE) 4; ~150-75 ka]. However, VE4 intra-canyon flows and lava dams (~River Mile [RM] 188) are not well preserved or constrained (Crow et al., 2008) and, although possible, it is uncertain if any lava dam waters backed up as far as the Palisades Creek area (RM 66).

This work builds upon the detailed and pioneering work in the Palisades Creek area by Lucchitta et al., 1995.

**10BE, OXYGEN ISOTOPES, AND GEOMORPHOLOGY OF LATE PLEISTOCENE STONE RUNS, TUFA, AND SCALLOPED KAIBAB LIMESTONE CLIFFS: TWIN CREEK CANYON, WESTERN GRAND CANYON, ARIZONA**

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Stone runs (SRs, aka, block streams) are valley-axis accumulations of predominantly large, coarse, angular or blocky boulders that exhibit flow-like or lobe-shaped surface morphology that form under cold-phase climate conditions; movement likely results from void-space/interstitial ice and/or sliding failure in basal, remolded clays (Caine, 1983). The relict, single-thread, valley-axis, SRs in the upper, north-south trending reach of Twin Creek Canyon in the western Grand Canyon, north of the Colorado River: (1) contain boulder rock debris derived from near-vertical, scallop-shaped Kaibab Limestone (KL) cliffs; (2) occur at an elevation between ~1340-1520 m; (3) exhibit an uneven surface morphology of openwork boulders (>1 m); (4) lack intercalated fine-grained material (typical of debris flows); (5) exhibit crude lobe-shaped surface features; (6) have longitudinal gradients ~ 5-6°; (7) occur perpendicular
to adjacent talus slopes (which contain younger and smaller boulders); (8) have a valley-axis trend discernible for ~2 km; and, (9) have diffuse terminal margins that grade into a mix of fluvial and colluvial deposits from tributary canyons. Relict periglacial, Late Pleistocene landforms have not been previously identified in western Grand Canyon. Recognition and documentation of a relict, cold climate erosion-transport-deposition system in western Grand Canyon could lead to a clearer understanding of past periglacial geomorphic processes, and help to establish a preliminary, Late Pleistocene mean annual air temperature (MAAT). Boelhouwers (1999) suggested that a MAAT of 0°C is necessary for development of SRs. Cosmogenic nuclide (CN) \(^{10}\)Be and \(^{26}\)Al surface exposure ages were obtained from differentially weathered chert nodules in large (>1 m) KL, stone run boulders. CN exposure ages (n = 3) for the SRs range from 9.54 to 15.2 ka; adjacent, smaller hillslope boulders (n = 2) yielded exposure ages of 4.51 and 4.58 ka. Preparation and CN processing was done at the Purdue Rare Isotope Measurement Lab; age was calculated using the CRONUS calculator (v.2.2) and the constant production rate model/spallation scaling scheme by Lal (1991) and Stone (2000). The range of exposure ages suggest that development of SRs was likely not the result of a single event, and may have developed after the last glacial maximum in the southwestern US (~19.4 ka; Guido et al., 2007). Previous studies of SRs report a polycyclic/complex development history which includes block rotation (Harris et al., 1998). As such, CN exposure ages on stone run boulders are regarded as minimum age estimates because development of SRs would likely include periods of block rotation and burial resulting in possible CN shielding; block rotation also lessen concerns about inherited CN exposure ages. Boulder source is from adjacent (~425-460 m high), scallop-shaped KL cliffs; non-banded (mostly inactive) tufa deposits are locally exposed along the base of the KL cliffs in both Twin Creek and nearby Twin Spring Canyons. The tufa deposits were likely precipitated under wet climate conditions. It is inferred that groundwater sapping was also more active under wet climate conditions. Active groundwater sapping is likely the process that formed the scalloped KL cliffs and the large KL boulders in the SRs. Oxygen isotopes on older tufa samples (n = 4), range from -12.75 to -13.47 parts per thousand relative to the Vienna Pee Dee Bel- emnite (‰vpdb) (average = -13.2‰); recent tufa samples (n = 5) average -10.5‰vpdb. No U-series age dates for the older tufa deposits have been obtained. Assuming isotopic equilibrium conditions, and a 1°C temperature change per 0.24‰ change in the \(\delta^{18}\)O of the calcite precipitate, the ~2.5‰ depletion in the older tufa samples represents a ~10°C temperature depression (relative to modern MAAT). This preliminary temperature depression estimate yields a MAAT low enough for SRs to form. The -10.5‰vpdb average for modern tufa (this study), agrees with average, modern oxygen isotope values (-10.5‰) from a detailed study of nearby Havasu Canyon travertine (south of the Colorado River; O’Brien et al.,
2006). Based on the preliminary results, it seems reasonable to infer that the SRs and formation of scalloped KL cliffs represent relict periglacial landforms and processes.

ETHICS AND ENVIRONMENTAL SAMPLING: THINGS YOU MAY NOT HAVE CONSIDERED

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Ethics, as defined by Merriam Webster Dictionary, are rules of behavior based on ideas about what is morally good and bad. Professionals who practice in the geoscience and environmental fields are often bound to perform their duties in accordance with a code of ethics established by professional organizations (e.g., American Institute of Professional Geologists [AIPG]), licensing bodies (e.g., state boards of licensure for professional geologists and engineers), and corporations. The principles presented in these codes of conduct set the expectations for behavior in order to reach desirable outcomes. By conducting work in an ethical manner, quality is achieved and risk is minimized or, ideally, avoided.

Environmental consulting and, specifically environmental sample collection, is an area of professional practice where conducting work in an ethical manner is of utmost importance. Integrity and ethical behavior should be displayed at all levels of an organization from the principal-in-charge to the field technician who is actually conducting and documenting the sampling activity. Examples of unethical behavior related to environmental sampling include: disregarding safety protocols; not complying with corporate governance policies or regulatory requirements; inaccurate or incomplete record keeping; falsifying information; omitting or creating misleading information; and plagiarizing in project reports without appropriately citing sources. Potential risks associated with unethical behavior include:

- Compromising the safety and well-being of the sampling crew and the public
- Unnecessary legal and environmental liabilities
- Unreliable/non-defensible data
- Loss or suspension of professional certifications or licenses
- Loss of employment
- Civil or criminal penalties

This presentation will discuss what constitutes ethical and
unethical behavior during the execution of environmental sampling projects. In addition, specific examples of unethical behavior and the potential implications associated with these actions will be presented.

**POTENTIAL FUTURE DECLINES IN BASE FLOW TO THE UPPER VERDE RIVER DUE TO GROUNDWATER EXTRACTION FROM THE BIG CHINO SUB-BASIN - AN APPLICATION OF THE NARGFM**

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This report builds on earlier work by the United States Geological Survey (USGS) in cooperation with the Arizona Department of Water Resources (ADWR) and Yavapai County to develop a regional flow model for northern Arizona. The USGS, in conjunction with the Verde River Basin Partnership (VRBP) and the Town of Clarkdale, subsequently applied the model in a series of simulations to gain a greater understanding of the past and potential future human impacts on the Middle Verde River’s streamflow.

The work discussed in this paper was carried out to: (A) test the accuracy and predictive capability of the model within the Big Chino and Little Chino sub-basins; (B) illustrate the historical change in base flow at the USGS Paulden and Clarkdale stream gages; and (C) perform forward-looking simulations for the period 2005-2110 that evaluate potential effects on base flow in the upper Verde River resulting from; (1) unchanged water demand from 2005 through 2110, (2) continuing drought, (3) increased water demand, (4) extraction of the ADWR allocated 12,000 acre-feet per year (ac-ft/yr) of groundwater from the central part of the Big Chino sub-basin beginning in 2020, and (5) the cumulative effect of cases (1) through (4).

My testing of USGS’s Northern Arizona Regional Groundwater-Flow Model (NARGFM) showed that excellent agreement was found between historically observed and simulated groundwater elevations within the area of concern. In addition, simulated trends in both groundwater elevation and discharge to the Verde River are accurate to within industry-standard ranges.

My forward-looking simulations using the NARGFM show that the cumulative effect of continuing drought, increased water demand, and extraction of 12,000 ac-ft/yr (16.6 cubic feet per second [cfs]) of groundwater from the Big Chino, will decrease the base flow to the Verde River by 14.7 cfs at the Paulden
stream gage by the year 2110. Since the base flow at the Paulden stream gage in 2005 was approximately 19 cfs, this would leave only 4.3 cfs in the river.

Declines in groundwater levels were also evident, and indicate that regional planning within Yavapai County is needed both to support future water supplies and to develop a long-term water management strategy that protects the Verde River.


GROUNDWATER MODELING’S ROLE IN STRATEGIC WATER RESOURCES PLANNING FOR CLARKDALE, ARIZONA

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The Town of Clarkdale purchased its water supply wells and began operating its own water company in 2006. Over the past five years, the Town has upgraded its wastewater treatment system and now has a source of A+ effluent. For the past 18 months, the Town has undertaken a formal water resources management planning process with the assistance of the University of Arizona’s Water Resources Research Center and Lacher Hydrological Consulting. As part of this process, a Water Advisory Board of known experts was formed to guide decisions. In addition, a series of public and expert meetings were held to educate the public and vet ideas with others with a similar situation to that facing Clarkdale. This process has helped identify water resources issues and opportunities for the Town, as well as solidify several high priority projects related to water resources management. As part of this process, the Town spelled out its mission to “provide a water resources management program that meets the needs of residents, businesses and our natural environment equitably in order to be a robust and resilient community.” Among the top water resources planning priorities for the Town is to understand the best and highest use of its A+ treated effluent. The vast majority of this effluent is lost to evaporation under the present disposal regime of spraying in a riparian area along a tributary to the Verde River. Groundwater modeling was used to explore the potential impacts over several decades of recharging Clarkdale’s effluent at various locations and with varying effi-
ciencies driven by a suite of different water demand scenarios. Impacts of particular yet competing interests include protection of groundwater levels at the Town’s primary water supply wells and mitigation of Clarkdale’s pumping impacts on the Verde River. The results of the groundwater modeling simulations will be used to balance the costs and benefits of the three general recharge options currently under consideration: a) recharging in basins near the Verde River, b) improving recharge efficiency at the current location north of the Town’s water supply wells and more distant from the river, or c) injecting recharge through new or existing wells closer to, or up-gradient of, the Town’s water supply wells and farther from the river. Each of these options has positive and negative facets which the Town will ultimately have to weigh against all of its sustainable community and economic planning objectives.

**ARIZONA FARMS OF THE FUTURE: THE CHANGING FACE OF IRRIGATION & WATER USE IN AGRICULTURE**

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Farmers in Arizona are implementing best management practices of the future today. One way they are doing this is by planting cotton over harvested wheat and barley plants, instead of clearing and plowing fields beforehand. This technique, called double cropping, prevents soil erosion and helps trap moisture by creating natural mulch.

The result is that they use the same amount of water today that they did in 1980. Water is a big part of a farm’s budget, and farmers have a bottom-line reason to be efficient. When you are growing a crop you have to make a commitment up front to give it all the water it needs – but not any more than that because it costs the farmer money.

Water conservation and use of best management practices makes sense because farmers are always looking for ways to make more efficient use of water to increase yields and profits. With agriculture accounting for about two-thirds of the water used in Arizona, a state program encourages farmers to adopt water-saving practices.

Through the Arizona Department of Water Resources’ Best Management Practices program, farmers receive incentives if they follow the State’s suggestions. The state allocates farms certain amounts of water rights, but farmers are allowed to use what they need if they participate in Best Management Practices. The goal: ensure 80 percent of the water applied to crops is absorbed and not wasted.
Recommendations from state officials can include lining irrigation ditches with concrete, laser-leveling fields, rotating crops, using drip irrigation, using sprinklers, reusing water not absorbed by the soil, measuring flow rates, analyzing soil and water, and scheduling irrigation when crops need it rather than at set intervals.

Farms have made better use of water since 1980 and in some areas irrigation use is 90 percent efficient. The reason is simple. When the right irrigation practices are used, greater benefit in the form of yields can be achieved with less. That represents a win-win situation.

INDUSTRIAL MINERAL PRODUCTION IN THE UNITED STATES - AN INCREASING RELIANCE ON IMPORTS

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The use of industrial minerals tends to grow and decline commensurate with fluctuations in population and economy. Industrial minerals are found in nearly every man-made material including glass, ceramics, plastics, pharmaceuticals, and paint.

The United States is endowed with large resources of many industrial minerals, and industrial minerals are mined in every state. However, industrial mineral resources, like all mineral resources, are a "wasting asset". Eventually individual deposits become depleted, mines and quarries close, new deposits must be found, and new mines and quarries need to be opened. But it is becoming increasingly difficult to mine and process some industrial minerals in some parts of the country. Many of the obvious or easy resources have already been mined. There are limits to distances that some heavy or bulky industrial minerals can economically be shipped. Furthermore, issues such as land use and zoning conflicts, and competition with foreign sources, may complicate or prevent the opening of new industrial mineral facilities.

Consequently, the United States is totally or partially dependent on imports for some industrial minerals, and that overall dependence is growing. In 1950, the US imported less than 15 percent of our industrial minerals: today the US imports nearly 40 percent. This includes importing nearly 100 percent of our arsenic, asbestos, bauxite, fluorspar, graphite, manganese, mica, and rare earth elements, and importing more than half (listed in decreasing order of import dependence) of iodine, potash, dimension stone, titanium mineral concentrates, industrial garnet, and barite.
Foreign suppliers of some industrial minerals are starting to be required to enforce regulations more comparable to U.S. regulations, and are keeping more minerals for internal consumption. This drives up the price of foreign supplies, and as a consequence, the imports of some industrial minerals are decreasing. For example, the production of fluorspar and rare-earth elements ceased during the latter part of the 20th century. Recently the United States has resumed mining of these commodities.

The results of sound, unbiased scientific studies of industrial minerals can be used by government and industry to help reduce the reliance on foreign imports of industrial minerals.

**MINE SCAMS**

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Mine scams involving precious metals mines in the USA over the last 35 years have created financial havoc for mine investors and damaged the reputation of the domestic mining industry. Mine scams have been particularly prevalent during periods of soaring precious metal prices in the 1979-1980 periods, as well as during the 2008-2010 period. This talk outlines the various types and structure of mine scams that have been used by unscrupulous individuals and mine scam promoters over the last 30 years. The technical information provided should be of interest to American Institute of Professional Geologists (AIPG) professionals that are considering expanding their area of expertise to precious metal deposits. It should provide them with relevant information that may help them stay out of complex legal entanglements that may arise while innocently or inadvertently providing professional services on a mine scam that involves potential or actual fraud.

**ANCESTRAL YUBA RIVER PLACER GOLD DEPOSITS, NORTHERN SIERRA NEVADA REGION, CALIFORNIA**

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The Ancestral Yuba placer gold deposits of the northern Sierra Nevada Region, California, represent the largest placer gold resource in the contiguous 48 United States. Approximately 20 million ounces of placer gold have been extracted from 20 billion cubic yards of alluvial material over the last 150 years. The Paleocene - Eocene age river system is one
of the oldest and richest paleochannel deposits in North America. This talk will briefly outline the major historic and contemporary placer mines in key mine districts and placer deposit areas. Paleo-channel configuration, gold deposits and stratigraphic relationships over broad geographic areas of the northern Sierra Nevada region will also be discussed.

THE GEOLOGIST’S ROLE IN ENVIRONMENTAL SITE CHARACTERIZATION AND REMEDIATION

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Environmental Site Characterization and Remediation activities can include Environmental Site Assessments, Soil Boring Advancement, Sediment and Surface Water Sampling, Monitoring Well Installation, Groundwater Sampling, and Remediation Oversight. Environmental Site Assessment can be considered the Site Discovery state. The geologist will review historical records for the site to determine if historic or current operations could have impacted the environment. A record review is typically followed by review of topographic maps, aerial photographs, soil surveys to determine the physical site setting. The physical site setting can be used to predict the movement of contaminants in the subsurface. If potential impacts are identified during the site discovery stage, site characterization is typically the next step. Site characterization includes collection of soil samples to determine the site-specific subsurface properties and installation of monitoring wells to determine the depth to groundwater and the flow direction. Collection of site-specific data is then used to develop a Conceptual Site Model (CSM). The CSM is then reviewed to prepare a remedial design for the site.

THE ROLE OF THE VERDE FORMATION IN CONTRIBUTING BASEFLOW TO THE VERDE RIVER – A CONTRARY VIEW

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Fifty years ago, Twenter and Metzger (1963) introduced the concept that groundwater originating as recharge on the Colorado Plateau moves downward through Paleozoic rocks and subsequently through the Tertiary Verde Formation to ultimately discharge in the Verde Valley as Verde River base flow. Since then, about a dozen papers have built on the concept of the Verde Formation being the groundwater conduit to the
Verde River. An alternate concept that merits consideration is that the Verde Formation acts as a semi-pervious barrier, rather than a conduit to regional groundwater movement, such that little groundwater discharges from the Verde Formation to the river.

Multiple lines of evidence support this contrary view. First, average winter base flow of 199 cubic feet per second (cfs) reported by Blasch and others (2006) for the Verde River gaging station near Camp Verde can be accounted for by the sum of measured discharges from upstream Paleozoic aquifers. As such, no discharge from the Verde Formation is required to account for the base flow leaving the Verde watershed. Secondly, the few seepage runs made in Verde Valley were not able to identify any inflow from the Verde Formation. This observation is consistent with the fact that the Verde Formation is known to be a confined aquifer beneath the Verde River and parts of its tributaries, such that substantial discharge from the Verde Formation to the River would not be expected to occur.

The areas of discharge from the Paleozoic aquifers tend to be located near the contacts of Paleozoic rocks with the lower-permeability Verde Formation. Page Springs on Oak Creek discharges above a fault which juxtaposes the Verde Formation against the Supai-Redwall aquifer. The 50 cfs discharge from Paleozoic rocks near Mormon Pocket-Sycamore Creek occurs just upstream from the contact with the Verde Formation.

It is probable that some unmeasured amount of groundwater does discharge from the Verde Formation to the Verde River alluvium. Owen-Joyce (1984) calculated a discharge of 0 to 1.4 cfs from the Verde Formation to the river in a 15-mile reach below Camp Verde; some of this discharge was from artesian wells. However, about two-thirds of the total pumpage in Verde Valley is from the Verde Formation (CYHWRS, 2010). Modeling the Verde Formation aquifer as being hydraulically well-connected to the Verde River will likely overestimate the impact of this pumping on the Verde River base flows.

THE PADRE CANYON EVAPORITES, COCONINO COUNTY, ARIZONA

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Groundwater in the C-Aquifer near Flagstaff, Arizona, typically contains less than 200 milligrams per liter (mg/L) total dissolved solids (TDS). The groundwater is calcium-bicarbonate type, generally containing less than 3 mg/L sulfate and less than 5 mg/L chloride. About 20 miles east from Flagstaff,
near Padre Canyon, sulfate concentrations abruptly increase from about 3 to about 150 mg/L within a distance of about 4 miles; chloride concentrations also increase, from about 3 to about 30 mg/L. Continuing about 10 miles further to the east, sulfate concentrations increase to a maximum of about 420 mg/L, and chloride concentrations reach about 60 mg/L, before declining further to the east. In this area, groundwater has become a calcium-sulfate type, containing as much as 824 mg/L TDS.

The only other calcium-sulfate type groundwater in the C-Aquifer is found near Snowflake, where vertical leakage from known underlying gypsum and anhydrite beds may account for the high sulfate concentrations. Similarly, the anomalously high sulfate and chloride concentrations near Padre Canyon strongly suggest the occurrence of evaporite beds in the Supai Formation underlying the Coconino Sandstone in this area. Evaporite deposits are known to occur within the Supai in the Holbrook Basin to the east.

Both the City of Flagstaff’s planned Red Gap Ranch wellfield and the Navajo Nation’s planned Southwest Leupp wellfield would be located generally between the Padre Canyon evaporite beds to the west and saline groundwater from the Holbrook Basin. Groundwater from both wellfields would be subject to anticipated increases in salinity over time, especially to sulfate concentrations exceeding the secondary drinking water standard of 250 mg/L. The City of Flagstaff expects to desalinate the groundwater from Red Gap Ranch; the Navajo Nation may do the same at their wellfield. Decisions on locations for future production wells should consider both current and future TDS concentrations for groundwater produced, as well as the chemical type of the groundwater (calcium sulfate or sodium chloride) and associated cost implications for desalination.

COMPOSITE PATTERNS TYPICAL OF WIDESPREAD HEAVY RAINFALL EVENTS IN THE PHOENIX, ARIZONA, METROPOLITAN AREA

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The Phoenix Rainfall Index (PRI) was developed at the NOAA National Weather Service (NWS) Weather Forecast Office (WFO) in Phoenix, Arizona, in 2008 as a means to better convey the spatial coverage and intensity of precipitation across the Phoenix Metropolitan Area (PMA). The PRI is calculated...
using daily rainfall measurements from the Maricopa County Flood Control District mesonet of automated local evaluation in real time (ALERT) precipitation gages and includes both spatial coverage and intensity terms. Prior to its development, rainfall amounts for the PMA were generally referenced to the single “official” surface observation at the City of Phoenix Sky Harbor International Airport. This single observation often did not adequately describe the coverage and intensity of precipitation across the entire region PMA due to its size (approximately 5,000 square kilometers [km²]) and spatial variability of precipitation.

Widespread heavy rainfall is not a frequent occurrence in the PMA, though several events have occurred throughout the years, often resulting in urban flooding, including inundation of low water crossings and normally dry washes.

This poster will look at typical patterns associated with widespread precipitation events which have occurred across the PMA. Historical PRI values equal to or greater than 12.7 millimeters (mm or 0.50 inches) per gage were used to help identify days where widespread rain fell across the PMA. A total of 43 events in the PRI historical database (July 1, 1998, to May 31, 2014) were found to match this criterion. Of these events, the vast majority (88 percent) occurred during the fall to spring seasons. Only five events occurred during the North American monsoon.

Composite analyses for the identified heavy precipitation events were created using Earth System Research Laboratory reanalysis data. The typical pattern was found to be characterized by a deep anomalous upper level trough located over the southern California coast, a southwest intrusion of deep moisture (precipitable water generally in excess of 20 kilograms per square meter [kg m⁻²]), a strong southwest low level jet, and approaching upper level subtropical jet core (left exit region).

A DRIER MORE VARIABLE HYDROLOGIC FUTURE COULD MEAN DIVERSE BUT SPARSE RIPARIAN SYSTEMS

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The Santa Cruz River basin, Arizona, faces profound changes in
climate, land use and hydrology over the next several decades. The combined changes in the physical forcing of riparian ecosystems may induce profound changes in the biological and geomorphic services that society derives from riparian ecosystems in the basin. Recent climate simulations demonstrate that winter precipitation is likely to decline across southern Arizona, the trend for summer rain is more uncertain and that the duration and intensity of droughts might increase while extreme rain events (e.g., the 10 year storm) will likely become more intense. The changes in climate forcing when combined with projected population growth will likely result in river systems that are less perennial but also more frequently scoured out by geomorphically significant storm flows. This combination of drier mean conditions but more extreme flood events will likely have specific effects on riparian ecological communities which will result in significant geomorphic change in these riparian systems. In particular, more frequent floods capable of scouring vegetation will likely result in a more diverse plant community than if floods were less frequent. However, there will likely be a loss of wetland species and charismatic mega-flora such as *Populus fremontii* from the currently perennial river systems that will become intermittent to ephemeral in the future. Additionally these vegetative changes will probably reduce the riparian systems ability to resist geomorphic evulsions and thus have significant implications for the communities near the banks of these rivers.

**AA LEACH PAD COVER DESIGN AND LONG-TERM MONITORING RESULTS: A SUCCESSFUL RECLAMATION PROJECT AT A NEVADA GOLD MINE**

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Barrick Goldstrike Mine is located in north-central Nevada. The AA Leach Pad is a high-density polyethylene (HDPE)-lined gold heap leach operated from 1987 through 1999. At the end of operation the total area of the pad was approximately 91 hectares, consisting of 50 million metric tons of run-of-mine leached ore. In 2000 and 2001 the AA Pad was reclaimed using an evapotranspiration (ET) cover designed to limit meteorological infiltration through the leach pad. The ET cover consists of 1.1 to 1.7 meters (m) of fine-grained soil cover derived from salvaged topsoil or Tertiary-aged valley fill deposits (Carlin silt) placed over the leached ore. To monitor the ET cover’s capacity to store and release precipitation water, eleven near-surface (up to 2.4 m below ground surface) cover
performance monitoring sensor nests were installed in 2001 and three additional sensor nests were installed in 2005. Sensor nests were instrumented at various depths with water content, soil water pressure potential, and temperature sensors, and in the 2005 sensor nests - water flux meters. Sensor nest locations were chosen to represent the range of solar aspect, slope location, proximity to constructed runoff channels, and cover material types on the reclaimed heap.

Monitoring of sensor nests continued for 10 years. Data indicated that the cover is performing well, limiting net percolation through the pad to approximately 1% of precipitation. Net percolation is highly dependent on precipitation, with higher than average precipitation years (on average once every five years) accounting for the majority of measured percolation. Estimated net percolation rates from AA Pad drain-down data agree with the average of the sensor nest estimates; estimated net percolation was variable depending on cover material type and location such as aspect and proximity to drainage channels.

The AA Leach Pad is the first large-scale heap leach facility in the western United States which has been robustly monitored for a relatively long term. Results from the AA Leach Pad cover monitoring study indicate that ET cover system design should consider the expected performance resulting during wet year precipitation periods and also cover system variability and location.

RISK EVALUATION OF DAM ERODIBILITY

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In recent years, many dams have experienced significantly larger flood events than they were designed for. Significant scouring/erosion of foundation rock due to overtopping has been reported at several dam sites worldwide. As future floods are expected to be more severe due to climate change, dam erodibility is becoming a significant risk concern. Hydrologic and geologic systems are dynamic and heterogeneous, but our knowledge of geologic and hydrologic parameters is often limited, raising the concern of uncertainties in dam erodibility analysis. A probabilistic approach provides an objective analysis framework to account for uncertainties in the dam erodibility evaluation.

The empirical Erodibility Index method and the Comprehensive Scour Model are the most common approaches used for dam erodibility analysis. The data with erosion and no erosion show exception to the Annandale’s criteria, causing uncertain-
ty associated with the criterion. We address this uncertainty by defining a zero-percent erosion probability criterion and a 100-percent erosion probability criterion to cover the region where some data show erosion and some data show no erosion. For simplicity, we assume these criteria to be represented by lines parallel to the Annandale’s criteria. For a given erodibility index and stream power, the probability of erosion is computed by linear interpolation.

Experienced geologists generally use a Brunton compass to manually collect geological data in the field. Geologic exploration could be a major effort if the rock outcrop is not easily accessible. Recently, terrestrial light detection and ranging (LiDAR) and three-dimensional photogrammetry techniques have been used to obtain digital high-resolution rock outcrop data for estimating statistical rock joint properties. They provide a cost-effective way to collect large amount of reliable data to develop probabilistic input parameters, such as the pole density contours.

We analyzed the potential for scour based on a 22.3-meter (m) high concrete dam founded on granitic rock. During the Probable Maximum Flood (PMF) event, the dam is overtopped and the impinging water jet impacts exposed rock in the downstream left and right abutments and plunge pool. Monte Carlo simulations were performed for various hydrologic and geological parameters. We developed the geomechanical properties of the rock from measurement of joint data and rock strength, and developed statistical information for geomechanical parameters. The combined effects of variability in the geomechanical analyses and the extreme flood flow are presented.

INTEGRATION OF RAIN GAUGE AND DOPPLERRADAR DATA USING BAYESIAN NON-PARAMETRIC APPROACH

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Precipitation is an essential part of the hydrologic process. Accurate representation of the spatial and temporal distribution of rainfall intensity is critical to development of robust calibrated hydrologic models. Rainfall data are commonly collected using rain gauges and Doppler radar. Rain gauge data are more accurate but they only yield information at point locations. Radar data provide continuous spatial information pixel-by-pixel but they are less accurate. This paper presents a Bayesian nonparametric approach for integrating gauge and radar data to develop more accurate and continuous rainfall interpretation. In a Bayesian framework, the resulting probability distribution of rainfall intensity (posterior distribution)
at a location at a time step is computed from a prior distribution and a likelihood function. In this paper, the prior distribution is estimated by applying geostatistical methods to rain gauge data. The likelihood function is calculated based on the mismatch errors between the rainfall radar and rainfall gauge data where they overlap. A nonparametric approach allows rainfall spatial structures to be intensity dependent. At each time step, a range of rainfall threshold levels is considered. For each threshold level, rain gauge and radar data are encoded into indicator values with “1” denoting rainfall intensity greater than the threshold level. Radar data are used to characterize the correlation structure of the indicator field. Indicator Kriging using the resulting correlation model is applied to gauge indicator data to compute the prior estimate of the probability of exceeding the rainfall threshold. Fault table based on comparison of gauge and radar indicator values is used to compute the likelihood at a location. The resulting posterior estimate of the probability of exceeding the rainfall threshold represents the cumulative probability density function value corresponding to the rainfall threshold at the location. Available rain gauge and radar data in southwest Florida were used to demonstrate this data integration approach and to benchmark its performance.

AN ADAPTIVE RELIABILITY-BASED OPTIMIZATION FRAMEWORK FOR INTEGRATED MANAGEMENT OF WATER RESOURCES

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The Northern Tampa Bay region of Florida has undergone tremendous growth in water demands over the past 50 years. Under an Optimized Regional Operations Plan (OROP), optimization-simulation models have been used to manage interconnected regional wellfields. A new generation of the OROP being developed is an adaptive integrated water resources management model that utilizes reliability-based optimization techniques to generate water supply operation schedule for groundwater production, surface water withdrawal, regional reservoir, and desalination plant. It is also applied to long-term water resources planning. The framework accounts for the uncertainties associated with the prediction of future rainfall, water demands, surface water availabilities, baseline groundwater levels, and hydrogeologic properties. The primary management goal is to satisfy water demands while protecting wetland ecology and preventing seawater intrusion. The developed method maximizes the reliability of achieving performance goals. This presentation will provide an overview
of the framework and the generation of stochastic realizations of spatially and temporally correlated rainfall, water demand, surface water availability, and unit response matrix derived from an integrated hydrologic model that simulates the interacting dynamic between groundwater and surface water systems.

**IMPACTS OF WILDFIRES ON WATER SUPPLIES**

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Forested watersheds throughout the USA provide stable sources of streamflow for over 3,400 municipalities and another 3,000 water supply systems. In the past two decades wildfires have increased in numbers, size, and severity due to climate changes, fuel buildups, and increases in ignition sources. This trend has placed water supply systems at increased risk of damage due to water quality degradation, floods, sedimentation of reservoirs, and infrastructure damage. This paper examines water supply impacts from the Rodeo-Chediski, Hayman, Schultz, Monument, and other wildfires. Several case studies from these fires are presented that give an overview of potential water supply disruptions from wildfires.

**EXPLORING ALTERNATIVE WATER MANAGEMENT CONCEPTS IN THE PRESCOTT AMA WITH UPDATED GROUNDWATER FLOW MODEL**

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In 1995 the Arizona Department of Water Resources created a groundwater flow model to simulate hydrologic conditions in portions of the Little Chino (LIC) and Upper Agua Fria (UAF) Sub-basins in the Prescott Active Management Area (PrAMA). The model simulates groundwater flow conditions in the Upper Alluvial Unit (UAU) and Lower Volcanic Unit (LVU) aquifers. The PrAMA model was previously updated in 2002 and 2006; the current model update simulates a 72-year period between 1939 and 2011. Some of the more significant model updates include: 1) an expansion of the aquitard separating the UAU and LVU aquifers in portions of the LIC and UAF sub-basins; and 2) updated natural recharge rates that, with respect to previous model versions, apply higher rates during "wet" periods (i.e., mid-1970s to mid-1990s) and lower rates during "drier" periods (early 1940s to mid-1960s and mid-1995 to
The model update report provides transparency to the calibration by: 1) the presentation of inversion statistics, and 2) disclosing results of numerous alternative conceptual models (ACMs). Based on available data, the most plausible ACMs indicate that about 2/3 of total natural recharge occurs along major tributaries (Granite Creek, Lynx Creek, etc.) during significant streamflow events (i.e., 1993, 2004/2005, etc.). Based on current model stress-period intervals, periodic streamflow recharge along major tributaries occurred during only about 10% of the total 72-year transient simulation period.

The PrAMA model was used to explore hypothetical simulations of past (“what-if”) and future conditions, to better understand potential impacts of alternative pumping locations and schedules, induced recharge, baseflow capture, and storage loss over space and time. For example, hypothetical well fields and pumping schedules were examined to estimate induced recharge potential (resulting in a reduction in runoff) while minimizing the capture of groundwater discharge. In addition, the model was used to explore alternative, stress-period intervals (annual, seasonal, monthly, etc.) in order to estimate relations between streamflow residence time and simulated groundwater recharge. Along with using the PrAMA model to understand the system hydrology in general, the PrAMA model can also be used for planning purposes. For example the model can provide insight into the benefits and/or risks associated with siting a well field and/or recharge facility. Some of these benefits may include: 1) estimating increased recharge potential (induced recharge and/or capture of groundwater discharge in both a relative and absolute context) for different areas; 2) evaluating alternative well-field locations with respect to supply potential, pump-lift costs, and existing/future infrastructure; and/or 3) estimating where and when interim water sources (and associated risks) can be best used until more permanent supplies become available, while minimizing adverse impacts of stakeholder objectives.

AN INTRODUCTION TO MODFLOW-USG, AN UNSTRUCTURED GRID VERSION OF MODFLOW

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An unstructured grid version of the MODFLOW model called MODFLOW-USG has recently been released by the United States Geological Survey (USGS) to increase flexibility in grid
design for adding resolution where needed and better representation of geologic conditions such as pinched layers and fault offsets. Additional tools surrounding MODFLOW-USG have also been developed to create a comprehensive modeling platform for complete analyses of complex water resource issues. These include various grid generation schemes, graphical user interfaces (GUIs), particle tracking routines, zone budget modules, parameter estimation codes, and dual domain flow and transport simulation capabilities among others. MODFLOW-USG and associated tools are summarized in this presentation and its use in addressing various current modeling challenges is discussed.

POSITIVE IMPACTS ON GROUNDWATER RESOURCES SUBSEQUENT TO WILDFIRES IN THE LINCOLN NATIONAL FOREST IN NEW MEXICO

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National Forests in the southwestern United States have become increasingly susceptible to wildfires as a result of various processes, including long-term drought, destruction of trees by bark beetles, and overgrown forests. The 2012 Little Bear Wildfire in the Lincoln National Forest in New Mexico burned more than 44,300 acres of which about 35,300 acres were National Forest Lands. The fire impacted numerous watersheds, including nearly 99 percent of the North Fork Eagle Creek Watershed. More than 51 percent of the North Fork Eagle Creek watershed was classified as having moderate- to high-burn severity. Reduced vegetation and reduction in woody debris on the forest floor appear to have resulted in an increase in groundwater recharge to both the shallow-alluvial and deep-volcanic aquifer systems based on monitoring well and precipitation data. The data suggest that a more active vegetation management strategy within our National Forests could provide more reliable water supplies.
AGUA CALIENTE-THE ONCE AND FUTURE SPRING

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The Agua Caliente (AC) Spring, within the Agua Caliente Regional Park in the northeast corner of the Tucson Basin, near the base of the Catalina Mountains in southern Arizona, has historically provided water for a number of uses over many generations, starting with Indian settlements, pre-modern farming, and recreational and riparian ponds for a modern public. Artesian thermal spring flow originates from deep fracture systems within granitic and gneissic bedrock and also from alluvial/sedimentary units located above the bedrock. From early records, two springs were present, a “Hot Spring” and a “Cold Spring”. Together, the springs produced flow of up to 500 gallons per minute (gpm). Sadly, the springs were blasted in the mid-1930s, creating one spring with lower temperature year round and with reduced flows to 150 -300 gpm. The springs were again blasted in the early 1960s, cutting the flow to a maximum of 100 - 125 gpm. By 2000, they maintained 80-120 gpm, supplying three passive recreational ponds at the regional park for wildlife, bird watchers and recreationists escaping the Tucson heat. In the mid-2000s spring flow gradually diminished to what is now just a trickle. Since 2000 at least 12 exempt domestic wells were drilled within one mile of AC Park, in addition to a Pima County Parks onsite well, all tapping the same bedrock artesian aquifer. Prior to 2000 at least four other wells were drilled that tap the same artesian aquifer as the AC Spring. The current estimated amount of pumping withdrawal from the artesian aquifer could be as high as 70-80 acre-feet per year (AF/yr) or 45-50 gpm. Coupled with a significant reduction in rainfall from 2012-2013, this amount of groundwater pumping withdrawal may be responsible for the severe reduction of AC spring flow. Two geologic cross sections constructed from driller’s logs, and published geologic information, suggests a regional low-angle detachment fault is present below the Agua Caliente Park site, with granitic bedrock below the fault surface in non-conformable contact with Pantano clay, shale, and conglomerate sedimentary units, and a moderate veneer of alluvium. Flowing groundwater conditions are identified in several of the cross-section wells, with water emanating from bedrock fractures as deep as 520-1050 feet below land surface (bfs). Water quality sampling of the AC Spring and on-site AC Park well strongly suggests the waters are from the same source. The oxygen and deuterium data show almost identical values. Other indicators that show close similarity include total dissolved solids (TDS), hydrogen ion concentration (pH),
sulfate, fluoride, sodium and chloride. Water chemistry data plotted into a Piper/trilinear diagram indicates the spring and well water are both sodium bicarbonate-sulfate water types. Evaluation of the past 20 years of rainfall data for three AC Watershed rain gages has shown that spring and winter rainfall has diminished by 15-17% since 2001. Based on a 2013 water balance evaluation, seepage, with a rate of 0.047 feet/day, appears to be the largest water loss at 72% from the single remaining wet pond. As such, plans are being formulated to reduce the pond footprint, install a base lining system and also create a cienega area for aquatics. Additional pump tests on the spring and well are also planned.

THE EFFECTS OF EFFLUENT DISCHARGE AND CONCENTRATION ON INFILTRATION IN THE SANTA CRUZ RIVER

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Wastewater generated in the Tucson metropolitan region is conveyed to and treated at the Roger Road and Ina Road Wastewater Reclamation Facilities (WRFs). Since 2005, approximately 15,000 acre-ft/year has been treated to reclaimed standards and returned to the city for reuse. The remaining 48,000+ acre-ft/year is discharged to the Santa Cruz River (Arizona), where a variable portion of the effluent infiltrates the streambed. The effluent that infiltrates the streambed contributes to recharge credits for stakeholders invested in the Santa Cruz River Managed Underground Storage Facility (USF) and the Lower Santa Cruz River Managed USF.

In the effluent dependent river, physical, chemical and biological processes work in combination to develop a clogging layer near the streambed surface, which reduces infiltration. Previous studies have shown that large storm events have the ability to scour away the clogging layer and is the most significant process contributing to establishing infiltration rates. Without the occurrence of large storm events, other parameters affect infiltration to a lesser degree and could be categorized as environment conditions, human activity, effluent quantity, and effluent quality.

As part of the Aquifer Protection Permits (APP) and Arizona
Pollutant Discharge Elimination System (AZPDES) authorizations, effluent discharge flow, biochemical oxygen demand (BOD) concentration, and total suspended solids (TSS) concentration are monitored and recorded daily at the outfalls of the WRFs to the Santa Cruz River. The daily recorded parameters were investigated individually and in combination, using statistical analyses, to determine their correlations with streambed infiltration in the Santa Cruz River.

From 2005 to 2008, 16 dry periods were analyzed during the spring and autumn seasons. A water balance of the effluent discharge was constructed for non-stormflow days during each period. Evapotranspiration was calculated using riparian vegetation surveys and detailed delineations of aerial photography of the surface water and streamside herbaceous vegetation. Infiltration was derived from the water balance as the residual of the calculated evapotranspiration, the known WRF effluent discharges and the known outflow discharge from the study area at the Cortaro Road USGS stream gauge.

Infiltration rates are extremely variable which makes establishing confident quantitative relationships with the parameters of interest unattainable. The results do illustrate the various direct and inverse relationships between the two sources of effluent discharge sources, the two water quality concentrations, and streambed infiltration on a seasonal time scale. The constant and varying characteristics of the riparian vegetation are also discussed as contributing to infiltration in the study area.

The WRFs have since received upgrades and improvements to accommodate growth needs through 2030 and meet new standards for limits on water quality concentrations for effluent being discharged to the Santa Cruz River. The study provides an assessment of the effluent infiltration rates before the upgrade improvements and an analysis of how WRF management practices have an effect on an effluent dependent river.

ANTICIPATING THE FUTURE OF WATER DEMAND – A NEW APPROACH

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Much attention has been focused on understanding the factors of water supply uncertainty and their implications for water resource management. Unfortunately, less attention has been paid to the factors of uncertainty associated with demand and their impact on our ability to forecast or estimate future water demands. In the past simple water demand forecasts based on GPCD and population growth were adequate for most financial and water resource planning. However over
the last decade, increasing uncertainty in the factors driving demand has resulted in inaccurate forecasts, generating a number of financing and system operations issues. This presentation will discuss factors of future uncertainty for water demand and proposes a new approach to planning under high uncertainty which moves away from forecasting to embrace anticipatory governance.

**ALKALINE FLUSH TECHNOLOGY: AN IN SITU TREATMENT METHOD FOR MINE IMPACTED ALLUVIAL AQUIFERS**

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Alkaline Flush (ALF) Technology involves the introduction of an alkaline solution into an acid/metal impacted alluvial aquifer to adjust water/sediment pH and chemistry with the intent to achieve long-term in situ remediation objectives. Along with the reduction in groundwater and sediment acidity, this technology allows for precipitation of metals of concern into stable mineral forms significantly reducing their aqueous concentrations over both the short-term and long-term. Application of ALF technology may provide a “resiliency period” or an “acceleration period”. This technology offers an opportunity for remediation of alluvial aquifer systems at costs lower than those associated with other potential remedial alternatives. The estimation of alkalinity required for treatment requires an understanding of short- and long-term sediment acidity. We will discuss our observations on determining the amount and characteristics of sediment acidity, plus how this information would be used to implement the ALF technology.

**WATER USE AND SOURCES FOR OIL AND NATURAL GAS ACTIVITIES IN SIX WESTERN STATES**

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Water is essential to the development of oil and natural gas resources, and like many other industries, water represents a
critical component of the supply chain. Water supports a wide variety of oil and natural gas activities, ranging from well site construction to well drilling and completion, and enhanced hydrocarbon recovery. Unconventional oil and gas development represents the largest water demand because the process involves hydraulic fracturing of tight hydrocarbon reservoirs thousands of feet below the surface using water injected under high pressure. Since the water demand occurs only during initial well field development and is not sustained over the entire life of a project, most operators either purchase or temporarily lease water resources from other owners or providers to meet the development schedule.

Even though the demand from the oil and natural gas industry is not perpetual, many urban and rural communities are concerned that large volumes of water are being diverted away from limited supplies that are already stressed by drought or over-allocated i.e., there is no remaining water available to grant new water rights without affecting other users. This is of particular concern in western states that are experiencing the highest level of oil and gas development.

Responsible management of water resources is a priority for all users and is necessary for economic growth, community development, and healthy ecosystems. In order to engage in constructive dialogue regarding water management, understanding the volume of water diverted for oil and natural gas activities and the impact on other users is imperative. Therefore, a study was conducted to gather the most currently available information regarding the volumes of water used for oil and natural gas activities in Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming relative to other uses (agricultural, municipal, industrial, recreational, etc.). Results of the study indicated that agriculture represents the largest user of water in the six western states. For the states that measure total water withdrawn, water use for oil and natural gas activities totals 1 percent or less.

The water sources evaluated in this study include surface water, groundwater, irrigation water, water purchased from third party water providers or vendors, treated wastewater (municipal, industrial, or produced water from a centralized treatment system), produced water, and interstate water transfers. A summary of the regulatory requirements to use these water sources is also included with this study.
LOOKING AT LANDSCAPES: EYE-TRACKING STUDIES OF WHERE WE LOOK ON PHOTOGRAPHS OF GEOLOGIC SCENERY

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We often show photographs of landscapes to students and others in class lectures and other presentations. But does the audience pay attention to what we think they should? New studies using eye-tracking technology show precisely where we look at such scenes and how long we spend on each object or geologic feature. These studies demonstrate that we spend most time looking at the center of the image, regardless of where the geology should have led us. Also, novices in the field are heavily distracted by the presence of humans, animals, and human-made objects in photographs. Such distractors cause student to limit how much of the scene they inspect, to focus on the wrong things, and to learn less than they should. The results provide guidance to anyone preparing a presentation, including this one.

DIRECTIONAL DRILLING FOR MINE DEWATERING: EXTENDING OUR REACH

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A robust and effective dewatering program is critical in an active, open pit mine in order to minimize slope instabilities and to advance mining. Conventional advanced dewatering practices generally require vertical in-pit wells and/or sump and pump methods. Vertical in-pit dewatering wells typically have a limited life span of nine months to one year due to extraction or access loss. The vertical orientation of these wells limits the opportunity of crossing multiple fault or fracture zones which are groundwater conduits in a hard rock aquifer setting. Additionally, submersible pump availability is drastically limited due to operational interruptions leading to less groundwater withdrawal. Maintenance of infrastructure such as piping and surface pumps is labor intensive and cumbersome, and the annual costs required to operate a conventional dewatering program can be quite significant.

Because of the many challenges inherent with conventional mine dewatering, technologies normally associated with the oil and gas industry were tested at Freeport-McMoRan Inc.’s (FMI) Morenci Operations to aid in the dewatering of the Garfield pit. FMI partnered with Schlumberger Water Services (SWS) to construct a directionally drilled well (DDW) for the
The primary objectives of directional drilling for dewatering were to: 1) increase expected life of a dewatering well, 2) drill across multiple, highly fractured faults zones with one borehole for water production, 3) collar a well outside the pit limits and set the submersible dewatering pump below the pit shell to reduce operational interruptions, 4) reduce in-pit infrastructure and surface pumps, and 5) reduce costs over the long run associated with mine dewatering.

The DDW was completed in April 2013 and collared outside of the Garfield pit with the final depth and location of the completed well beneath the life-of-mine surface. The well (Well C) has a measured length of 2,406 feet, a total vertical depth of 1,728 feet, and a finished casing diameter of 9.625 inches. The trajectory of Well C crossed multiple groundwater sources resulting in an average groundwater yield of 650 gallons per minute. Additionally, because of the collar and well location, the pump availability was 96% during the first year of service. The high yield of this well has reduced the in-pit infrastructure by reducing the number of in-pit wells and the need for sumps. By reducing the number of in-pit wells, cost savings are anticipated for the remaining life-of-mine. The success of Well C has contributed significantly to more efficient mine dewatering that is required to advance the Garfield pit to the final pit bottom and indicates the possibility of expanding the use of replacing conventional mine dewatering with directional drilling throughout the Morenci Operations. This paper discusses directional well construction and the results of FMI’s pioneering efforts in advanced mine dewatering.

EVALUATING THE PERFORMANCE OF CMIP5 CLIMATE PROJECTIONS OVER THE COLORADO RIVER BASIN

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Climate projections from global climate models (GCMs) and the associated subsequent streamflow projections are traditionally assumed by water resource managers to have an equal probability of occurrence. This assumption is quite pervasive throughout the water resources community with minimal studies being performed to question which climate models are better suited to specific geographic regions. Determination of the most suitable climate model to project climate and streamflow information would be beneficial to water resource managers.
Given highly variable hydrology, topography, and runoff within the Colorado River Basin, it is important to understand the capabilities of various GCMs to capture historical climate variability. This study aims to evaluate the latest Coupled Model Intercomparison Project Phase 5 (CMIP5) projections with regards to the ability to capture/replicate historical climate conditions and patterns. This study aims to inform resource managers on methods to evaluate climate projections to better understand future climate conditions and the impact to surface hydrology. The knowledge generated through this study will allow water resource management agencies to better understand which global climate models may be more reliable for future projections.

ARIZONA PROJECT WET STEM PROGRAMS

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Water as a subject is universal. It is central to all of life, to energy production, manufacturing and agriculture. Crosscutting concepts in the Next Generation Science Standards make clear that the fields of science and engineering are mutually supportive. Technology and mathematics are integral parts of both subjects. **Science, Technology, Engineering and Mathematics (STEM) education is an interdisciplinary approach to learning which removes the traditional barriers separating the four disciplines of science, technology, engineering and mathematics, and integrates them into real world, rigorous and relevant learning experiences for students.**

Water is therefore an optimum theme for effective subject integration; essential for life and used indirectly to make just about everything. It is woven into the fabric of our existence here on earth. This session will demonstrate how Arizona Project WET (Water Education for Teachers) or APW programs offer real-world, rigorous and relevant STEM learning experiences that offer students an opportunity to develop critical and creative thinking skills, making them better prepared for today’s workforce.

In our programs, mathematical thinking skills are a focal point. Students measure and collect data, think through the variables of interest and develop equations, calculate answers, think through the conversion of units and analyze data graphically. Applied mathematics is an essential tool used to make sense of data and communicate effectively.

Engineering becomes understandable as the application of science and mathematics to solve real-world problems. Stu-
students learn engineering practices like listing criteria and constraints, developing models, using models to test designs, and iteration and retesting to find practical optimal solutions.

APW’s STEM programs model the purposeful use of technology too. Some programs utilize field equipment that chemists, hydrologists, aquatic biologists, soil scientists and biologists use regularly in their work. All programs model the use of computers. Excel is a focal point of instruction: from basic data manipulation, to inputting functions, to graphing data, to creating a model to test variables. Google Earth and Google docs are utilized to bring relevancy and real-world applicability into instruction. Prezi, an online presentation program, is utilized as a tool to record ideas, data, photos, videos and discoveries about their studies. Prezi is also enables users to link ideas to tell a story that is represented as an interconnected system.

Collaboration and communication too are important STEM skills for life. Students engaged in APW STEM programs refine their ideas and position working closely with their peers. They work together to find solutions to relevant challenges; work that involves the exchange of ideas, knowledge and/or resources to achieve a goal. Collaboration also requires perseverance, patience, listening and speaking skills. APW reaches tens of thousands of students each year with STEM experiences.

DISTRIBUTION AND IDENTIFICATION OF FACTORS INFLUENCING RATES OF MANGANESE CONCENTRATIONS IN GROUNDWATER IN LEBANON, CONNECTICUT

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Manganese is naturally occurring in the environment (both in rock and soil) and is essential for good health. However, high concentrations of manganese in groundwater can have serious health implications and has been known to be toxic to the nervous system. Although manganese is ubiquitous in drinking water in the United States, the rate of release from soil or bedrock is largely overlooked in many rural areas that principally rely on groundwater from fractured bedrock wells. As such, domestic well owners are strongly encouraged to test well water regularly to ensure manganese concentrations do not exceed the drinking water action level. In Lebanon, Connecticut, the majority of the residents obtain drinking water from domestic wells and many residents currently have filtra-
tion systems installed. In cooperation with the Connecticut Department of Energy and Environmental Protection, Connecticut Department of Public Health, and the town of Lebanon, approximately 100 domestic bedrock wells were sampled and analyzed for manganese prior to any treatment. To estimate the rate at which manganese has leached from the bedrock and examine the possible factors that contribute to these varying rates, current concentrations were compared to historical water quality analyses of these same bedrock wells which typically occurred when the wells were drilled. These factors include, but are not limited to, natural bedrock and soil conditions as well as anthropogenic factors associated with urban development.

**TECHNICAL, PERMITTING, AND LEGAL ASPECTS OF REPLACEMENT WELLS IN ARIZONA’S ACTIVE MANAGEMENT AREAS**

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Thousands of Non-Exempt wells in Arizona’s Active Management Areas (AMA) will likely be replaced in the next several decades as older wells develop structural, capacity, or water quality problems, and as urban development encroaches onto irrigated lands, resulting in re-location of wells and conversion of well sites to municipal use. Placement of new wells in developed areas is challenging because available land is limited and well spacing rules restrict pumping capacity in many locations for new wells. Thus, the technical, permitting, and legal aspects of replacement of non-exempt wells must be factored into water resource assessments for irrigation districts, municipalities, land developers, and consultants.

Many wells in Arizona were drilled for irrigation purposes using older technology. To select a drilling technology and materials for a replacement well, many factors must be evaluated, including: site-specific hydrogeologic conditions; well diameter and required production capacity; planned well use; projected well life span; and logistical issues, such as waste disposal and drilling site size.

Replacement well permits fall into two categories: replacement wells in new locations, and replacement wells in approximately the same location (R12-15-13). Permits for replacement wells in new locations are located more than 660 feet from the original well; these wells must undergo an analysis of impacts to surrounding land or other water users in the area; however, the rule language specifies that offsets in groundwater withdrawals between the original and proposed wells
could potentially be considered in the analysis. Replacement wells in approximately the same location are located within 660 feet of the original well and are not subject to an impact analysis, but are limited to the permitted annual withdrawal amount from the original well.

The majority of wells that are likely candidates for replacement were installed prior to enactment of the Groundwater Code in 1980. These “pre-code” wells are not subject to the well spacing rules (R12-15-13), finalized in 2006. Replacements for pre-code wells are limited to an annual production volume equal to the registered “maximum pump capacity” of the original well for continuous pumping. The information contained in the State well registry for pre-code wells is often inaccurate and may not reflect the actual maximum capacity. Thus, to preserve the well owner’s withdrawal entitlement at a given well site, the construction and pumping records for the original well should be evaluated to determine if the information on file should be corrected.

In cases where a third party requests abandonment of a well to accommodate proposed development, the well owner will typically seek to limit risk by requiring the third party to be responsible for providing a replacement well meeting the owner’s requirements. Recent precedent has established that the construction parameters of the original well do not comprise the full extent of requirements; rather, well capacity and water quality are the primary requirements that must be met for owners to accept replacement wells.

A GENERAL OVERVIEW OF DIRECTIONALLY DRILLED HORIZONTAL REMEDIATION WELLS AND THE BENEFITS IN ENVIRONMENTAL REMEDIAL APPLICATIONS

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Directional drilling was invented in the 1920s for the oil field industry to increase oil production and later adapted for utility installations in the 1990s for installing pipelines and conduits. Now, directional drilling is used to install horizontal remediation wells (HRWs) for the environmental industry to cost-effectively remediate large subsurface areas, even within active and complex industrial sites, which is difficult if not impossible with traditional vertical wells or other in situ approaches.

Because of the ability to cross under roadways, railroads, building foundations, pipeline and utility corridors, and other surface or subsurface structures, horizontal wells are effec-
tively being used in environmental remedial applications at often active industrial sites or other contaminated sites for air sparging, biosparging, bioventing, in situ chemical oxidation, soil vapor extraction, landfill leachate collection, landfill gas collection, free product recovery, and soil sampling for site assessments. Moreover, since the effective radius of influence of a properly designed and installed well is along the entire length of screened interval of the horizontal well, a single horizontal well can effectively treat an area that would otherwise require multiple vertical wells saving time and money. This session provides an overview of HRWs and discusses the benefits of environmental applications.

NATURALLY-OCCURRING METALS CONCENTRATIONS IN MICHIGAN SOILS: A 2014 SURVEY

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Closure of hazardous waste sites can be aided through the use of a soil survey of naturally-occurring metals and metalloids (hereafter simply referred to as metals). Numerous previous studies have addressed naturally-occurring metals in soils. Data for these studies came from either field sampling or publicly available environmental files. Two previous studies were conducted in Michigan to report naturally-occurring metal concentrations in soil. Known as the Michigan Background Soil Survey (MBSS), the first study was published in 1991. After acquiring more data, a second study was published in 2005. The first study looked at 16 metals and the second study looked at 25 metals. Both studies differentiated data by soil type and glacial lobe. Basic statistics were applied to each dataset. Statistics reported in the 2005 survey include: mean, standard deviation, minimum, maximum, range, and distribution. For data below detection limits, one-half the detection limit was used.

A new study has been started and will look at the same 25 metals from the 2005 survey with the addition of boron (metalloid). Data will be separated by soil type and glacial lobe in this study as well. Basic statistics used in the 2005 survey will be used along with looking at variance and goodness-of-fit tests. Analysis of data from the new study will go into greater detail than the previous studies in Michigan. Although data have been collected throughout the whole state, due to limited time, southern Michigan has been chosen to be looked at in greater detail. Spatial distribution of each metal will be mapped and displayed to observe any trends. Data will be compared to a bedrock map to examine any spatial patterns. Also the influence, if any, from drift thickness will be stud-
ied. Preliminary results show that bedrock has an influence on naturally-occurring metals concentrations in soils. Areas with Coldwater Shale for bedrock have higher occurrences of arsenic (metalloid) in soils.

**EVALUATING EROSION RISK MITIGATION FROM FOREST RESTORATION TREATMENTS USING ALLUVAL CHRONOLOGY AND HYDRAULIC MODELING**

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Severe wildfires in the forested, arid southwestern United States make watersheds highly susceptible to post-fire flooding, sediment transport, and debris flows. Wildfires have increased in size and severity due to land-use practices, including fire suppression, throughout the twentieth century, and climate change that has increased the occurrence of drought. Forest restoration treatments are being planned and implemented to reduce risks of severe wildfire and subsequent flooding and erosion. The Four Forest Restoration Initiative (4FRI) is a large scale forest thinning project being planned by the United States Forest Service and collaborators on ~6,070 square kilometers (km²) of federal land in the Southwest. Due to excessively steep terrain and non-market-supported logging costs, two high risk watersheds in the Coconino National Forest near the city of Flagstaff, Arizona, will not be restored through 4FRI. The city is planning the Flagstaff Watershed Protection Project (FWPP) to restore forested watersheds feeding a vital city reservoir (Lake Mary) and upslope of city infrastructure and residential areas at risk of fire and post-fire flooding (Dry Lake Hills).

Schultz Creek is a 17 km² drainage network within the Dry Lake Hills area contained by the Rio de Flag watershed which flows through densely populated residential areas and the cultural center of Flagstaff. Previous studies and local catastrophic wildfires provide evidence to suggest that runoff from post-fire monsoonal precipitation could result in flooding 2.2 to 6 times greater than the pre-fire 100-year flood, with costly damages caused by hyperconcentrated flows and erosion.

This study uses the US Army Corps of Engineers’ Hydrologic Engineering Center’s River Analysis System (HEC-RAS) to model hydraulics and sediment transport resulting from post-
fire runoff in various forest density conditions in the Schultz Creek watershed. The purpose is to compare storm water hydraulics following a catastrophic wildfire in an untreated forest with storm water hydraulics following FWPP treatments. Geomorphic mapping, sediment profile descriptions, sediment analysis, and radiocarbon dating of macroscopic charcoal were employed to develop an alluvial chronology and to approximate the volume of stored sediments along the axial channel that could be mobilized during high peak flows. Sediment availability is a major control on the degree of erosion and sediment transport, and studies of post-fire sediment yields in the Southwest have revealed about 75% of coarse-grained sediment yield comes from channels (as opposed to hillslopes). This study outlines a specific set of methods that can be used to estimate stored sediments in steep, ephemeral channels to improve effectiveness of post-fire erosion mitigation as well as forest treatment planning.

THE BURMISTER SYSTEM OF SOIL CLASSIFICATION: HISTORY AND APPLICATION

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The Burmister System of soil classification was first proposed in 1941 by Donald M. Burmister (1895-1981), a native son of Prescott, Arizona (territory and state), as a means of characterizing native soils for use in earthen dams, as highway sub-grade, or foundations, based on field observations and grain size analysis. The elements of Burmister’s original system are (1) a visual appraisal of the grain size in terms of the predominant grain size: gravel, sand, silt (non-plastic fines), and clay (plastic fines); (2) fineness or mean grain size, calculated as a geometric mean; (3) dispersion, a measure of geological sorting, and (4) shape of grading curve, roughly a measure of geological skewness. Items 2-4 are based on semi-log graph paper. Item 1, the visual appraisal, specifies the predominant size fraction (gravel, sand, silt, or clay), with the subordinate size fraction modified by the descriptors “and” (40-50% abundance), “some” (20-40%), “little” (10-20%), or “trace” (0-10%). For a variety of reasons Burmister’s system never achieved the formal recognition of competing classification systems developed before and after, such as the U.S. Bureau of Soil (1890-1895), the Wentworth Scale (1922), Public Roads classification (1927-1929), Unified System (1953), the Soil Conservation Service (SCS - 1954 onward), and others. With the advent of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980, Burmister’s system was quickly adopted by the environmental services industry for site characterization through the intensive use of test boring contrac-
tors who had used the system for geotechnical evaluations. Burmister’s system is commonly combined with elements of other systems, most notably the Unified and SCS systems.

One of Burmister’s most significant, but perhaps least known achievements, was his evaluation of the soils underlying the White House prior to its renovation during the Truman administration (1948–1952). By 1948, the ceiling of the White House Blue Room was dangerously near collapse, which prompted the renovation. At the time, the White House walls were supported by shallow footings at a depth of roughly five feet in sand with interbedded silt and clay. The renovation called for a complete interior demolition, with new construction to include a significant basement that doubled as a fallout shelter. The new construction required that the exterior walls be underpinned to a depth of 25 feet, in a layer of gravel. Would the gravel support the foundation of the rebuilt White House? Burmister elegantly demonstrated that the gravel would do the job, and the rest is history.

Selected References:


REMOTE CONTROLLED MONITORING FOR MINE CLOSURE

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As mines are following the path of reclamation, quality of water becomes an important focal point as flow paths run through the mine site and continue to downstream ecosystems. After a site is reclaimed, there is a need for the continued monitoring of water quality, which becomes costly and uneconomical if done through human sampling methods. A graduate research study is in place at an Arizona mine to indefinitely and automatically monitor water quality downstream of a pregnant leach solution (PLS) retention dam. The system uses a suite of sensors to monitor parameters such as hydrogen ion concentration (pH), dissolved oxygen (DO), oxidation-reduction potential (ORP), conductivity, temperature, and ion concentrations of copper and selenium. This poster session will give an outline of the system and a general hypothesis on current parameter levels and what we expect to see after further testing of system, including system reliability and future implications.
INVESTIGATION OF AN OIL SHALE FIRE AT WINDFALL MOUNTAIN

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An Initial Assessment of an In Situ Formation Fire

In late September of 2012, smoke was reported on a ridge visible from the Yukon River in Yukon-Charley Rivers National Preserve in east central Alaska. By October, the smoke had been reported not as a wildland fire, but some sort of “geologic event”, as it appeared that the ground itself was smoking.

National Park Service employees conducted a site visit on July 18, 2013. The goal of the site visit was to ascertain if the fumes from the fire could pose health hazards to residents of Eagle. Additional objectives were to collect data to characterize and identify formation properties that could determine the possible cause of combustion.

Procedures employed while on site included the use of an infrared thermal imaging scope to safely approach active formation fires. Continuous gas monitoring of seven gases most likely to be products of combustion at an oil shale fire were monitored to determine the nature of, and hazards posed by, gases emitted. Temperature probes were used to measure temperatures of the ground where active emissions were occurring. Temperatures recorded in active fissures ranged from 140 to 285 ºC. Samples of the shale formation were collected for future analysis. Photographs of the site were taken while on the ground and include unburned portions of the shale formation in-place, as well as slumped blocks of strongly weathered shale showing sulfur staining and a high degree of fissile fracture.

GROUNDWATER UNDER THE DIRECT INFLUENCE OF SURFACE WATER, CITY OF CHARLOTTE, MICHIGAN: A CASE STUDY

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The Surface Water Treatment Rule (SWTR) introduced groundwater under the direct influence of surface water (GWUDI) over 20 years ago. The concept of GWUDI is that certain groundwater sources that receive recharge from surface water bodies may be at risk for contamination by Giardia and Cryptosporidium. Sources deemed GWUDI are considered as
surface water sources and are required to provide filtration to remove these microorganisms. In the SWTR, the EPA defines GWUDI as: “Any water beneath the surface of the ground with significant occurrence of insects, other macroorganisms, algae, or large diameter pathogens such as Giardia lamblia” or “Any water beneath the surface of the ground with significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH that closely correlate to climatological or surface water conditions”.

The city of Charlotte, Michigan, operates three water supply production wells. The well field is situated in glacial outwash deposits near the Battle Creek River. Relying upon historical total coliform bacteria results, the Michigan Department of Environmental Quality (MDEQ) made a regulatory determination that all three wells were GWUDI. To address MDEQ concerns, and to eventually convince MDEQ to reverse their decision, the consulting firm AMEC, on behalf of the city, undertook a year-long study of the wells and river by measuring temperature, conductivity, pH and turbidity weekly and microscopic particulate analysis (MPA) monthly.

The wells were tested using combinations of the criteria specified by US Environmental Protection Agency (USEPA) (site specific, MPA, turbidity, conductivity, pH, temperature). The MPA data present scores of low risk in most tests. Data from the well field as well as other locations within the State of Michigan were used to support the conclusion that the wells are not GWUDI. These data, along with the potential financial implications of the MDEQ’s determination and will be presented and discussed.

FLOODING, EROSION, SEEPAGE AND TREATMENT: BALANCING RISK AND COSTS IN MINE CLOSURE DESIGNS

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Mines worldwide are examining closure alternatives for leach heaps, tailings, mine waste and other facilities. These closure plans can include long term flood management, erosion of cover materials, seepage of impacted solutions and water treatment. Capital and Operation/Care and Maintenance (O&M) costs are staggeringly high. The closure design needs to carefully select approaches, designs and criteria that balance risk of failure with capital and O&M costs. The paper
explores both qualitatively and quantitatively how closure op-
tions can be impacted by: site and materials characterization;
engineering judgment and precedent; risk evaluation; choice
of environmental return periods (e.g. earthquakes, storms, wet
periods, droughts and perturbations to the dataset); factors of
safety; assumed facility life; level of maintenance and operator
error; and robust designs.

USING SPECTRAL REFLECTANCE SIGNATURES TO DIFFERENTIATE BETWEEN BENNETT REEF LIMESTONE BEDS

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Spectral reflectance scans of limestone aggregates provided by the Kansas Department of Transportation (KDOT) and de-
ervived from four individual beds of the Permian Bennett Reef Limestone Member of the Red Eagle Limestone collected
from the Whitaker Quarry in Winfield, Kansas, appear to have unique curve reflectance intensities and patterns. We have
concluded that it may be possible to differentiate between different limestone beds using spectroradiometer reflectance
data and, therefore, be useful to KDOT to more quickly iden-
tify specific limestone beds.

STATISTICAL ANALYSIS OF LEFT-CENSORED GEOCHEMICAL DATA

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Geochemical datasets frequently contain left-censored data, i.e., the actual concentration falls in the range between 0 and
the detection limit (DL). These data are referred to as nonde-
tects (NDs). An ND does not necessarily mean the analyte was
not present but, if it was present, it was at a concentration
below the DL. In addition to NDs, contract labs often report
estimated values (often flagged with a “J”) which lie between
the DL and the reporting limit (RL). The RL is the level at or
above which the lab will state the result is quantitative. A com-
mon approach to statistically analyzing left-censored data
is to use substitution (e.g., ½DL). Although still a common
practice, substitution can introduce bias to statistical analy-
theses. Fortunately, there are a number of statistical techniques
specifically designed to handle left-censored data that do not
compromise the results of statistical analyses by using substitution. All of these techniques work with NDs and some work with estimated data. There are a number of techniques for calculating summary statistics for left-censored data including nonparametric Kaplan-Meier survival statistics, regression on order statistics (ROS), and the Turnbull interval-censored method. As the name implies, the Turnbull method works with interval-censored data (i.e., quantitative data ≥ RL, DL-RL [estimated], and 0-DL). In the latter two cases, an interval is used, i.e., the true value lies somewhere within the interval but picking a single value such as ½DL is not required. Interval-censored data can also be used on nonparametric, multivariate ordination techniques such as nonmetric multidimensional scaling (NMDS) and the interval-censored score test—an analog of the generalized Wilcoxon test. Kendall’s tau (\(\tau\)) is a nonparametric correlation analysis that can be applied to left-censored data. For this test, the estimated (J-flagged) values are used. Kendall’s \(\tau\) is analogous to the familiar parametric Pearson’s \(r\) and, like Pearson’s \(r\), the test for Kendall’s \(\tau\) also provides a measure of the correlation significance. The case study for this presentation will include the geochemical data and statistical results from the Hawaii Ordnance Reef Follow-Up investigation of the U.S. Army’s Remotely Operated Underwater Munitions Recovery System.

WATER DEMAND PLANNING: A MUNICIPAL PERSPECTIVE

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Chandler recently completed its 2014 Water Demand Update. The Update refined Chandler’s build out water demand forecast using updated water use data, future residential housing units, and future non-residential floor space. Chandler uses economic development and planning forecasts to project activities related to growth and redevelopment. Each one of these on-going activities were created with a specific purpose, and integrating them with water planning required meaningful two way communications across departments within the City. All forecasts have uncertainty and are biased to reflect the area of interest. The paper describes the procedure used to adapt the various non-water demand forecasts into the water demand forecast, and how future uncertainties are considered in water demand forecasting.
SIMPLIFIED MODEL OF BANK FAILURE AS A FUNCTION OF GROUNDWATER/RIVER STAGE DYNAMICS

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River stage changes create groundwater waves that can destabilize the banks and lead to significant, sometimes catastrophic failures. In particular, these failures are a critical part of the river system dynamics downstream of hydroelectric dams in places such as the Colorado River in the Grand Canyon. This paper describes a simple solution to the groundwater wave equation. The solution allows arbitrary river stage change functions, thus allowing long and varied time records to be considered. Coupled with a simple bank stability model, a full river stage / bank failure risk model is established. The model is then applied to the Colorado River in the Grand Canyon and shown to accurately predict bank failure rates.

SOME ISSUES IN GROUNDWATER MODELING


Models come in a variety of forms, from conceptual models and physical models to computational and numerical models. The focus here is on numerical models that solve sets of equations (conservation laws, equations of state, constitutive relations) that describe the flow of water, energy and other components in the subsurface. Such models are helpful in a number of ways – they combine disparate types of information about a site into a single entity that can test the consistency of data sets, can estimate the relative importance of difference processes or properties, can make predictions (after proper calibration) about future behavior, and form the basis for optimization and management of resources. There are lots of models available, some as freeware (for example, the United States Geological Survey [USGS] and United States Department of Agriculture [USDA] suites of models) but many advanced models are developed in-house. Having a computational model is only part of the solution to an application modeling effort – having the knowledge and experience to know how to use models appropriately is equally, if not more, important. Earlier hydrologic models were fairly simple, but as methods to obtain more data developed and evolved, and...
as areas of application expanded to diverse disciplines such as oil recovery, mineral evolution in aqueous environments, mining, greenhouse gas evolution in landfills, and remediation of contaminated water supplies, models have become more complex.

Major areas of groundwater modeling research are centered on dealing with sparsity of data, accounting for multi-scale heterogeneity in the subsurface, coupling flow with chemical and biochemical processes, and inversion (calibration). There are models that have outstanding chemical/biochemical capabilities but simple flow capability, such as the USGS PHREEQC code, and models with extensive flow (multi-phase, multi-component, multi-dimensional) capability but limited chemistry. The availability of multi-processor computer systems allows coupling the best of both capabilities. Sparsity of data is a common problem at many sites, partly due to the costs involved. Fortunately, for some applications, the needed answers are not greatly sensitive to small-scale heterogeneity, although in many cases, it must be accounted for. Sensitivity analysis can indicate how much data is needed, and where it should be sampled, to provide reliable answers. Methods for determining sensitivity of flow rates, concentrations and temperature to properties of a site and to boundary conditions and injection/extraction schedules, for example, include both statistical and stochastic methods as well as deterministic. The adjoint method is an efficient tool for creating sensitivity maps. It has been used in various disciplines with considerable success. Interval methods, although not as well known, are another powerful method useful not only for sensitivity analysis for also for inversion/calibration applications. Inverse problems require careful treatment. First, it is important to determine if a unique solution actually exists for the given data set and site conditions. If not, it is usually possible to determine what additional information is needed to provide a unique solution, or at least to assign a probability to each solution. Examples are given to illustrate these methods and issues.

THE VIRTUE OF FLUX MEASUREMENTS DURING HYDRAULIC TOMOGRAPHIC SURVEYS

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The approaches to the performance of pumping test analyses are evaluated based on the agreement between observed and estimated data. Many of them consider head/drawdown
data, while others take hard data (i.e., local measurements of parameters such as hydraulic conductivity) into account. Flux data, however, are rarely considered. Fluxes (= advective velocity * effective porosity) control the transport of solute in groundwater systems and it is much more sensitive to the presence of fracture channels than head. Moreover, as a source of redundancy of data, the principle of reciprocity holds for heads but not fluxes in confined aquifers. This suggests the use of a combination of head and flux measurements may be beneficial.

Hydraulic Tomography (HT) has been proposed as a method for characterizing aquifer heterogeneity. During an HT survey, an aquifer is sequentially stressed at various locations while responses at other locations are monitored. An inverse model is then used stochastically to incorporate all the observed data to provide a best, unbiased estimate of the hydraulic parameter fields of an aquifer model. A new HT method is developed for conditioning hydraulic parameter estimates with both head and flux measurements. Using numerical experiments, we conclude that inclusion of flux in HT greatly improves the detection of fractures, and significantly improves the predictions of layered systems with multiple scales of heterogeneity. These results suggest the application of flux profiles should not be limited to resolving heterogeneity along a borehole or to imply connectivity between boreholes. Rather, they should be considered as a field and be inverted jointly with head measurements. The use of a mixture of flux and head measurements for HT may reduce redundancy and lower the data requirement for generating high resolution maps of hydraulic conductivity.

HYDRAULIC TOMOGRAPHY: LET DATA TELL THE STORY

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Hydraulic tomography (HT) is an innovative approach for groundwater aquifer characterization (Yeh and Liu 2000). It involves collecting responses throughout an aquifer due to a sequence of overlapping aquifer tests and then calibrating a heterogeneous groundwater flow model using the observed responses from all the tests. Multiple sets of aquifer tests and their observed responses improve the groundwater inverse problem because they cross validate each other. As a result, the estimated hydraulic property fields become more detailed and less uncertain than those computed from a single set of data (i.e. traditional pumping test analysis).
Here we discuss some of the lessons learned from two recent field demonstrations of hydraulic tomography. At the Mizunami Site in Japan [Illman et al. 2009], we conducted HT analysis on a kilometers-wide fractured system. The wells installed by the client are not evenly distributed. This allows the discovery of faults and fractures at multiple scales. The features identified by HT agree with those found in prior geological studies. Yet they are irregular in shape and reflect more directly the variation in hydraulic parameters.

At the North Campus Research Site (NCRS) in Waterloo, Canada [Berg and Illman 2011, 2013], ten wells are installed in a square pattern. Well clusters or inflatable packers are used to isolate local pumping/observation intervals. A series of pumping tests was conducted at nine of the intervals while the drawdown responses were recorded at the others. The differences and similarities in the responses of the independent pumping tests provided numerous pieces of information on aquifer heterogeneity. In this presentation, we discuss qualitatively what some of them imply, and demonstrate that HT is a logical way to systematically incorporate these pieces to provide a reliable estimate of the hydraulic parameter field.

**IN SITU COPPER MINING**

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Excelsior is developing a large in situ recovery (ISR) copper project in southeastern Arizona. The results of the recent prefeasibility study indicate that the project has the potential to be one of the lowest cost producers of copper cathode in the United States; capital costs are also industry leading. The project’s remote location presents very low permitting risk; and the ISR mining method offers the potential for full remediation, making this one of the most environmental friendly mining projects in development today. Commercial production is to commence in 2017.

**DEEP GROUNDWATER FLOW THROUGH INTERCONNECTED FRACTURE NETWORKS**

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While many parts of the near-surface water cycle have been
well-studied, the flow of water at depth is not as well understood. Groundwater tables are often drawn without a lower limit because we do not know the depth range of many groundwater systems. Furthermore, while meteoric waters tend to flow down from the surface, magmatic waters flow up from depth, and the intersection between these two water systems needs to be studied in more detail. We are studying the nature and flow of deep groundwater, primarily with the goal of identifying new fresh groundwater resources but also of understanding the interaction of meteoric and magmatic waters. We have identified four hydrological anomalies that are consistent with the existence of fresh groundwater at depth. These are (1) tectonic evidence of groundwater flow under mountains, (2) geochemical findings of inter-basin flow of water through mountains, (3) detection of aquifers under ancient river beds, and (4) the possible occurrence of freshwater flow in submarine canyons on the continental shelf. We are testing the hypothesis that these anomalies can be explained by the existence of deep groundwater flow through fractured rock.

We hypothesize that precipitation in tectonically active mountain regions can penetrate deep beneath the mountains by traveling through faults and fractures. These faults and fractures would then connect at depth with high-permeability, laterally extensive layers in sedimentary basins. Because the basins are regularly supplied by rainwater, they would constitute a renewable water resource. Prime candidates for areas where deep groundwater resources might exist are Mount Shasta (California), Cyprus, Oman, Spain, and Afghanistan. These regions have tectonically active mountain ranges, as well as a current societal need for more water resources. Our review of the literature on rock and fault mechanics demonstrates that in such regions, fracture networks can be created and maintained over geologically significant periods of time. We have also found several studies documenting inter-basin water flow at depth in a variety of structural settings using an array of geochemical parameters. For the regions outlined above, we will be using water budget calculations based on satellite data, in situ geophysical testing, and computer modeling to assess the potential for the existence of new, freshwater resources at depth. While these five regions are our primary target sites, the methods used can be applied to other places in the world with mountainous topography.

If a significant amount of water is flowing at depth, it would have a serious impact on our concept of the water cycle and freshwater budget calculations. Aside from the societal benefits of discovering more freshwater resources, we hope to develop a more comprehensive understanding of fluid flow through fractures as well as the larger scale of groundwater regimes. The anomalies discussed above give clues to the nature of this deep flow. Exploring it in the context of highly faulted mountainous areas has provided several important,
initial insights into the extent of deep groundwater and its properties.

PLAYA LAKES WATER RESOURCE ASSESSMENT AND IMPLICATIONS FOR OGALLALA AQUIFER RECHARGE

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The Texas Water Development Board (TWDB) is studying the water resource potential of playa lakes in the Texas High Plains in partnership with the US Department of Agriculture (USDA) - Agricultural Research Service (ARS) and Texas Tech University. Phase 1 of the TWDB research seeks to measure the volume of water available in playas and current recharge rates from playas into the underlying Ogallala Aquifer.

As part of Phase 1, the flooding history of 72 playas was reconstructed for an 18 year period of record using geographic information systems (GIS) analysis of Landsat imagery. The results indicate an average annual total volume of water collected in Texas playas of 191,000 acre-feet. The average daily volume of water in playas declined from approximately 95,000 acre-feet in 1996 to approximately 25,000 acre-feet in 2014. Similar trends are observed for larger watersheds in the High Plains, including Lake Meredith and Lake Mackenzie, and have been associated with the Pacific Decadal Oscillation (PDO) and Atlantic Multi-decadal Oscillation (AMO). The period of record for the current study is not long enough to resolve the full cycle of these global-scale climate variations.

Current recharge rates were estimated from monitoring data for 47 separate flood events at 23 playas. Infiltration rates varied from zero to over 40 millimeters per day (mm/d), averaging 7.5 mm/d. The measured infiltration rates were typically highest for the smallest flood events where a larger fraction of the flood water was taken up to replenish soil moisture. Modeling and tracer studies to assess deep soil moisture movement are in progress.

Phase 2 of the TWDB program will assess the effectiveness of playa modifications to increase recharge. Given the scarcity of surface water resources on the High Plains, playa modifications will focus on playas that collect the greatest volume of water and where the water can be utilized in a manner that maximizes its productive value. The remote-sensing methods developed in Phase 1 offer a means to quickly screen candidate playas on the basis of an initial field topographic survey and satellite image analysis.
FRIENDS OF TONTO NATIONAL FOREST

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Recently formed, the not-for-profit Friends of Tonto National Forest (FTNF) has taken on the mission of continuing the Riparian Photo-Point Project initiated by the Tonto National Forest. Thirty plus volunteers now gather under the banner of FTNF to collect photographic images of the streams and water courses that run through the forest. Photo point monitoring uses photographs of a landscape, taken at the same place, at the same time of year to document the changes that take place over time.

The Riparian Photo-Point Project which began in the 1980s has gathered thousands of images taken by over one hundred volunteers at more than 1200 permanent photo point locations to document baseline conditions and monitor changes in riparian vegetation and stream channel condition over time. The goal of FTNF is to continue to this process so Arizonans of the future can look at the Tonto National Forest as a living ecosystem changing and not changing as time passes.

PATTERNS AND TRENDS IN MUNICIPAL WATER DEMAND: IMPACTS OF CHANGING TASTES, TECHNOLOGIES AND DEMOGRAPHICS

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Two ongoing studies in Pima and Maricopa counties (Arizona) have attempted to improve understanding of trends in residential water demand by taking a broad, integrative approach and considering over a dozen factors of water demand. Particular attention has been paid to efficiency standards for appliances and fixtures, socio-demographic trends, changing tastes in landscapes, and the declining popularity of backyard pools.

The project also is considering factors that trigger changes in water demand, such as actions of new home owners and home flippers, and reactions to breakdown or obsolescence of water-using appliances and fixtures. A wide array of data sources has been tapped, including assessors’ databases over more than a decade, 20 years of building permit data, records of new and existing home sales, census and other socio-demographic data, and remote sensing data.
Preliminary findings include:
1. Indoor water demand is becoming more seasonal, while outdoor demand is becoming less seasonal.
2. Adoption of horizontal axis washing machines is reducing indoor demand but remains limited by their higher cost.
3. Homeowners are abandoning, reducing and converting turf and winter over-seeding is waning.
4. New swimming pools are becoming less common, their average surface area is shrinking, and there is a small but growing trend in removing existing pools.
5. Except in lower-valued homes, evaporative coolers soon will be largely replaced by air conditioning units.
6. “Home flipping” results in more water-efficient fixtures and appliances and reductions in irrigated landscaping.
7. Voluntary efficiency standards have become de facto standards for some appliances such as dishwashers.
8. Mandatory efficiency standards for fixtures in certain large states, such as California and Texas, can become de facto standards in smaller neighboring states.
9. Household size appears to have stabilized after decades of declines, but shifting socio-demographics are impacting demand patterns in complex ways.

Overall, the downward trend in household water demand appears likely to continue for the foreseeable future. Study results are captured in a dynamic forecasting model that supports scenario analysis and allows a variety of “what if?” questions to be addressed.

INTEGRATING SCIENCE AND COMMUNITIES IN NORTHEASTERN NEW MEXICO: THE UNION COUNTY HYDROGEOLOGY PROJECT

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The area around the town of Clayton, in northeastern New Mexico, was not a declared groundwater basin until September of 2005. In the years leading up to 2005, attempts to stop drilling of additional water wells for irrigation and stock use led to multiple lawsuits in the community. Because there were no regulations in place and the geology of the area had not been studied in a hydrologic framework since the 1960s, there
was no basic information for decisions to be made with regards to drilling new wells and use of groundwater. In 2006, the Northeast Soil and Water Conservation District (NESWCD), based in Clayton, decided that a county-scale hydrogeology project was needed to help develop community guidelines for groundwater development. The Union County Hydrogeology Project (UCHP) is unique in that this project was initially undertaken by members of the community who developed a program of biannual static water level measurements in wells across the county. In addition, the project has support from the majority of land owners in Union County and the scientists working on the project have worked closely with local community leaders to integrate this large project into everyday activities. Community integration efforts include presenting data at the Annual Producers Meeting and at the county fair, as well as other regional conferences on water use and development. Previous assumptions were that the primary aquifers being utilized were the Tertiary Ogallala Formation and the Upper Cretaceous Dakota Group. However, evaluation of surface bedrock exposures and well cuttings from petroleum exploration wells drilled in eastern Union County demonstrate that the subsurface geology is more complex than might be expected. This subsurface data, along with initial $^{14}$C dates, water chemistry, and hydrographs from data recorders suggest that the aquifer system in Union County is partitioned and substantially more complicated than the “oceans of water” that has often described the area.

**IMPROVED DEMAND FORECASTS THROUGH DYNAMIC SIMULATION MODELING: THE POWER OF DASHBOARDS, SCENARIOS, AND MONTE CARLO METHODS**


Historically, models of municipal water demand focused on a limited number of factors and used econometric methods to determine rates of change and price and income elasticities of demand. The few models that attempted to capture a wider range of factors that affect municipal water demand tended to be spreadsheet-based.

The case is made for using dynamic simulation modeling to improve understanding factors and trends in municipal demand. For starters, the modular structure and icon-based representation of system components increases transparency and allows non-technical users to better understand
Another major advantage to a dynamic simulation approach is the dashboard interface, which visualizes key system inputs and graphically displays model outputs. A variety of controls allow users to vary inputs, allowing non-technical users to ask “what if?” questions.

Scenario analysis also is made easier. Scenarios can be defined as internally consistent sets of assumptions about the future. Dynamic simulation modeling allows for easier comparisons among various scenarios.

A key strength in dynamic simulation modeling is how systems with uncertain or stochastic components are represented. Uncertainties may include the future rate of new home construction or the recurrence of drought conditions. Monte Carlo or probabilistic simulation is used to quantitatively represent uncertainties. The model is then run many times, with inputs chosen randomly according to the defined probability distributions. The resulting simulations incorporate probability distributions for outcomes.

The results of studies on residential water demand in Pima and Maricopa counties (Arizona) have been incorporated into dynamic simulation models to support planning efforts by water providers, wholesalers, and regulators. Examples are shown of how the particular features of dynamic simulation modeling can be used to produce more comprehensive and realistic forecasts.
AHS, formed in 1985, is dedicated to advancing hydrology and water resource research, planning, and development. AHS provides an open forum for professionals to exchange information, but also supports public understanding, education, and training in the science and technology of hydrology and water resources. An important part of AHS’ mission is promoting the responsible use, management, and preservation of water resources in the arid southwest.
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