Young Professionals

Professional Affairs: Licensure

Peer Reviewed Articles:

Hydrogeology:
- Meeting the Demand for Water Supply in Texas and Florida cities
- Infrared Probe Test for Dye Tracer Study
- Sinkholes
Tales from the Field: Hauling What?
David M. Abbott, Jr., CPG-04570

My first job in mining was as a field tech for Earth Sciences, Inc. (ESI), a consulting mining exploration firm in Golden, in the late ’60s. ESI had projects in both the Leadville and Alma areas of Colorado. In those days, the annual 22+ mile pack burro race was run from Leadville (10,152 ft elev.) to Fairplay (9,953 ft elev.) over 13,185 ft elev. Mosquito Pass—race motto: “Get your ass up the pass!”—in one year and from Fairplay to Leadville the next. Burros, or asses, have to carry 33 pounds of mining gear including a gold pan, a shovel, and a pick ax. Alma is on the road between the two towns. ESI’s summer picnic coincided with the burro race and ESI would pay the entry fee for one of the summer interns who agreed to run the Vice President’s burro for the first mile or two of the race. ESI employees would watch the start of the race and then drive to the other side of the Mosquito Range to one of our properties and watch the end of the race and have our picnic. Two of the older ESI employees were old farm boys and they had the horse trailer needed to haul the burro from Golden to Leadville or Fairplay and back. Our time cards at the time were free form; you wrote a description of what you did on a day. So these two men recorded 8 hours of “hauling ass” to get a rise out of the office staff—how often can you legitimately use this as an accurate job description. A couple of years later, ESI was being audited and one of the auditors found these time cards and wanted to know what these two were doing. The answer was, “Hauling the jack ass from Golden to Fairplay and back.”
 I’m a proud member of the International Order of Ragged Ass Miners. Burro racing is Colorado’s State sport, a homegrown sport that’s spread to some other states, https://www.ccburroracing.com.
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On the Cover: View in the area of Ushuaia (i.e., the “end of the world” or “fin del mundo”) in Tierra del Fuego, Argentina. Photo Courtesy of Robert Font, CPG-03953
The mission of the American Institute of Professional Geologists (AIPG) is to be an effective advocate for the profession of geology and to serve its members through activities and programs that support continuing professional development and promote high standards of ethical conduct.

AIPG encourages submission of articles and editorials for publication in TPG on topics related to the science and profession of geology. Submissions shall be of interest to the members of AIPG, other professional geologists, and others interested in the earth sciences. Articles and editorials may be noted as follows at the discretion of the Editor. “The opinions, positions or conclusions presented herein are those of the author and do not necessarily reflect the opinions, positions or conclusions of the American Institute of Professional Geologists.” All materials submitted for publication, including author opinions contained therein, shall include accurate and appropriate references. The Editor has the authority to solicit, edit, accept, or reject articles and editorials and other written material for publication. The Executive Committee has the authority if it so chooses to act on any particular case to support or overrule actions of the Editor regarding the solicitation, editing, acceptance, or rejection of any particular article, editorial, or other written material for publication.

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American Institute of Professional Geologists (AIPG) is the only national organization that certifies the competence and ethical conduct of geological scientists in all branches of the science. It adheres to the principles of professional responsibility and public service, and is the ombudsman for the geological profession. It was founded in 1963 to promote the profession of geology and to provide certification for geologists to establish a standard of excellence for the profession. Since then, more than 10,000 individuals have demonstrated their commitment to the highest levels of competence and ethical conduct and been certified by AIPG.

The mission of the American Institute of Professional Geologists (AIPG) is to be an effective advocate for the profession of geology and to serve its members through activities and programs that support continuing professional development and promote high standards of ethical conduct.
I'm excited about this issue because we have four Peer Reviewed papers, all on the theme of Groundwater Hydrology. Three of these, each very different from the others, concern karst aquifers, and the other concerns a major water-supply project in Florida. A second major theme of this issue is a set of three papers that I think will be of interest to Young Professionals: two are by young professionals, in the first the author tells why she is fascinated by the biogeochemical process that go on in caves and salt domes, the second is a comparison of ArcMap and the Open Source software QGIS/GRASS. The last is by a Board Member who has looked at the demographics of AIPG and thought hard about what we can do to serve younger members better: he proposes a formal mentorship program and he wants to hear your views on the subject.

We also, sadly, have five obituaries in this issue: two of these people I knew and respected very highly. Two were people I didn’t know personally but who had an enormous impact on those who did know them. The fifth was a lady who not only was a good geologist, but wrote a series of thrillers with geologists as their heroes: she wasn’t an AIPG member, but was well-known to members in the South West, and I think deserves commemoration as someone who brought our profession to wider notice.

In that vein, there is also a group of papers under the heading “Professional Affairs”: I hope this will also be a regular feature of TPG. In this issue is a piece about a change making it easier for geoscientists moving into Arizona to practice there, as well as an announcement by AGI of a “licensing intern”, and two pieces submitted by AEG members to the Geologic Legislative Action Group, which is composed of AGI, AIPG, AASG, ASBOG, GSA, and the National Speleological Society, among others. One of the pieces lays out a model program for geoscientists in each state to keep informed about legislative affairs, provides guidance on how to interact with legislators in general, and also on how to pick and support legislative champions. The second piece makes three concrete proposals, the first of which is to act on the first essay, the second is to set up a nationwide and state-by-state organizational framework for interacting with legislatures, and the third is to come up with funding to pay for all this. I’m bringing these to your attention because I am very aware, after what happened in my state last year, that geoscientists are regarded as “low-hanging fruit” by extreme free-market activists, such as the Institute for Justice and ALEC, in their campaign to abolish all forms of professional licensing. They regard us as a small insignificant group with no public impact for good or bad: they do not realize that our work literally underpins our national infrastructure, makes water supply possible, and provides the metallic, non-metallic and energy commodities that make our civilization possible, not to mention our work on earthquake, volcano, tsunami and flooding warning systems. As far as numbers go, we are about as numerous as brain surgeons and who would like to be operated on by an unlicensed brain surgeon? (But that may be in our future, too). We can’t all write thrillers, but we can and should learn to interact with the public and their representatives, and do so on a regular basis.

In our letters column we have two letters expressing appreciation for the work of AIPG and TPG on behalf of the profession, and one letter each for and against the evidence for global warming.

In the meantime we have an impassioned President’s letter citing the changes in her home State of Alaska, and in David’s column he recommends a video about rising sea levels. I have watched the video and it is good, and mostly even-handed. Furthermore, AAPG, our sister organization and group of sceptics on this question appointed an ad hoc committee to study the issue in 2018: their report is due out very soon (AAPG Explorer June 2019, page 30) , potentially leaving us exposed as the last earth science institution without an official position.

I hope that in this issue all of you, our readers, will find something to engage your opinions, something of interest, and above all, something of use to you in your work.

John L. Berry, CPG-04032

Introduction: Water Supply in the Austin-San Antonio Corridor

The Texas Water Development Board (TWDB) projection is that the thirteen counties that comprise the Austin-San Antonio corridor will increase their combined population from a current estimate of 4.5 million (2018) to 5.8 million or more by 2030. Figure 1 shows the area encompassed by the San Antonio to Austin Corridor including Bexar, Comal, Kendall and Guadalupe counties to the south, Hays, Blanco and Caldwell counties in the middle, and Travis, Williamson, Bastrop, Lee, Milam and Burleson counties in the northern part of the growth area.

Just as in California’s Silicon Valley, this Central Texas corridor is creating an identity of its own while retaining the identity of the two cities that anchor the growth, namely San Antonio in Bexar County and Austin in Travis County. It will truly be a high-tech corridor that will blend good jobs with a combination of rural and city-living in a great climate. The 1.3 million in population growth projected over the next 12 years will create an enormous need for construction of homes and supply of water, electricity, services, hospitals, and schools. The anchor cities of Austin and San Antonio are about 79 miles apart and are connected by excellent roads to anchor further expansion. The growth will create dormitory communities and business hubs in all surrounding counties. Counties in between San Antonio and Austin which today are primarily rural will most likely skyrocket their population.
Comal County, for example, is anticipated to grow its population by 50,000 people, or more than 35 percent, to nearly 195,000 people. The population and employment growth in the area will require major growth in the accompanying utility services (water, power, refuse collection, phone, etc.).

In this paper we will address how such growth will require infrastructure projects to provide the additional water needed. The debate is how we are going to manage a growth in water consumption of between 50 and 100 billion gallons of water by 2030 and where is it going to come from, be it surface water, treated water, out-of-area imported water, groundwater or most likely all the above. If the growth in supply is to be from groundwater it will come most likely from the Carrizo-Wilcox aquifer system, the Trinity aquifer system or other more localized aquifer systems.

To illustrate the size of the challenge, in the southern end of the corridor, the San Antonio Water System (SAWS) today is working on the Vista Ridge Project to produce water from the Carrizo-Wilcox aquifer and bring down 16.3 billion gallons of water per year through a 142 mile long pipeline from Burleson County in the NE to Bexar County in the SW (see Figure 1). On the other end of the corridor to the north lies Austin in Travis County. It principally gets its water from Lake Austin and Lake Travis which are dammed reservoirs on the Colorado River. The City of Austin and other communities operate treatment plants to process the stored water in Lake Austin and Lake Travis used by industry and residents. Austin operates the Davis and Ullrich treatment plants on Lake Austin and the Handcox Water Treatment Plant on Lake Travis (Figure 1). The major growth areas between Austin and Georgetown (particularly Williamson County, including Round Rock) also have opportunities to develop large-scale regional groundwater projects from the Carrizo-Wilcox aquifer in Bastrop, Lee and Milam Counties.

Suburban Water Supplies

Figure 2 illustrates the distribution of the types of new water sources as proposed by the 2016 regional water plan compiled by the South-Central Texas Regional Water Planning Group (SCTRWPG) including the City of San Antonio. New surface water sources and new groundwater sources are expected to comprise 17 percent and 16 percent of the total new water resources in the region by 2070, or about 134,000 and 126,000 acre-feet per year, respectively (1). High-growth areas include significant portions of northern Bexar, Kendall, Comal, Guadalupe, Hays and Caldwell counties. The 2016 SCTRWPG (Region L) plan (1) reports that municipal water demands will more than double in each of Caldwell, Comal, Guadalupe and Kendall counties from 2020 to 2070, while Bexar County municipal demands will increase from about 299,000 to approximately 443,300 acre-feet per year during the same period.

The Hill Country area outside of San Antonio is not favorably situated for additional reservoir construction and reservoirs currently require decades for permit approvals and construction. Therefore, the suburban high-growth areas are and will continue to be more dependent on groundwater
sources or water supply arrangements with major providers in Austin and San Antonio. A specific supplier, Canyon Lake Water Service Company, is a state-regulated investor-owned utility providing reservoir water in Comal and southern Blanco Counties using Canyon Lake (see Figure 1) as a source. It also utilizes some groundwater and operates several wastewater treatment plants. Currently it serves approximately 30,000 people. Also, the Guadalupe Blanco River Authority (GBRA) has been involved in the area since 1933 and has developed raw water supply projects, water and wastewater treatment, distribution systems and other projects.

Texas Water Supply Company (TWSC), a water producer and wholesale supplier in Comal and Bexar counties (subject area), is working on developing additional groundwater alternatives that tap the Middle Trinity aquifer, a viable alternative that currently produces potable water being supplied to SAWS at a rate of about 5.5 billion gallons per year (or about 17,000 acre-feet annually). TWSC is also developing other groundwater fields to further their supply capability in a sustainable manner. The Middle Trinity aquifer supplies TWSC’s comprehensive testing and monitoring programs demonstrate that the targeted supplies can be produced reliably and responsibly.

Local Groundwater Supply

The state of Texas recognizes 9 Major Aquifers and 22 Minor Aquifers. These aquifers today provide more than 60 percent of the water used in the State. The aquifers tapped in the Austin to San Antonio corridor are the Edwards Balcones Fault Zone (BFZ), the Trinity and the Carrizo-Wilcox (see Figure 1). The complex and varied geology within northern Bexar and southern Comal Counties in the central to southernmost part of the San Antonio to Austin corridor provides a unique setting for producing significant groundwater supplies. Hydrogeologic considerations, geologic structure including faulting and fracturing, and secondary porosity development all strongly influence the availability of groundwater, including the amount of groundwater in storage, the capability of the aquifers to transmit water, recharge rates and distribution, seasonal water-level fluctuations and well productivity. The targeted aquifer in the area for most of the water supply is what the US Geological Survey (USGS) terms the Middle Zone of the Trinity aquifer (2) and is herein termed the Middle Trinity aquifer. The Upper Trinity aquifer typically yields small and sometimes unreliable water supplies to wells locally. The Middle Trinity aquifer is the most reliable aquifer in the subject area and the underlying Lower Trinity aquifer can also yield substantial and reliable supplies; however, the water tends to be somewhat brackish in some areas. Wells generating over 1,000 gallons per minute are currently successfully operating in the Middle Trinity aquifer. The Lower Trinity aquifer could be considered for conjunctive use projects such as aquifer storage and recovery (ASR). Productive portions of the Edwards aquifer do not occur beneath the primary growth areas in northern Bexar County. Additionally, permit allocations for producing Edwards’ aquifer water are not readily available due to regulatory restrictions.

Figure 3 - Surface Geology.
Hydrostratigraphy and Structure

Rock units composed of Cretaceous-age terrigenous sediments and marine carbonates mold the landscape and form important hydrologic units and water-bearing zones across northern Bexar and southern Comal counties. The Middle Trinity aquifer units were deposited on a shallow-marine carbonate platform as clastic-carbonate “couplets” during marine transgressions (2). The Middle Trinity interval includes two of the three Trinity Group couplets; the lower including the Hammett Shale Member and the Cow Creek Limestone Member of the Pearsall Formation, and the upper couplet contains the Hensell Sand Member of the Pearsall Formation and the lower member of the Glen Rose Limestone (Table 1). The upper member of the Glen Rose Limestone is also a part of the upper couplet but is included in the Upper Trinity aquifer. The Hammett Shale forms a consistent confining unit between the Middle Trinity aquifer and the underlying Lower Trinity aquifer. The USGS, as a result of the work of Clark and Morris (2), has recently delineated distinct hydrostratigraphic units (HSUs) within the Middle Trinity aquifer; four (4) definite water-bearing zones and five (5) confining or semi-confining layers. Table 1 provides a summary of descriptions, thicknesses and overall character of each of the HSUs (2).

 Faulting and corresponding fracturing associated with the Balcones Fault Zone may be the primary factor influencing the characteristics of the Middle Trinity aquifer. Numerous en-echelon faults with fault planes trending primarily from southwest to northeast extend across the subject area. Relative displacement of faults varies considerably. Figure 3 shows a map of the surface geology illustrating numerous faults. Figure 4 is a cross section across part of one of the subject TWSC well fields. Comparing records from the subject well fields to structural geology and thickness maps provided by the TWDB show that the depth and thickness of the Middle Trinity aquifer in northern Bexar and southern Comal county are more favorable for well completion than in other areas of the Central Texas Hill Country and the aquifer is commonly twice as thick and a couple hundred feet deeper in the subject area (3 and 4).

Aquifer Hydraulic Characteristics

The USGS notes that the complexity of the Middle Trinity aquifer has resulted from its depositional history, bioturbation, diagenesis, primary and secondary porosity, and faulting and fracturing, which have all resulted in “…development of modified porosity, permeability and transmissivity within and between aquifers” (2). Like many carbonate aquifers exhibiting some karst characteristics, the Middle Trinity aquifer overall exhibits relatively low specific yield and storage coefficient values. However, on a site-by-site basis, large cavernous openings result in large local storage values in many wells.

Depending upon the amount of fault displacement and the juxtaposition of HSUs in the Middle Trinity aquifer, faults may form barriers to groundwater flow, may provide preferential and enhanced flow paths, or may have no effect on groundwater flow direction or rate. Some areas are dominated by primary porosity while other areas, particularly along faults, fractures and bedding planes, exhibit considerable local secondary porosity ranging up to large caverns and caves. Thus, the aquifer permeability and resulting transmissivity ranges from low to extremely high, often in very small areas, as exhibited by specific capacity values in wells that range from less than one to 140 gpm/ft. As a result, aquifer conditions at neighboring well sites can vary significantly, and

Table 1. Summary of Hydro-stratigraphic Units – Middle Trinity Aquifer

<table>
<thead>
<tr>
<th>HSU Unit Name</th>
<th>Thickness Range</th>
<th>Rock Characteristics</th>
<th>Hydrologic Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulverde</td>
<td>30 to 40 feet</td>
<td>Limestone, shale and evaporites with some fabric-selective porosity. Upper shale layer forms confining layer</td>
<td>Semi-confining</td>
</tr>
<tr>
<td>Little Blanco</td>
<td>30 to 40 feet</td>
<td>Resistive limestone with considerable interconnected porosity and some cave development</td>
<td>Water-bearing</td>
</tr>
<tr>
<td>Twin Sisters</td>
<td>10 to 65 feet</td>
<td>Thin argillaceous limestone beds with interbedded mudstone and shale layers</td>
<td>Semi-confining</td>
</tr>
<tr>
<td>Doeppenschmidt</td>
<td>40 to 80 feet</td>
<td>Thicker resistant limestone beds grading laterally into patch reefs. Interconnected and considerable secondary porosity</td>
<td>Water-bearing</td>
</tr>
<tr>
<td>Rust</td>
<td>40 to 70 feet</td>
<td>Alternating beds of argillaceous limestone and mudstone. Secondary porosity not developed except near faults</td>
<td>Semi-confining</td>
</tr>
<tr>
<td>Honey Creek</td>
<td>45 to 60 feet</td>
<td>Lowest and most productive unit in Glen Rose. Thick beds with biogenic and secondary porosity – particularly in the lower half</td>
<td>Water-bearing</td>
</tr>
<tr>
<td>Hensell</td>
<td>0 to 60 feet</td>
<td>Claystone, siltstone, sandstone, sand and conglomerate. Grades upward into Lower Glen Rose. Not productive in some areas</td>
<td>Semi-confining</td>
</tr>
<tr>
<td>Cow Creek</td>
<td>40 to 70 feet</td>
<td>Carbonate sand, some areas of patch reefs and dolomitic layers. Well-developed interconnected primary and secondary porosity. Primary water-bearing zone in the area</td>
<td>Water-bearing</td>
</tr>
<tr>
<td>Hammett</td>
<td>50 feet</td>
<td>Claystone, siltstone, dolomitic limestone and dolomite. Locally characterized by “swelling clays” in drilled holes</td>
<td>Confining</td>
</tr>
</tbody>
</table>

*After USGS designations provided by Clark, Golab, and Morris, 2016 (2)
it takes a locally experienced hydrologist to best identify the proper location of new wells. However, the opportunity for sustainable large production levels exists with proper well siting.

**Recharge, Water Levels and Discharge**

The Middle Trinity aquifer in Bexar and Comal counties is primarily under artesian or leaky-artesian conditions. Even in areas near the outcrop, stratification and karst conditions tend to cause the aquifer to behave as if it were confined or semi-confined. The aquifers in the Bexar and Comal County area are much more sensitive to climate (i.e., wet-dry cycles) than the primary aquifers in the Panhandle, Permian Basin, Trans-Pecos, and (especially) those aquifers located south and east of Interstate 35.

Like that of the Edwards aquifer, the overall small storage capacity of the Middle Trinity aquifer and the confined conditions result in water levels in local production wells fluctuating through wet-dry cycles. Seasonal fluctuations also have been recorded. Additionally, water-levels respond relatively rapidly to significant rainfall events indicating that substantial recharge occurs through stream losses where the Middle Trinity is exposed in stream-beds. It is likely that recharged water migrates along faults and fracture planes from the overlying Upper Trinity aquifer (i.e., Upper Glen Rose Limestone) to the Middle Trinity (5). Figure 5 shows the relationship between historical rainfall and local water levels in the Middle Trinity aquifer. Groundwater flow and stream flow modeling indicate that pumping from the local Trinity aquifer will cause very small reductions
in flows for example to Cibolo Creek. Locally, there are no significant springs issuing from the local Middle Trinity aquifer. However, Jacob’s Well in Hays County is a large spring that flows from cavernous openings in the Lower Glen Rose Limestone. Numerous small and seasonal springs flow from the Upper Trinity aquifer (i.e. Upper Glen Rose Limestone) but not from the Middle Trinity aquifer.

**Well Yields, Water Quality and Water Availability**

Due to the hydrogeological and hydraulic complexity of the Trinity aquifer, productivity of wells completed in the Middle Trinity aquifer can vary significantly even within small areas. Spatial distribution of reported specific capacity values for several local wells show that some areas are much more highly productive than others. Cleaning or developing wells often opens rock openings to significantly enhance the productivity of the wells. Known/calculated specific capacity values for local municipal supply wells range from less than one to 140 gallons per minute per foot (gpm/ft).

Water wells in the area routinely produce between tens of gallons per minute to well over a thousand gallons per minute. Due to considerable seasonal water-level fluctuations, the available drawdown in wells can vary significantly and pumping rates must be managed as the aquifer stage changes. For the subject well fields, seasonal water-level changes are significantly greater than the interference drawdown between wells and are the primary controlling factor in effectively managing the well fields. Long-term monitoring shows that seasonal fluctuations can be as much as 200 feet, while aquifer testing shows the interference drawdown between closely spaced wells is a few tens of feet. Additionally, a simulation of the well field pumping using the state-approved groundwater availability model (GAM) showed that long-term interference between well fields is much less than seasonal fluctuations (6 and 7). Therefore, pumping rates from wells and well fields may fluctuate considerably depending on wet-dry cycles. However, fields can be designed to maximize production by properly siting and designing wells including larger diameter screened wells. Existing fields can be operated to maximize production by proper modeling. For example, TWSC operates a field of wells known as the “West Field” completed in the Middle Trinity producing consistently over 15,000 gallons per minute of water. Other similar fields can be operated in the Middle Trinity; however, the aquifers must be appropriately managed by the various operators to avoid depletion. TWSC has conducted extensive testing on a second field known as the “East Field” including specific capacity tests in all individual wells as well as groundwater modeling and believes that TWSC can consistently double existing production capacity (of the West Field) by combining the West and East Fields and operating them in a sustainable manner. Groundwater modeling utilizing the TWDB’s GAM corroborates TWSC’s testing and monitoring results that local groundwater resources in this field can be developed for long-term use, and that seasonal water-level fluctuations will be the primary factor in the subject area in order to provide reliable water supplies (1 and 7).

Geologic and groundwater flow variability also result in some local water-quality variations. While most local wells properly completed in the Middle Trinity yield potable groundwater, some wells yield water with slightly higher mineral content. Particularly, fluoride and/or sulfate concentrations can be slightly elevated although rarely are they above drinking water limits. Blending generally proves to be effective to ensure potable drinking water.

**Water Supply Development Considerations**

Developing long-term, reliable groundwater supplies requires careful consideration of numerous factors. Environmentally sound local water development for the next several decades will likely include:

- Optimal placement of freshwater well fields – because stratigraphy, faulting and the development of secondary porosity are keys to well and well-field productivity and water quality, proper well siting programs including exploration and testing are important. Additionally, well completion and development must account for local conditions;
- Monitoring and management – seasonal and relatively rapid water-level fluctuations are best managed with real-time monitoring equipment and controls including Supervisory Control and Data Acquisition (SCADA) systems, continuous water-level (and water-quality) recorders, pumping rate readouts, Variable Frequency Drive (VFD) controls and remote access;
- Blending – most of TWSCs wells produce fresh and potable water, while some blending may be needed from time to time to ensure compliance with state drinking water standards. Such blending increases the overall water availability;
- Potential aquifer storage and recovery (ASR) implementation – the deeper Lower Trinity aquifer may provide a suitable reservoir for effective ASR, as it is isolated from the Middle Trinity and may be favorably productive. ASR could utilize seasonally available excess treated surface water or excess groundwater pumped during wet periods, allowing for recovery during critically dry times;
- Local desalination of brackish groundwater – potentially, down-dip portions of the Middle Trinity aquifer and the Lower Trinity aquifer could also be tapped for supplies; and,
- Regulatory and legal constraints – the current well fields are “grandfathered” from current permitting requirements. However, at some time there may be aquifer management, regulatory or legal constraints placed on local production. Similarly, all other water supplies will be faced with similar challenges.

The results of TWSC testing and the modeling done by regional authorities provide a consistent picture that shows that the Middle Trinity represents a viable source of groundwater for the region. The conjunctive use potential, including collaborative operations with surface water providers, ASR and desalination, provide a “safety factor” and alternatives that will allow for managing in cases of severe drought, climate change, and regulatory/management changes.

**Conclusions**

A common perception exists that the Trinity aquifer cannot yield substantial reliable groundwater supplies. Such belief is due to experiences in the past with unreliable shallow wells in the Hill Country, small springs that go dry seasonally, large water-level fluctuations, parts of the aquifer having unfavorable hydraulic characteristics, and the belief that pumping will harm all springs and streams. Also, available information demonstrates that some parts of the Middle Trinity aquifer in the Texas Hill Country are not as favorably situated for groundwater production as is the subject area. The Middle Trinity aquifer, however, is uniquely situated in parts of northern Bexar and southern Comal counties (subject area) to allow for developing significant and reliable groundwater supplies.

Continued on p. 41
Dear Keri, Aaron, and the Executive Committee,

I just received your congratulatory letter and Pin as a token of appreciation for my forty (40) years of active support of the Institute. I’ve been wearing my existing ‘aging’ AIPG Pin with pride, and I will certainly be glad to replace it with this new ‘40 yr.’ badge you have bestowed upon me. Thank you.

I also want to take this opportunity to convey my sincere appreciation to the leadership at National for all the good work you are doing for our Membership, and for representing the benchmark for our ethical standards we strive to uphold as we continue to ‘set the bar’ for practicing a wide range of geological services for the general public, both here and abroad. I judge that all of the other CPGs before me, and those who come after me, working in our truly fascinating, exciting, and influential field, feel likewise. Needless to say, its indeed a privilege to maintain my Membership thus far, and I will optimistically look forward to passing my next milestone within a not-to-distant future! Count on my continued support.

Most Sincerely,
Charles Rich, CPG-4433

Dear Editor:

I was reading the submissions from David Abbott and Peter Dohms in the section on climate change in the second quarter issue of TPG. The point about uncertainty is well taken. Also, of course, as geologists we know that climate changes over time, and for that matter, if large number of species become extinct for any reason, new ones will evolve to take their place with time. It has happened before, is happening now, and could even include us humans someday. The concern with anthropogenic climate change is that we ourselves are negatively impacting our own comfort and survival in a dramatic way, and we are a sentient species that should be clever enough to take action. In the past mass extinctions involved enormous volcanic eruptions or meteor impacts, which insurance companies would rank as “Acts of God.” Unfortunately, the drama of the present “Act of Man” is a bit lost when David Abbott’s Figure 2 and Peter Dohms’ graph are viewed separately; they are on very different scales, and an important point can be lost. Below I present Peter Dohms’ graph with the information from David Abbott’s Figure 2 added. The information in Figure 2 shows that, whatever the uncertainty, the temperature has increased 0.5-1°C in the past 20-30 years. While that is hard to represent on a scale of a diagram representing the past eleven thousand years, I put in a heavy line that represents an average of the two, about 0.75°C, which is only a few times thicker than it ought to be at scale. Then the rest of Figure 2 shows estimates ranging from a very conservative and optimistic 1°C over a span of one hundred years to a possible 5°C. The box I added on the right side of the graph represents a middling figure of 3°C, at approximately the right thickness for 100 years; 5°C would be even more extreme. The sharpest warming trend after the End of the Last Glacial was about 4°C in about 800 years judging from the diagram, whereas we might be heading for up to 5°C in 100 years. Adding this in makes our current warming period look a bit more special. As abrupt warming occurs over the next century sea water expansion plus melting of the ice caps can be reasonably expected to produce something stronger than the average for the past eleven millennia. Worse yet, we have now built important cities along the coastline. In the eight hundred year period following the end of the last glaciation, our Neolithic forebears had no problem scooting back to accommodate rising sea levels, but having a similar warming in a tenth of the time today will certainly have a terrible impact, and that is only one aspect of the problem.

Regards,
Margaret Venable, CPG-11080
Dear Editor:

I am compelled to reply to Messrs. Simms and Diefendorf, who took me to task in the Vol. 56 No. 3 (summer) issue of TPG. Also, I wish to thank Mr. Wojcik for his positive comment.

Dr. Simms took issue with the end date of the graph I supplied with my letter published in the Second Quarter TPG issue, suggesting that it has been supplanted with more recent data. He was even kind enough to supply a copy of the IPCC’s latest spaghetti model graph of the past 2000 years of climate: if Dr. Simms would like to see a spaghetti model graph, here’s one that compares all of the IPPC warming models against observed temperatures since 1977:

The squares are actual observations. A wise person once said, “All models of natural systems are inaccurate; some are however useful.” In the face of comparison with actual data, the models in this spaghetti graph appear to not be useful.

Dr. Simms also asked for peer-reviewed citations for the observations I offered of sea level strand lines in Northwest Florida. Since I’ve been retired for 7 years and have moved 1800 miles away from the professional library I had while working, I had to work somewhat from memory. I recalled, and found online, a publication of the Florida Geological Survey; Bulletin No. 46, “The Geology of Escambia and Santa Rosa Counties, western Florida Panhandle,” by Marsh, Owen and Thayer, 1966. Pages 88 – 90 identify confirmed shore-line terraces at elevations of 30 and 70 feet above present sea level, and less obvious terraces ranging in elevations of 80 – 280 feet (!) above sea level, all of Pleistocene age (i.e., during the various glacial and interglacial episodes). The subsurface strand line elevations I quoted naturally have no such citations, and are frankly of less pertinence to the discussion at hand (warming resulting in postulated future sea level elevation increases).

Mr. Diefendorf expresses pain that his letter in the Jan.-Mar. issue of TPG failed to open the discussion on how to mitigate climate change that he had hoped, but instead re-fueled the debate on the reality of anthropogenic global warming. Unfortunately, as noted above and in my previous letter, the debate is not settled, no matter how much global warming advocates might wish it to be. There are many websites where the case against anthropogenic global warming is made in a much more compelling fashion that I can hope to achieve in this limited forum.

Since it appears to be the case that debate about anthropogenic climate change is raging on, it might be useful for the Institute to poll its members about their opinion on the topic.

Thank you for this opportunity to comment.

Sincerely,
Peter H. Dohms, CPG-7141

Editor’s Note: I thank Dr. Dohms for his suggestion of a poll of the AIPG Membership on this issue. Serious consideration is being given to taking such a poll, but it will not be done through the pages of TPG.
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The City of Lakeland’s Northeast Wellfield from Conceptualization to Production

Authors

Charles W. Drake, PG, (pictured left)
W. Bruce LaFrenz, PG, MEM-2035 (pictured center)
W. Michael Dennis, Ph.D. (pictured right)

Abstract

This article describes the 30-year history of the City of Lakeland, Florida northeast wellfield from project conceptualization to production and continued monitoring. It also describes a multi-disciplinary approach to evaluation of causes of water-stress of on-site wetlands and the successful interpretation of causes and possible remedies. Implementation of restoration activities agreed between the Southwest Florida Water Management District (SWFWMD) and the City of Lakeland in 2007 allows the City to withdraw groundwater from a stable source of supply without harming nearby wetlands. The restoration project reversed hydrologic changes and harm caused by historical agricultural and silvicultural practices.

Introduction

The City of Lakeland is located in west-Central Florida (Figure 1); and in 1987 recognized that a supply of drinking water was needed in the eastern side of the City service area to supplement emergency supply and to meet system pressure requirements. The City’s first water supply wells had been constructed in the early 1900s, and with growth, the City had expanded its water distribution system and added new wells to increase supply and maintain adequate system pressure. Expansion from the original highlands areas toward the east had resulted in increasing differences in elevation and pressure within the water distribution system. The resulting distributed wellfield served adequately, but the residence time of the water in the potable water system and irregular system pressure concerns complicated management of the system. Between the mid-1970s and early 1980s the City constructed a new consolidated wellfield and improved the water distribution system. In approximately 1980, the dispersed old wells were de-commissioned and the thirteen new Upper Floridan Aquifer (UFA) wells became the sole source for a new 54 million gallon per day (MGD) split treatment lime softening plant.

The UFA is part of the Floridan Aquifer System (FAS) and extends across all of Florida and into Alabama, Georgia and South Carolina: it is the major source of fresh water for potable, irrigation, and commercial/industrial use for Florida. Across the State, it ranges from unconfined to semi-confined to fully confined. A significant portion of the permeability (Budd and Vacher, 2004) is in secondary porosity (fractures and solution conduits), and most of the balance is in high-permeability limestone: consequently the UFA is a highly heterogeneous and anisotropic aquifer. It includes some of the most productive aquifer zones in Florida and is the source of more than half

Figure 1 - Location of City of Lakeland Wellfields. Combee well is permitted as part of the Northeast wellfield.
of Florida’s potable water (Fernald and Purdum, 1998) and the source of many freshwater springs (Rosenau, et al., 1977).

In northern central Polk County, Florida, transmissivity of the UFA can range from 10,000 ft² day⁻¹ to more than 100,000 ft² day⁻¹ and leakance¹ can range from less than 10⁻³ ft day⁻¹ ft⁻¹ to 10⁻⁵ ft day⁻¹ ft⁻¹ (DRMP, 1990, HAI, 2002). Greater potential for harm from drawdown can occur at the lower range of transmissivity and higher range of leakance; hence, it is critical that these hydrogeologic parameters are reliably known during wellfield design so that excessive groundwater pumping at permitted rates will not cause unacceptable environmental impacts and groundwater quality remains stable.

Collectively, City administration and City water utility decision makers (hereafter, “City leaders”) recognized that minimizing on-site and off-site impacts was essential, so selection of a new UFA wellfield site included a requirement to purchase enough land to provide a buffer from development and any potential off-site impacts due to withdrawals. To ensure that enough land was purchased, an extensive hydrogeologic testing program was designed to collect sufficient data to calculate transmissivity, storage and leakance for use in predicting scale and extent of impacts. This program was submitted to the Southwest Florida Water Management District (SWFWMD) for review, comment and approval prior to implementation of the program. The SWFWMD is the regulatory agency responsible for permitting water use in west-Central Florida, so it was important to reach agreement on the aquifer testing and analysis protocol to simplify review of the water use permit (WUP) application. Through an extensive literature and property search the City leaders identified an 800-acre parcel (Figure 1) and entered into a lease-to-purchase agreement with the land owner. Purchase was contingent on satisfactory reliable yield determined by hydrogeologic testing and on obtaining a WUP from the SWFWMD.

Northeast wellfield area

The top of the unweathered UFA at the wellfield site is roughly 90 feet below land surface and is overlain successively by 50 or more feet of lower yield weathered limestone and calcareous clay (“sandy clay to clayey sand” on Figure 2), by a thin sand or limestone interval (“sand”), and by clay beds 10 or more feet thick. The uppermost three to five feet comprise clean well-sorted fine sand (Figure 2), (DRMP, 1990; Peterson, 2007). We refer to the semiconfined sand layer as an “intermediate aquifer” to distinguish it from the unconfined surficial sands, rather than to suggest it is connected to or an extension of the Intermediate Artesian aquifer recognized throughout southern and southwestern central Florida.

The northeast wellfield property (henceforth NE wellfield) is roughly equally divided between low relief uplands and shallow wooded wetlands. Few other than depressional soils are listed as frequently inundated, and upland soils are generally well drained (NRCS on-line soil survey, Polk County, Florida). Historically, as shown in the aerial photograph from 1941 (Figure 3), uplands consisted of South Florida Flatwoods (pine flatwoods) with only a few feet of relief and very gently sloping convex topography. Before alteration, areas most distant from wetlands were nearly flat-lying, and the low relief resulted in shallow groundwater gradients within natural wetlands catchments. The darker areas on the crests of divides between areas of wooded wetlands indicate that these flat crests retain stormwater in ephemeral wetlands or microtopography. This storm water apparently then drains away slowly to the wetlands proper by overland and shallow groundwater flow.

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1. Vertical leakance is defined as the average vertical hydraulic conductivity of the confining unit sediment divided by the thickness of semi-confining beds between the aquifer and source beds.
Leakage of groundwater from the shallow surficial sands to underlying aquifers is limited by the low permeability (Grubb, 1977) and moderate thickness of semiconfining beds (DRMP, 1990; HAI, 2001).

Figure 3 - 1941 USDA aerial photograph showing the area of the Lakeland NE wellfield. Darker vegetation was cypress and hardwood wetlands and lighter areas were pine flatwood uplands. Standing water shows as very dark patches and tilled land shows as very light regular features.

Wetlands on the NE wellfield property comprise both connected and isolated wetlands. In general terms the water budget for a wetland is:

$$\text{Delta } V = P_n + S_i + G_i - ET - S_o - G_o.$$  \hspace{1cm} \text{(eq. 1)}$$

Where Delta V is volume of water in storage. Inflow components are net direct precipitation ($P_n$), surface water inflow including streamflow and overland flow ($S_i$), and groundwater inflow ($G_i$). Outflow components are evapotranspiration (ET), surface water outflow including streamflow and overbank storm flow ($S_o$), and groundwater outflow ($G_o$) (Mitsch and Gosselink, 1986). The NE wellfield wetlands water budget comprises limited groundwater inflow ($G_i$), direct precipitation ($P_n$), and overland stormflow as sources ($S_i$); and evapotranspiration (ET), surface drainage (for connected wetlands) ($S_o$), and negligible leakage to the Upper Floridan aquifer ($G_o$) because of low permeability bedded clays as sinks. On the NE wellfield property the generally low relief allowed isolated wetlands to exchange surface water during extreme storm events. NE wellfield wetlands also have naturally relatively low ratios of catchment to wetland area (Figure 3).

Figure 3 is a 1941 aerial photograph illustrating historical land cover and drainage patterns on most of the NE wellfield property, and Figure 4 is a 1990 aerial photograph showing the same area after conversion of uplands areas to improved pasture and with additional ditching to drain the land to promote growth of forage grasses (City of Lakeland, FL contracted aerial photograph).

Site Suitability

In 1990, the first of three aquifer performance tests (APT) to estimate transmissivity, storage coefficient, and leakance factor was performed. The first APT included construction of a test well to production well standards near the center of the property (Fig. 4) and two clusters of observation wells. The test well (NE-1) is 16-inches in diameter, cased to 123 feet below land surface (bbls), and open borehole to total depth of 780 feet bbls. The potentiometric head in the surficial aquifer, in an intermediate artesian aquifer, and in the UFA aquifer was logged at each of the two observation well clusters. The clusters are located approximately 100 feet and 1000 feet from well NE-1. The observation well clusters comprised a 2-inch diameter surficial aquifer well screened from five to 10 feet bbls, a 4-inch diameter intermediate artesian aquifer well screened from 12.5 feet bbls to 27.5 feet bbls, and a 4-inch diameter UFA production zone observation well open to approximately the same interval as NE-1 (120-780 ft). The potentiometric head response to the APT was also monitored and logged at one on-site existing out-of-service UFA well open from 42 to 376 feet and three off-site UFA wells. The first APT was run for 72 hours with well NE-1 at a discharge of 2,040 gallons per minute (GPM). Drawdown data were corrected for regional interference using SWFWMD monitor wells that were unaffected by the APT and corrected for antecedent trends of on-site observation wells using curves fitted to pre- and post-pumping data (DRMP, 1990).

The aquifer hydraulic properties derived from the APT were used to simulate wellfield drawdown impacts of five UFA supply wells (Figure 4) using the Prickett-Lonnquist Aquifer Simulation Model (PLASM) (Prickett and Lonnquist, 1971) in 1990 (DRMP, 1990). The values used in PLASM were 1.26 x 10^6 gallons per day per foot (gpd/ft) and storativity of 9.3 x 10^-5 (dimensionless). The PLASM simulations showed that proposed operation of the NE wellfield would not cause harm to wetlands or other users when pumping at a combined annual average daily flow of 9 million gallons per day (MGD) and at a maximum monthly average daily flow of 16 MGD. (The original PLASM predictions were confirmed using a regional MODFLOW model for later permit applications.) Predicted drawdown was within acceptable limits of the SWFWMD, and a WUP was issued in 1991.

Figure 4 - 1990 aerial photograph of the same area (white outline) as Figure 3 after alteration for enhanced offsite drainage and conversion of pine flatwoods to improved pasture. (Contract Aerial Photograph, City of Lakeland.)

The City completed purchase of the NE wellfield property, and in accordance with the WUP conditions, a hydrobiological monitoring program was prepared and approved. Pumping from the NE wellfield did not begin until October 2005, but
the City implemented the monitoring plan in 1994 and monitored without interruption groundwater level and ecological responses to changes in weather for more than 11 years before wellfield pumping commenced. The City continuously records data from monitoring wells, rainfall gauges, evaporation pans, and wetland staff gauges, groundwater head and ecological responses to operation of the NE wellfield. Those data are collected and evaluated each year and are submitted annually to the SWFWMD. The City’s monitoring network currently consists of 52 monitoring wells in wetlands, in the surficial aquifer, in the local “intermediate” aquifer, and the UFA. Figure 5 shows monitoring stations aboard the NE wellfield.

Before the wellfield was put into operation, the City completed a second APT in accordance with conditions of the WUP, and a third APT was performed by the SWFWMD. When the wellfield was put into production the baseline data were crucial for demonstrating that groundwater pumping was having no adverse impact on wetlands. The Governing Board of the SWFWMD approved the City’s WUP renewal in 2008, but at an allocation of 4 MGD, AADF$^2$ – the rate at which the City had theretofore utilized the wellfield based on system demand. In an abundance of caution, the SWFWMD renewed the WUP with a requirement to implement a wellfield (wetland) improvement plan.

**Changes to wetland hydrology**

Long term changes to wetland health were noted long before pumping began. Prior to commencement of pumping wetland canopy flora were generally healthy, but some wetlands experienced prolonged dry periods, frequent absence of soil saturation or inundation, below normal water levels (i.e., stage), lowering of indicators of normal water elevation (i.e., pool), and invasion of upland vegetation. During the pre-pumping period, offsite discharge from the property was rare. Conditions in the wetlands were essentially unchanged after the start of pumping. Also, pumping of the NE wellfield began in October 2005 near the time when the planted pines had almost completely covered the surrounding uplands. Pine plantation canopy cover at that time was very dense. The combined effects of the pines (almost no overland flow to the wetlands), and in the opinion of the SWFWMD, a consequence of pumping, resulted in a prolonged dry period in the wetlands. Data from the multiple APTs, soil borings, and laboratory permeability tests demonstrated that the leakage from the surficial aquifer to underlying aquifers was very low; so low that the head difference between the two aquifers was approximately 10 feet. Realizing early that the change in timing and duration of wetland inundation (hydroperiod) wasn’t due to pumpage and induced leakage, other parts of the water budget that could impact the surficial aquifer and wetlands were considered. The differences evident between Figures 3, 4, and 6 show that significant changes to the property had occurred.

Two significant historical changes that could have caused net negative effects on hydrology of the NE wellfield wetlands were (1) drainage caused by ditching to connect and drain wetlands, and (2) conversion of natural land cover in the catchments of most wetlands from natural pine flatwoods to improved pasture. Ditching occurred before 1941 and increased surface water runoff from wetlands ($S_0$, eq. 1); it also limited the maximum pool elevation in the wetlands. Conversion of uplands from natural pine flatwoods to improved pasture occurred between 1941 and 1958. This change also increased stormflow runoff to the wetlands but reduced bank storage in the catchments, decreased groundwater baseflow, and speeded up off-site discharge of water from the wetlands. Both occurred many years before acquisition of the property by the City in 1990.

Beginning in the late 1990s, many of the upland areas within the NE wellfield were converted from improved pasture to silviculture. The former pasture was plowed into a ridge and furrow system that retained water and limited surface drainage ($S_i$) to the wetlands. Slash pine was planted in the furrows and within a few years leaf litter had accumulated to thicknesses of 15 cm (~6 in) or more. As the planted trees matured the combined effect of interception of precipitation and increased ET further reduced flow from the catchments to the wetlands. Hydrologic and hydrobiologic monitoring showed that the surficial aquifer and some wetlands recharged quickly after storms but drained quickly as well. Whereas the improved pasture had increased runoff to wetlands, the pine


![Figure 5 - Environmental Monitoring and Management Plan Network and other testing locations.](image)
planted pines also increased leaf area and leaf litter so recharge decreased because of greater interception and upland storage on the NE wellfield property.

Taken together, it appeared that the altered system stored less water than the unaltered system and the wetlands received less overland stormflow, but that a nearly natural hydrology could be restored.

**Restoration of wetland hydrology**

The first stage of the rehydration program at the NE wellfield property was to harvest approximately 200 acres of planted pine (Figure 6) and regrade the land to approximate the topography that existed circa 1940. Because detailed land surface elevation information from that period did not exist for the property, a digital topographic model (DTM) was created based on existing topography, the shapes and gradients of natural edges of wetlands, historical wetland hydrobiological indicators, and historical soil types and indicators. The goal was to construct a topography that could recreate a hydrologic flow system consistent with that of the 1940s.

The restored hydrology had to improve on-site wetland hydroperiods but could not cause unacceptable off-site impacts. Blocking of ditches was selected as the best means to hold water in the wetlands and to restore the hydroperiod using water from surface water inflow and the overland flow that would occur after recontouring the land. In addition, blocking ditches could not result in flooding upstream property, nor could ditch blocks prevent downstream off-site discharge. Surface water monitoring stations were installed to record the movement of surface water to and from the NE wellfield property and between different parts of the wellfield. The surface water flow data, in conjunction with the monitoring well data, were used to construct an interconnected pond routing model to determine where ditch blocks should be constructed (Figure 6) and the overflow elevation that would achieve hydrologic restoration objectives without creating unacceptable up- or down-stream.

The wetland rehydration program at the NE wellfield property achieved the desired results as demonstrated by the monitoring data and analyses conducted before and after completion of construction. Wetlands on the NE wellfield property now generally remain inundated for most of the year, and fill bank-full during the wet season. Wetland ecology has been partially restored, and upland species invasion has decreased significantly in the monitored wetlands.
Following completion of the rehydration project, wet season storms now routinely fill the wetlands, and the reduction in drainage from the wetland allows base flow to reduce the rate of stage decline during the dry season. Hydrographs similar to the one near P5AW are recorded for the other wetlands. Surficial aquifer water levels stay consistently high, with few periods of very low water levels.

**Conclusion – a team effort**

Ecologists and soil scientists hired by the City of Lakeland examined the NE wellfield wetlands and determined that the wetlands had been subject to altered hydroperiods for a very long time. Hydrogeologists determined that the soils, geological conditions, and aquifer hydraulic properties were not consistent with rapid leakage of water from wetlands; and identified more recent pine plantations as one of several possible alterations to the NE wellfield property that could account for significant changes in wetland hydrology. Stormwater hydrologists and engineers evaluated historical conditions to design a restoration plan based on restoring predevelopment wetland isolation or reduced connectedness, with removal of planted pines and recontouring of uplands catchments to overland flow of water to wetlands. Based on the proposed restoration plan, in 2008, the City was issued a 20-year WUP by the SWFWMD for the NE wellfield, which provides the City with the ability to extend the permit for an additional 10 years with a simple letter request. This type of extension could only be obtained by demonstrating a positive environmental impact using the direct hydrologic data collected since construction of the NE wellfield.

**References**


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It’s something of a running joke at my job that I’m obsessed with R, an open source programming language popular for statistical computing and graphics. What takes 25 columns of formulae in Excel or 25 steps (with nuisance intermediate shapefiles) in ArcMap can typically be reduced to a few simple – and importantly, reproducible – lines of code in R. As a user-friendly language with powerful and versatile data analysis options (hundreds of useful packages are a search query away), R’s potential is hard to overstate.

Some months ago, however, I needed to delineate a watershed using a drainage point and a DEM. Watershed delineation is one of those rare items that (to my knowledge) has yet to feature in an R package, so I decided to use ArcMap. After all, I had previously done this work in ArcMap and didn’t want to waste time on another approach that might not work.

As this was for a personal project, I loaded up my ArcMap .mxd file on my personal laptop and got to work – or I would have, except that ArcMap continually crashed while trying to run just the first step. Granting that my laptop was aged, I moved the project to my more powerful desktop computer, only to encounter the same slowness. I spent an hour optimizing ArcMap using the usual canned tricks before giving up in frustration. Some weeks later, I attempted once more, only to be greeted by a licensing error that mocked my perfectly valid and unexpired license. Annoyed by this erroneous claim and unable to quickly resolve it, I decided to jump ship to an open source alternative. If the alternative was slow, so is ArcMap, and at least it wouldn’t nag about expensive licenses!

Fortunately, thanks to an unrelated project involving unsupervised classification of satellite imagery, I already had QGIS with GRASS installed on my laptop. QGIS is an open source GIS software, and GRASS is a powerful programming toolbox that easily links into the program. A quick search revealed that this combination gave me the ability to delineate watersheds, so I opened QGIS and dragged in my DEM and drainage point. A few fast button-clicks later, I had a lovely and accurate watershed. I was blown away by how fast and easy the process was – and it was completely free.

Compared to R, I admit that ArcMap holds appeal for certain tasks – such as conveniently scrolling through projected geospatial data or easily creating professional maps with drag-and-drop capabilities, for example. Plus, some users prefer not to deal with code. However, after my QGIS experience, I’m astounded at its low market penetration compared to ArcMap. With a decent GUI and a robust feature set, QGIS (especially with GRASS) can deliver almost anything the user demands – quickly and for free. Price aside, ArcMap has seemingly grown bloated and slow over time – the inevitable consequence of its unparalleled market share (I confess I’ve yet to try ArcGIS for Desktop, so maybe that platform has addressed performance complaints). Fig. 1 is an example of a simple map made quickly using R.

That said, I acknowledge that ArcMap revolutionized GIS software and continues to offer key features; some of its tools (Network Analyst comes to mind) and third-party extensions probably haven’t been fully replicated elsewhere.
As a user-friendly language with powerful and versatile data analyses options (hundreds of useful packages are a search query away), R’s potential is hard to overstate.

Second, I hold nothing but praise for ESRI’s field data collection apps. Finally, I acknowledge that some level of fees is necessary to underwrite ESRI’s enterprise-level support and development. Despite these concessions, however, I echo a long list of academics and industry experts in holding that open source software options like QGIS and R represent the way of the future, for any number of reasons ranging from reproducibility and transparency to cost savings (see Moore and Hutchinson’s 2017 piece, “Why Watershed Analysts Should Use R for Data Processing and Analysis,” in The Confluence for a recent example).

While the perceived inconvenience of coding precludes R for many users, no such barriers exist for QGIS; I am therefore convinced the main reason QGIS hasn’t seen wider adoption is simply inertia. ArcMap pioneered the GIS scene and companies expect proficiency in the software, leading schools to (appropriately, given market forces) focus on ArcMap in many geospatial classes. Unsurprisingly, there is a learning curve involved in going from ArcMap to QGIS, although I would venture that QGIS isn’t any less user-friendly than its proprietary cousin: most longtime ArcMap users suffer from an “expert’s blind spot” and forget how daunting its interface can be to the uninitiated. However, those able to learn ArcMap have demonstrated that they can learn QGIS (and R, for that matter). Meanwhile, educators interested in introducing students to QGIS – but rightly concerned with meeting market demands for skills in ArcMap – might consider holding class lessons in ArcMap using licensed school computers, while assigning simpler homework projects in QGIS; this would spare students the trouble of licensing their personal laptops, while giving them experience in both platforms.

As with ArcMap, most people will not develop expertise overnight, but basic proficiency can come relatively quickly. While there is some overlap in layout between ArcMap and QGIS, where the two diverge (a frequent occurrence), a simple search engine query on “how to X in QGIS” usually results in a number of helpful articles and posts (more often than not on Stack Overflow). More than once, after I’ve cast aside the baggage that I inevitably carry from years of ArcMap usage, I’ve recognized that QGIS’s setup was ultimately the more intuitive. As I continue to use it, QGIS has consistently pleased me with its functionality (especially in concert with GRASS, and I should also mention the plugin Serval for easy raster editing).

Due to its combination of key suites of features and market dominance, ArcMap will rightfully continue to play a crucial role in many organization’s geospatial operations. However, for those struggling to pay ArcMap fees, or simply hoping to expand their skillsets and capabilities, some combination of QGIS and R (or other open source platforms) can superpower analyses at little monetary expense. Put more simply, I rely on ArcMap and R on my work computer, but favor QGIS and R at home…and these days, I’m finding myself using QGIS more and more even in the former.

While the perceived inconvenience of coding precludes R for many users, no such barriers exist for QGIS; I am therefore convinced the main reason QGIS hasn’t seen wider adoption is simply inertia. ArcMap pioneered the GIS scene and companies expect proficiency in the software, leading schools to (appropriately, given market forces) focus on ArcMap in many geospatial classes. Unsurprisingly, there is a learning curve involved in going from ArcMap to QGIS, although I would venture that QGIS isn’t any less user-friendly than its proprietary cousin: most longtime ArcMap users suffer from an “expert's blind spot” and forget how daunting its interface can be to the uninitiated.
When my love affair with geology began I was too young to even know it as a branch of science. Any outdoor activity meant collecting a new rock, questioning their origin and staring at their beauty in awe. As I grew older, science became my passion and my appreciation for the natural world grew. Geology was presented to me as a possible major by my college advisor during orientation, and I was completely hooked when he told me hiking and camping were required to earn my degree. Little did I know that there was also something unexpected, my love for the outdoors would soon turn into love for smelly, slimy stuff!

During my undergraduate studies, I became fascinated with the interconnectedness of living and non-living worlds and wanted to understand how these connections work. A huge opportunity presented itself when I was offered a Master’s project on how microbial activity affects cave formation and the limits of life since these “bugs” thrive in a subsurface environment with no sunlight and little oxygen. The project required me to get my hands dirty in caves, and as I become more experienced with speleology/caving, I was once again able to combine hobbies with my wish to learn how the bright, white, sticky microbial biofilms, or “tiny bug slime” that sometimes exist in caves, work. The white stuff turned out to be accumulations of tiny native sulfur globules formed by the oxidation of sulfide, which gives one a nose full of rotten-egg smell! The toxic sulfur compound is a lesson for a lifetime, or one would think...

As it turns out, climbing, crawling, traversing, and wiggling my way through the large Frasassi cave system (near Genga in east central Italy) while carrying about 20 pounds of gear and being covered in mud during my Master’s did not turn me away from inhaling the stench of sulfur. Instead of being fed up, I began to seek it out. Shifting my focus from cave systems to salt diapirs for my Ph.D. research, I quickly encountered an old friend, native sulfur. In the top and sometimes flanking position of salt diapirs, an assemblage of lithologies, referred to as caprock, can be found and generally consists of anhydrite located next to the salt, then gypsum, and occasionally carbonate-dominated lithologies. Sometimes, the carbonate caprock is associated with large quantities of native sulfur. One example for such a setting is the Spindletop salt diapir, which triggered the Texas oil boom. Once oil production at Spindletop was exhausted, the caprock of the salt dome was mined for sulfur.

Today, carbonate caprocks are relevant in manifold ways for oil and gas exploration. They can act as reservoirs, traps, seals, or conduits for hydrocarbons and pose possible drilling hazards. Furthermore, the spatial and temporal presence or absence of caprocks, as well as their lithological composition, record the geological history of a salt diapir. This record provides essential information about kinematics, fluid migration and composition, and thermal history. Presumably, carbonate caprock on salt diapirs forms in two stages. First, salt-undersaturated water preferentially dissolves halite, leading to the underplating of less soluble anhydrite to the base of older caprock. Second, microbes or thermochemical sulfate reduction mediate the replacement of sulfate minerals, i.e. gypsum and anhydrite, with carbonate minerals and native sulfur by coupling the oxidation of hydrocarbons to sulfate reduction. While the mechanistic details of these transformations are not known, there is a consensus regarding the overall processes. In contrast, the last step in the formation of limestone-sulfur caprock assemblages, namely the genesis of native sulfur, is controversial.

The currently best accepted model for the genesis of native sulfur in limestone-sulfur caprock assemblages postulates that sulfate-reducing bacteria produce sulfide, which is then oxidized by molecular oxygen (O2) to native sulfur. What bugs me (pun intended) about this explanation is that to generate large native sulfur deposits there needs to be an ample, well-balanced supply of O2, which must meet the following three conditions: (i) be abundant enough to allow for the oxidation of sulfide to native sulfur, but (ii) sufficiently scarce enough to prevent further oxidation of native sulfur to sulfate, and (iii) can be kept away from the sulfate-reducing bacteria for whom O2 is toxic. From my observations in the cave systems – where air is available – I understand that comparably small amounts of native sulfur can be generated in this way, but it is difficult to conceive how this can be achieved on the large scale of native sulfur deposits associated with caprock on salt domes. Putting simultaneously hydrocarbons, O2 and sulfate-reducing bacteria into one box leads to contradictions, as O2 and sulfate-reducing bacteria must be kept apart to avoid poisoning the bacteria, and O2 and hydrocarbons must be kept apart to avoid direct consumption of the O2 during hydrocarbon oxidation. Of course, explanations that make this scenario feasible can be found, such as fluctuations between hydrocarbon and O2 supply. During one phase sulfate is reduced to sulfide, whereas during the next phase sulfide is oxidized by O2 to native sulfur.

Geology was presented to me as a possible major by my college advisor during orientation, and I was completely hooked when he told me hiking and camping were required to earn my degree. Little did I know that there was also something unexpected, my love for the outdoors would soon turn into love for smelly, slimy stuff!
While this scenario is possible, one must ask: is there not an easier explanation? Which is exactly the question I aim to answer with my Ph.D. research.

Alternatives to the genesis of native sulfur by oxidation of sulfide with an oxidant (such as oxygen or nitrate) would be oxidation of sulfide with the help of light, thermochemical sulfate reduction or a ‘direct’ formation of native sulfur by microbes without the help of an external oxidant. The first option is not possible for carbonate caprock formation because this happens underground in the absence of light. On the other hand, generating native sulfur through abiotic thermochemical sulfate reduction at elevated temperatures is a possibility, whereas the microbial option is thermodynamically possible but has never been observed. While there are geochemical tools that allow us to elucidate the temperature of carbonate caprock formation and thereby check if thermochemical sulfate reduction was responsible for the genesis of native sulfur associated with the carbonate, testing the microbial option is a daunting task: detecting an unknown, hidden process is like chasing down a ghost. What would help in this endeavor is to know a reason why microbes might make native sulfur. I think that too much sulfide is just too stinky for them: at high concentrations, sulfide is toxic to organisms. Thus, if one puts hydrocarbons and sulfate-reducing bacteria into one box, they might produce sulfide, but only up to the point where sulfide accumulation would kill them. Under such circumstances, it would be beneficial for the sulfate-reducing bacteria to switch from the production of toxic sulfide to harmless native sulfur.

This closed-box scenario is the direct opposite of the generally accepted model for native sulfur formation where there is a need for ample supply with O₂. The system in which native sulfur is formed requires in one case very restricted fluid exchange to ensure build-up of sulfide to toxic levels, whereas it requires in the other case ample fluid exchange to ensure supply with O₂. With this, the daunting task has become much less intimidating: as for the determination of the formation temperature of carbonate rocks, there are also geochemical tools that can be used to assess if these rocks, and the native sulfur, formed under restricted or ample fluid supply. Moreover, having a hypothesis for when the microbes switch from stinky sulfide to native sulfur production also provides me with ideas how to trick them into doing this in laboratory incubation experiments.

These concepts guide me in my Ph.D. research, from the bramble and biting insects-infested Damon mound salt diapir near Houston, TX in March to icy field work at the salt diapirs in Colorado and Utah in November, and during the hours playing with stinky mud in the laboratory at UTEP. How amazing is it to be a geologist!!

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Book Release

The Art of Water Wells
by Marvin F. Glotfelty, RG

The book is a comprehensive overview of well systems ideal for everyone working in the groundwater field.

It provides practical information of water wells—covering everything from site selection to design, drilling methods, economics, and more—and is written in a fashion that is understandable, technically accurate, and applicable to real-world situations.

At more than 170 pages and featuring numerous drawings, photos, tables, and appendices, it is designed to be a valuable resource for well designers, contractors, engineers, water managers, and hydrogeologists.

2019 / 173 pages
Catalog #T1116
https://my.ngwa.org/NC__Product?id=a1838000012aPlyAAE
2020 National AIPG Executive Officer Election Results

“...the geologic specialties and interests vary widely across the country. I think another way to engage more members in the State Sections is to gather and evaluate data on each State’s membership makeup. With the data in hand, the section will be able to plan activities and meetings to better serve their membership.”

2020 National President-Elect
Nancy J. Wolverson, CPG-11048
Reno, Nevada

“I will encourage reaching out to other organizations in Latin America with two goals: of increasing AIPG membership and providing opportunities for AIPG members to offer workshops at events in Latin America.”

2020 National Vice President
Dawn H. Garcia, CPG-8313
Tucson, Arizona

“Serving the organization has truly been a privilege for me, and I am excited about contributing well into the future. My goal is to work with our team to bring people together, help move the organization forward, and uphold the values upon which our organization is based.”

2020-21 National Secretary
Sara K. Pearson, CPG-10650
Portland, Michigan

“The opportunity to assess the needs of Young Professionals and create programs specifically to support them will increase the overall value of AIPG membership and ensure that AIPG is extending the necessary efforts to maintain Young Professional membership numbers.”

2020 National Young Professional
Jessica Davey, YP-0413
Denver, Colorado
The AIPG Executive Committee asked me to analyze the makeup of the membership and to delve into why people have historically joined AIPG. These questions have lead me to discover a most exciting way to expand our organization and to envision how it can add relevance and value to every AIPG member, students, young professionals, mid-career people and seniors.

One thing is very true: Young Professionals are our future. David Abbott (CPG-04570) clearly showed (Fig. 1) in the third quarter 2018 TPG that three peak groups have passed through the ranks of our membership: the ‘Founders’, who aged out between 2001 and 2011, the ‘Boomers’, now the majority of our members, but whose average age is now about 65, and the ‘Young Professionals’, whose number is rapidly increasing. The numbers of members in the cohorts between these groups (i.e. ages 30 – 50 and 70+ in 2018) are relatively very small. This creates a unique and difficult environment for young professionals coming into the market: a great lack of mentors. Similarly, firms that are losing their more senior professionals won’t have enough trained and experienced recruits to choose from when seeking to fill staff openings. Young professionals will need to accelerate their immersion into the industry.

Doug Bartlett (CPG-08433) speaks in the same TPG article on industry’s need for new recruits with practical skill. These skill sets are best developed by merging academic training with the practical know-how of the industry at large. He also recognizes that young professionals are at a perfect juncture to find mentors from the boomer and older generation. Nothing trumps the professional and life experiences gained by living a successful life. Doug stated that our young professionals characteristically want to do something that matters and to contribute to society. Success in this way so often automatically yields financial successes and respect in one’s industry.

Realistically, the role of geoscientists will increase in the future due to population growth, and thus growth in demand for resources and public demand for measures to increase the safety of our populations during more varied climate conditions. Heat, drought, flooding, unreliable snow packs, geologic hazards, wildfires, earth movement and agricultural stressors each require geoscientists with the expertise and practical knowledge that can solve these mounting conditions. So, what does it take to develop and maintain a highly skilled group of geoscientists who can respond effectively to these challenges?

To answer this, we need to look at the demographics of our organization and community/industry trends that affect the needs of the communities that they serve. I queried over 3,600 records from our association database for member birth date, join date and primary specialty. In addition, I sent out a short questionnaire to all our 7,000-plus membership asking them what attracted them to AIPG, what benefits and opportunities keep them interested and what additional benefits and opportunities would they like our organization to provide. Their responses, and the phone interviews that I had with students, young professional and senior members, built a database of information that, I believe, characterizes who we are now and what we need to do next.

Over three quarters of our membership is 55 years old or older and we are dominated by environmental professionals (35%, approximately), with a heterogeneous distribution of other disciplines. The breadth of geoscientific disciplines at AIPG is broad (over 34 general categories). Past surges in new members (1990-1996, 2007 and 2014-2018) were again dominated by environmental geologists and hydrogeologists, with economic geology trailing. The remaining technical disciplines have consistently been present through these years.

The age distribution is elucidated by looking at the age distribution histograms illustrated by David Abbott and Douglas Bartlett’s article (Fig. 1). As the “Baby Boomer” peak ages from 2001 to 2011 and 2018, a second peak begins to develop among the under-25s in 2001 and becomes more significant in 2018 at the 25-30 age group (our millennial young professionals). If you visualize the “Baby Boomer” peak tracking to the right as the “Millennial” peak builds and also tracks to the right, our organization will lose senior members a lot faster than it gains young new members.

What do our members value? Based on my conversations and input from the survey, networking and the CPG credential are the primary drivers in
maintaining membership. The 2018 presentation titled, “The Geologic Profession at a Crossroads” introduced a new member category that might be called “CPG-A”. This is an interesting idea because there is purpose in enhancing the CPG qualifications for young professionals.

I also asked students at UC Davis and Sonoma State in California for their input on what kind of professional interactions they valued. Here are their ideas:

1. Desire more interaction with a wide range of geologic disciplines;
2. Would like conferences to have different types of table sessions (different companies, different disciplines);
3. Interested in podcasts related to geoscience mentoring;
4. Cyber meetings work better than traditional meetings but need both;
5. Being a part of out-of-state student section meetings is desired;
6. Open ended Q&A on careers (non-technical) as an informal meeting, intermittently;
7. Would like Young Professionals to speak to them as well as senior professionals;
8. Social beer bars are a must to help networking and
9. Internship workshops every year.

I would venture to say that students are almost unanimous in supporting this wish-list.

What are the strengths of AIPG? And what actions can we take to most benefit all members: students, young professionals, mid-career people and seniors?

A: Strengths

1. Our greatest strength is the CPG standard. Industry standards are lacking in many places and certifications and registrations in some states are ephemeral. State geological licensing programs are under threat. Young professionals need a standard that is recognized and will always be around.

2. AIPG is currently over 7,000 members and specialties within our membership are highly diverse. Over three quarters of the membership can be categorized as potential mentors, depending on their desire to play such a role.

B. Actions: Let us support students and young professionals by creating two special programs:

1. Develop a CPG-A program that enhances the requirements for technical skill and high moral and ethical professionalism. This program will include a number of training requirements that include communications, work ethics and values, tolerance building and problem solving approaches. All efforts will enhance employability because the young professionals will build their skill sets, communicate better than many other non-AIPG young professionals and strengthen their tenacity to overcome academic, social and management obstacles. New CPG-A members will be acknowledged publically, internally within our organization and in the industry at large. Once a person obtains their CPG-A, they will become involved in more leadership roles at Section meetings, maintain their continuing education requirements, and eventually serve in a mentor capacity with other members. The credential improves opportunities to find profes-
2019 AIPG Honors and Awards

Frank R. Ettensohn, CPG-11978
Lexington, Kentucky
Distinguished Service Memorial Medal

Although I have been an educator, geologist, and researcher for nearly 45 years, I am a relative newcomer to AIPG, having been a member for only 11 years. Hence, I am extremely honored — and somewhat amazed — to receive this award, especially considering the contributions of its namesake, Ben H. Parker, and former award recipients. I would be terribly remiss if I did not thank AIPG and the Kentucky Chapter for all that they have given me as a professional geologist. I also own a great debt of gratitude to my family, those who educated me, my University and colleagues, and my many students, all of whom have afforded me opportunities to learn and grow as a geologist. My sincere thanks to all!

As a professional geologist and educator, I would like to take a few moments to discuss one of the most fundamental challenges that we face — communication with the public. It is well-known that the public generally does not understand what we do, why we do it, or the significance of what we do. We geologists do well at explaining the technical aspects of our trade, especially among ourselves. However, for those people outside our group, like civil servants, business and other stakeholders, politicians, and everyday people without a science background, we are not connecting on a level that they can understand. These people are looking for responses to their concerns, not scientific facts. Moreover, they are looking for timely responses based on their values and beliefs, especially trust and fairness. It is quite possible that many people actually identify geologists as part of the problem when it comes to environmental crises and climate change. I only bring up these issues because it is becoming increasingly important that we learn to communicate more effectively with the public. Personal interactions with the public, student mentoring, sharing personal experiences, among others, are ways that we can interact more productively with the public. To that end, it is important for us to share with the public the interest, excitement and fascination that brought us into this field. It was that interest and fascination — as well as a concern for its continued sustenance — that brought me here today, and as I end, I would like to encourage each of us to convey that same excitement and concern to the public as a normal part of our professional responsibilities.

Again, thank you much!

Samuel W. Gowen, CPG-07284
Clifton Park, New York
Martin Van Couvering Memorial Service to the Institute Award

It is a great honor and surprise to me to be given the Martin Van Couvering Memorial Award; particularly, since it is my perception that I have received much more from AIPG through friendships and personal growth than I have been able to give to AIPG and the profession as a whole. Thanks to you all for this honor and support. I also thank my wife, the rest of my family, and my colleagues at Alpha Geoscience for their support.

It has been my pleasure to support AIPG at the Section level continuously since the late 1980s. This effort has been most recently focused toward professional licensing in New York and the Section’s Angelo Tagliacozzo Memorial Scholarship. The ability to help so many students over the decades has been a gratifying experience for many of us in the Section.

My involvement at the National level came suddenly when I answered a call by my friend, and National President, Dan St. Germain to help AIPG establish a position paper on Climate Change. I soon realized that Dan was going to draw me in deeper to the challenge than I initially anticipated. I also did not realize at that time how polarizing that issue can be and the danger to the fabric of the organization if not handled properly. A group of us met the challenge and many good friendships came out of it. One of the biggest surprises out of that experience was to be asked to accept the nomination for National President. I spent some time worrying over the time commitment until my son said that I had to accept because of a dream related to AIPG and personal development that I told the family about many years earlier. It was apparent from the dream that

The American Institute of Professional Geologists (AIPG) has a history of effective and outstanding service to the profession of geology. From its beginning in 1963, the Institute has emphasized the role that professional geologists play in this fascinating, changing, and highly complex world in which we live.

In an Institute such as this, there are so many highly motivated geologists contributing to the profession, the Institute, the public, and the nations in which we live and work that the identification of a select few for particular awards is a monumental task. The continued success of the Honors and Awards Program is dependent on an accessible nominating process and a diligent screening of those nominated. This is done by the Honors and Awards Committee.

Currently, there are six honors bestowed by the Institute: Ben H. Parker Memorial Distinguished Service Medal, Martin Van Couvering Memorial Service to the Institute Award, John T. Galey, Sr., Memorial Public Service Award, Award of Honorary Membership, Outstanding Achievement Award, and Presidential Certificate of Merit.

Descriptions of the awards, past recipients, and the nomination forms can be found on the AIPG National website or contact the AIPG National Headquarters office.
AIPG is an ideal organization for me to help the profession improve itself and for my own personal growth in the process. This award is an indication to me that I have progressed toward in reaching that goal. Thank you!

David M. Abbott, Jr.
CPG-04570
Denver, Colorado

John T. Galey, Sr.,
Memorial Public Service Award

I was surprised when I was informed that I was to receive the John T. Galey, Sr. Memorial Public Service Award. I had the pleasure of meeting John Galey, Sr., at a couple of AIPG annual meetings early in my career. I know, or at least have met, most of the 34 previous recipients of this award. Many of them have been state geologists or politically active on a state or federal level or involved in programs that fostered public education about geology. I’ve actually nominated a couple of them for this award. But I didn’t think I’d done that much in the way of giving expert testimony to governmental units, by serving on governmental commissions and committees, and by providing geological expertise where it was needed by the public at large,” the published criteria for this award.

So, I called Executive Director Aaron Johnson and asked which of my professional activities were cited in my nomination for this award. I was reminded that I spent roughly the first half of my career as a geologist with the US Securities and Exchange Commission helping mining and oil and gas companies comply with the SEC’s disclosure requirements and investigating allegations of mining and oil and gas fraud and assisting in the prosecution of warranted cases. And that I’ve periodically investigated and helped prosecute mining fraud since becoming a consultant. More details about my public service and other career activities are contained in the award citation and in my acceptance of the Ben H. Parker Memorial Award in 2015 (TPG, Oct/Nov/Dec ’15).

AIPG has been an important part of my professional life. Even before I had enough years of experience to qualify for Certification—at the time, CPG was the only membership class—I’d been encouraged to attend Colorado Section meetings and then-Executive Director Art Brunton put me on the mailing list. You get of an organization what you put into it; an old but true observation. Through AIPG I’ve met and worked with many wonderful people in many places.

I now realize that I’ve been involved in public service to geoscience in one way or another throughout my career. I appreciate AIPG’s bringing this work to my attention and giving me the John T. Galey, Sr. Memorial Public Service Award.

To younger geoscientists: I remember being in your position at annual meetings in Pasadena and Jackson Hole and Keystone listening to the award citations and acceptance remarks never expecting to be an awardee. Get to know meeting attendees, young and old. This is a great organization. It depends on volunteers. Step up and be an active part of your home sections and contribute to national as you are able. You’ll be welcomed and, sooner than you think, you may be receiving one of AIPG’s awards.

Several Student and Young Professional Members have received Presidential Certificates of Merit.

Section Leadership Awards

Robert D. Campbell,
MEM-1564
Pleasanton, California

Section Leadership Award
California

I submit this statement of recommendation supporting Robert D. Campbell as the 2019 AIPG California Section Mentor award recipient. Mr. Campbell has followed a professional path that has optimized both experiences and academ-
Jeffrey J. Frederick, CPG-10989
Elmsted, New York
Section Leadership Award Northeast

Jeff Frederick has been an active member of the Northeast (NE) Section Executive Committee (ExCom) since 2010. One of Jeff’s long-held professional career goals has been to mentor young geologists. In addition to responsibly executing whatever duties and responsibilities that have been entrusted to him while serving on the NE Section ExCom, Jeff has also looked for ways to mentor young geologists. He served a two-year term as President-Elect, two consecutive two-year terms as President, a two-year term as Past-President, and presently serves as an At-Large member. During this time, Jeff has tirelessly directed, supported or participated in virtually all NE Section activities. Some examples include the daylong Spring and Fall General Meetings (field trip, dinner, after-dinner guest speaker), promoting the formation of student chapters (there are now three), serving as web master, sponsorship of short courses, a search for a new editor of the NE Section newsletter (published 4X during the year), continued support to the successful effort to license geologists in the state of New York, and selection of a web hosting company for the NE Section website.

As an actual recipient of the Angelo Tagliacozzo Memorial Geological Scholarship in 1994, Jeff has also been a long-time and very strong supporter of this scholarship that is offered annually by the NE Section. Just one example of his support was to spearhead and kickoff the Christmas 2014 scholarship fund drive with a generous contribution himself. That fund drive ultimately resulted in more than $9,000 being contributed to the scholarship fund. In addition to his multiple NE Section duties, from 2016-2017 Jeff also served as an Advisory Board member on the National ExCom. Most recently, Jeff has taken a lead role in the planning efforts to support the NE Section’s hosting of the AIPG 2019 Annual Meeting in Burlington, VT.

No matter what activity the NE Section has undertaken in the past nine years, Jeff Frederick has been part of it. In doing so, he has helped to advance the mission and goals of both AIPG and the NE Section, while demonstrating his commitment to advance the geology profession and foster the development of young geologists. Jeff deserves wider recognition outside of the NE Section for his efforts and is thus worthy of receiving the AIPG Section Leadership Award.

Nomination by James Jacobs, CPG-7760.

Jeffrey M. Groncki, CPG-11118
Lake Zurich, Illinois
Section Leadership Award Illinois/Indiana

This award is perfectly suited for the recognition of an outstanding leader within the Illinois/Indiana Section.

In 2008, the Illinois/Indiana Section initiated an effort to re-kindle participation in the section. A core group of geologists in the area met and organized biannual meetings and a section newsletter in alternating quarters. Jeff Groncki was one of the first to step up and support, call, push to grow section participation. Jeff also served as the technical editor coordinating the conference papers and presentations for AIPG’s National Conference in Chicago, which was hosted by the section in 2011. Jeff’s re-kinding efforts and support also came at a time when numerous regulations were being developed that directly affected our profession, and included related State licensure (Illinois Geological Licensing Act). Jeff Groncki stepped up with the initial core group of IL/IN Board members by taking a leadership role in the development of regulations within the state. With Jeff stepping up to act as a liaison among other professional geological societies in Illinois, AIPG quickly became recognized among non-member peers, and highly relevant to our state government. In fact, since February of 2014, Jeff has served as Chairman of the Illinois Licensing Board for the Illinois Department of Financial and Professional Regulations.

Jeff has served as IL/In Section Board member for 10-years, Vice-President for 4 years, from 2012 to 2014, and Section President from 2014 to 2017. Jeff is a Senior Manager for Walgreens Corporation and responsible for North American Environmental Engineering operations and applications. Jeff has applied his geological skills with a high degree of competence and is exemplary of what AIPG values, and represents its professional ethics on a daily basis. The contributions from Jeff are too numerous to list but needless to say, Jeff is a strong leader, solid geologist and represents exactly what this award is all about.

It is with this written recommendation that I wish to have Jeff Groncki Nominated and awarded The Section Leadership Award.

Nomination by David Pyles, CPG-7364.

Keith B. Rapp, CPG-10447
Woodbury, Minnesota
Section Leadership Award Minnesota

I am nominating Keith Rapp, CPG-10447, for the AIPG Section Leadership Award from the Minnesota Section. Keith is a long time, active member of the Minnesota Section of AIPG. He has volunteered for many leadership positions over the years; most notably in my years of involvement with AIPG, he has been an officer, lead field trips, run our website, and now serves on the state licensing board.

Continued on p. 54
**Steps to be Taken Regularly/ How to be Proactive in Protecting Licensure and Other Geologic Programs**

1. Understand how your state legislature works.
   a. When are they in session, when are deadlines, etc.
   b. Identify committees that bills would be referred to regarding AEG issues.

2. Stay current on who is in office.

3. Take opportunities to meet with senator / representative / legislative committee consultants that work AEG topic areas.
   a. Introduce yourself and AEG, explain why licensure is important in your state, what is a geologist and applicable projects that are critical for a professional geologist to be a part of – good to cite project in your state that went poorly when a geologist wasn’t consulted or their advice not followed (ie CA – Oroville Dam).
   b. This step could greatly reduce the “Angie’s List” approach to eliminate needless licenses.
   c. Provide a one page fact sheet to leave behind visits, have a larger packet of information available for key members and staff.

4. Offer to be a resource for senator / representative / legislative committees.
   As a professional society you should offer your support of bills that align with your association’s mission with regard to legislative activity. This shows the committees/ Representatives/ Senators that you are actively following the issues and earnest about your offer of being a sounding board.

5. Identify senator / representative / legislative committees who will be ‘allies’ if a bill to eliminate licensure is proposed. Call prior to beginning of session and periodically to see if they hear of anything in the works. The point is to never get to the point of anything being written. Much easier to fight.

6. Stay current each year on list of bills by monitoring your state’s legislative website. Monitoring should be done at a minimum on a weekly basis. Several states have compiled lists of key words to help more efficiently flag bills that could be a problem. A copy of the key word list is attached and also available on the AEG Website (after signing on, go to “resources” and then to “licensure resources” and follow the prompts).

7. Create email list of geologist professional societies in the state who can help advocate for geologist-related issues.
   a. State Licensure board, Groundwater Resource Association, - these resource may know someone who can help when an issue comes up.
   b. Remember that some state boards cannot advocate for political issues, but members can still serve as resources.

**ARIZONA RECIPROCITY**

Contributed by R. Douglas Bartlett, CPG--8433

An interesting development in Arizona regarding professional licensing.

This notice came from Public Policy Partners - the lobbying firm we used a few years ago when deregulation of geologists was proposed. A bill is pending the Governor’s signature that would mandate reciprocity for professionals licensed in other states when they move to Arizona. This may mean deregulation is off the table for the time being.

**LICENSEES WELCOME**

The Governor mentioned reciprocity for occupational licensing in his State of the State speech and this week that bill cleared its last hurdle before heading to the Governor’s desk. HB2569 Occupational Licensing; Reciprocity, sponsored by Representative Warren Petersen would require a regulating entity to issue an occupational license or certificate to someone who has established residency in Arizona and has that same license or certificate in another state provided that person is in good standing and the previous state has the equal practice requirements. This “universal” license would only be valid in Arizona and does not affect any states in which Arizona has an interstate compact. See below for comments from both the Governor and bill sponsor.

“We’ve heard too many stories of licensed, experienced professionals denied the opportunity to work upon moving to Arizona. With this first-in-the-nation reform, Arizonans who have recently moved here will be able to put their skills to work faster and without all the red tape. I thank Representative Petersen for his leadership and for sponsoring the bill and members of the House and Senate for their bipartisan support.” - Governor Ducey

“For qualified professionals who move to our state looking to work, let’s get government out of the way and let them get to work. I’m proud to have introduced this important legislation to help put Arizonans to work and I thank my colleagues for their support to pass this bill. We look forward to Governor Ducey’s signature on this bill.” - Representative Warren Petersen
If a bill to eliminate licensure is found:

1. Contact the legislative committee who drafted the bill to get more information/see if it is an oversight that can be removed.

2. Identify who is sponsoring the bill, meet with the author’s office immediately and present your concerns and let them know you will unfortunately have to oppose if they proceed.

3. Meet with Committee staff early in the process to let them know your concerns. Also provide a packet of information for the committee staff which will help them in developing the analysis.

4. Send an Alert to communicate to email list of geologists with the problem and what is being done, and contact the AEG Licensure Committee.
   a. Who has been contacted within the legislature?
   b. What more information is needed?
   c. What is the status of the bill and when are the next major deadlines voting – rewrites?
   d. What is needed – contact of someone from the legislative party, letters of opposition?
   e. Get letters of opposition sent to Author, committee consultants, members of the committee, as soon as the bill is sent to the committee. Letters should reflect issues related to public health, safety and welfare. Sample letters are available on the AEG website.
   f. Determine whether there may be a need for help from a lobbyist and funding to do so. If needed, obtain the appropriate form from the AEG website. The form is in MS Word and is formatted so that it can be easily filled out and, if needed, edited.

5. Write a letter to your senator / representative / legislative committees on behalf of AEG and other respected professional entities.

6. Stick with it to the end, even if it the bill is rewritten to remove the language it can be added back in at the last minute. Need to continue to monitor the legislation.

Editor’s Note:

This Article was prepared on behalf of AEG by Greg Hempen, AEG Past President (2017-2018), for the Geologic Legislative Action Group, which is composed of representatives from AGI (American Geosciences Institute), AIPG, GSA and GSA-EEDG (GSA Environmental and Engineering Geology Division), AEG, AASG (American Association of State Geologists), ASBOG (National Association of State Boards of Geology), NCKRI (National Cave and Karst Research Institute) and NSS (National Speleological Society. In many cases the representatives on this committee are the leaders of the organization concerned (Pres. Keri Nutter and Exec. Dir. Aaron Johnson for AIPG, for example, and Pres. Allyson Anderson book of AGI, as well as Past-President Hempen of AEG). The Geologic Legislative Action Group’s mandate is to devise a joint strategy for obtaining and maintaining effective input to all of 51 legislative bodies in this country.

Dr. Hempen’s and Dr. Beswick’s notes present the most cogent approach to dealing with Legislatures that I have seen in my 18-month involvement with the Texas legislature: they lay out the levels of financial and time commitment that will be required, and the reasons this level of commitment is required if we want to be effective. They also present a well-thought-out plan of action.

Your Editor wishes to thank Dr. Hempen for his permission, in fact, encouragement, to use this important summary of what we need to do to ensure the place of geology in, and the ability of geologists to, improve and ensure public welfare and safety in this great country. J.L.B.

Proposals from AEG to the Geologic Legislative Action Group

There are three related proposals that AEG would like to raise with the Geologic Legislative Action Group (with initial discussions held on Monday, November 5, 2018 AEG has been involved with supporting Geologic Licensure since the early 1980s. Legislation, which AEG has considered potentially harmful to public welfare and the environment, has been introduced over the last decade in several states concerning science education, water rights, geologic hazards, and geologic licensure.

AEG created its own Licensure Committee and implemented a support fund after careful review of legal and tax issues concerning our tax status. AEG believes the professional, applied geology community needs to be more proactive and act to assist practice groups in each state on how to handle legislative concerns. [A file on Proactive Concerns from the AEG Licensure Committee is included with this narrative.]

The first proposal is educational. Applied geologists, and particularly licensed, certified and registered geologists, should be educated by our practice organizations regarding potentially harmful legislation to public welfare, the environment, and our practice. Members of our practice organizations should be encouraged to know, to annually correspond with, and to be resources for their state legislators. In this way professional geologists can be a source trusted by their legislators for advice on geologic impacts to public health, safety and welfare. Applied geologists must be a vocal and involved body with their state legislators.

The second proposal is organizational. AEG believes a captaincy (for lack of a better term) of three to five applied geologists should be formed in every state to: understand their state’s legislative activities, assess bills, and be the nexus with the intrastate professional geologists and regional or US, geologic organizations. The applied geologists should reside in the state for which they will be acting and must be licensed or registered in that state, if that state has a geologic practice licensure board. The geologists of the captaincy cannot be state employees nor be on the geologic practice licensure board, because they must be able to speak out on legislative issues. The individual applied geologists should have staggered terms, perhaps of two or three years, in order that each person would know their limited length of service and so that burn-out would not occur.
AEG trusts that such a captaincy of professional applied geologists could be developed in every state from the members of this action group’s organizations. Some states already have independent bodies from which such individuals could be approached. Most states would need to have our organizations collaborate with applied geologists to seek the members of a state’s captaincy.

The third proposal is annually funding a legislative tracking service. [This proposal should not be funded until the first two proposals have been implemented to some extent.] Too often the professional community learns very late about an important bill, which may require our support or our request for revision or our opposition. A legislative tracking service provides bill filings and movements every business day for all 50 state legislatures and the federal legislative branch. [Our action group could be informed of bills ahead of paid lobbyists.] This data allows us to seek to support or revise or oppose bills early in the committee cycle. Our applied geologists, as voting state residents, at this early stage can have the most productive and least expensive influence with their own legislators on bills. (AIPG Editor’s note: Dr. Hempen has informed me that AEG’s Board of Directors has now authorized funding of a legislative tracking service (LTS). Two additional services are being reviewed in August 2019 to resolve the best LTS for distributing legislative data to voluntary state captaincies. AEG may be able to contract for a LTS to start providing bill tracking on or about October 1, 2019).

AEG carefully evaluated one tracking service this past summer. A tracking service uses a Boolean Logic search of provided keywords to identify bills of interest. In AEG’s opinion, a professional staff from among an organization of our action group must be involved in receiving the daily bill tracking reports. Paid staff can be available every business day of the year. Volunteers, and particularly applied geologists, may not be available for long periods. The professional staff would: coordinate the contact with the tracking service, pay its invoices and arrange the effective keywords for legislative tracking; keep and modify the state captaincy lists and the email lists of committees of our action group’s organizations; and, send the tracking service’s daily state tracking information to the appropriate state captaincy and the organizational committees of our action group. In the summer of 2018, one tracking service was estimated to cost $8,000 to $12,000 annually, depending upon some search parameters. AEG’s professional staff receiving the tracked bills is estimated to cost $8,000 to $16,000 annually. [46 state legislatures meet annually for differing session lengths. 4 state legislatures meet only in odd-numbered years.] The state captaincy receiving the daily state tracking information from the professional staff would resolve its importance to their state. The need for three to five applied geologists to be members of the captaincy would assure that at least one of the individuals could act for all. During a state’s legislative session, notices on many tracked bills might be received daily, particularly early in the session. It should be easy to resolve whether an individual bill was important, note worthy or unimportant. Important bills would be alerted to the state’s professional geologic organizations for determination of support or revision or opposition to the noted important bill(s). The captaincy would not necessarily lead the legislative approach to the important bills, but would be involved in some capacity. The state’s applied geologists (first proposal) would be sought to request the determined action on the important bill(s) by their contact with their legislators. Note-worthy bills might be followed by the captaincy and the state’s professional geologic organizations until such bills: become important by some action; become unimportant; or, fail to have committee consideration. Respectfully submitted,

Greg Hempen, PhD, PE, RG
AEG Past President (2017-2018)

Too often the professional community learns very late about an important bill, which may require our support or our request for revision or our opposition. A legislative tracking service provides bill filings and movements every business day for all 50 state legislatures and the federal legislative branch.

Geologist, Geological Communicator and Author Killed

TPG is indebted to Barb Murphy and the Arizona Geology e-Magazine for this report, for details see: https://blog.azgs.arizona.edu/blog/2019-08/death-family-sarah-andrews-brown.

Few of us have the talent to bring Geology before the public in as exciting a way as did Sarah Brown, but her life should serve as an inspiration to all of us to engage with the public as effectively as we can for the benefit of our profession, our nation, and the world. Her family has lost three vital and beloved members, and the profession has lost an important champion. -TPG Editor

Sarah (Andrews) Brown, petroleum geologist and author of the Em Hansen mystery series, passed away in a private plane crash along with her husband, Damon, and their son Duncan on 24 July 2019. Sarah’s murder mystery, ‘Fault Line’, was loosely based on Lee Allison’s (former Arizona State Geologist and AIPG John T. Galey Awardee, deceased Aug. 2016) experiences as Utah State Geologist in Salt Lake City leading up to the 2002 Olympics. Through her friendship with Lee, Sarah became a friend of the Association of American State Geologists (AASG) and the AZGS and would occasionally visit and regale geologists with stories of murder and mayhem (involving geology, of course). Sarah was an incredible person who led a very full life.

She was the award-winning author, pilot, artist, teacher, and professional geologist who brought the excitement of geology to the public through her mystery stories. She adeptly engaged scientist friends in her research, often rewarding them with veiled appearances in her books, sometimes with unfortunate outcomes. In her dozen books, geologists, paleontologists, biologists, accountants, and graduate students, among others, were murdered. Her chief alter ego, petroleum geologist turned forensic geologist, Em Hansen, demonstrated that geological principles can be used not only to solve murders and scientific problems but also to address social concerns. She painted positive pictures of petroleum, mining, environmental, engineering, and research geologists in industry, the USGS, state geological surveys, and academia.
The AIPG Section Leadership Award was established by the Executive Committee in 2013 to recognize one or more of our members who have demonstrated a long-term commitment and have been long-term contributors to AIPG at the section level. AIPG has many sections where one or more individuals have demonstrated exceptional leadership for their section and in many instances kept the section together and moving forward. These individuals are commonly not known at the National level or by AIPG members outside of their sections; however, their contributions have been vital to their sections and they perform this work because of their commitment to our profession and AIPG. All active section members are eligible. It is not required to be a current or past section officer. The award will consist of a plaque (or similar) that will be presented to the awardees at the annual meeting of AIPG.

Based on the above criteria the Awards Committee may select multiple nominees for the award.

The AIPG Section Leadership Award is administered by the Executive Committee of AIPG. The selection of the winning member(s) will be decided by the AIPG Awards Committee. The deadline for submittal of nominees for the AIPG Section Leadership Award, to AIPG National Headquarters, is January 15th of each year. The nomination form for AIPG Section Leadership Award is presented below. The awardees will be announced in April so they may attend the annual meeting.

AIPG Section Leadership Award Nomination Form
http://www.aipg.org/sectionleadershipaward

Name of Candidate: ___________________________________ Section: ______________________
Address:____________________________________________________
Address:____________________________________________________
Telephone Number: ___________________________ Fax: ___________________________
E-Mail: ________________________________________________

Name of Person Making Nomination: ___________________________________ Section: ______
Address:____________________________________________________
Address:____________________________________________________
Telephone Number: ___________________________ Fax: ___________________________
E-Mail: ________________________________________________
Date: ________________________________________________
Signature: _____________________________________________

Supporting Statement (In brief here, but please attach a detailed letter of support) ____________________________

Return to: AIPG
Awards Committee
1333 W. 120th Avenue, Suite 211
Westminster, Colorado 80234-2710
or E-mail to aipg@aipg.org

DEADLINE: Completed nominations must be received by January 15, 2020.
How Your AIPG Dues Help Advance the Geology Profession

Aaron W. Johnson, MEM-2783
awj@aipg.org

Fall is upon us, and with it, the time to renew membership in AIPG. You’ll notice a dues increase this year, the first since 2016. We recognize that your hard-earned dollars are valuable, and we did not reach this decision lightly. The increase is approximately 2% per annum, which roughly corresponds to the increase in the consumer price index for the Denver metro area. Our goal is provide the best services we can to you, our members.

Approximately half of AIPG’s annual expenditures go directly to members, either as member services or via the expenditures necessary to host our annual meeting or other continuing education events, seminars, and courses. The National Office staff works diligently to ensure that your member records are up-to-date, letters of good standing are issued quickly and accurately, and that AIPG complies with all state, federal, and international laws and guidelines. Members of the National Office staff work tirelessly to address issues that impact our profession, and we dedicate our time and effort to fight on your behalf when issues pertaining to licensure, registration, certification, public reporting for purposes of investment, changes to policies in or programs at the state or federal level arise.

Your dues provide support for specific programs and initiatives. Among these are AIPG’s participation in the Federal Advisory Committee for the National Cooperative Geologic Mapping Program (NCGMP). The NCGMP provides funding for applied geologic mapping and derivative map products, mostly produced by state surveys or by university researchers in conjunction with state surveys. The Institute also works directly with credentialing organizations abroad to ensure that members that hold the CPG title can maximize their career potential in the international space. AIPG has reciprocal recognition agreements with The Geological Society of London, The European Federation of Geologists, the Institute of Geologists of Ireland, and Geoscientists Canada. We work assiduously to see that your CPG is recognized by CRIRSCO and the members of the CRIRSCO family (JORC, PERC, SAIMM, etc.)1 and Geoscientists Canada so that members who possess the requisite experience can be recognized when reporting on ore deposits.

AIPG is also working in partnership with the Association of State Boards of Geology (ASBOG), the American Geosciences Institute (AGI), with financial assistance from the Foundation of AIPG to develop an informational program that we can deploy to legislators and legislative staff, to better illustrate the impact our profession has on human health and safety and the economic health and financial vitality of local, state, and national economies. This partnership provides funding for a geology intern to construct a database of concrete examples of the impact of professional geologists on the public. Finally, your dues help us support students at the local, state, and national levels. Last year, AIPG awarded more than $25,000 in scholarships funded from the Foundation of AIPG, the AIPG National Office Grants Program, and by individual AIPG sections. Your participation in AIPG is a critical component of training the next generation of geologists.

These examples are but a few of the ways in which your membership in AIPG has a larger impact on our profession. I personally am grateful to each of you for the resources you provide to AIPG, and I recognize your contributions, both financial and of your time, energy, and expertise on our behalf. I wish each of you a safe, healthy, and productive fall.

Best Regards,

Aaron

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1. The Committee for Mineral Reserves International Reporting Standards (CRIRSCO), which was formed in 1994 under the auspices of the Council of Mining and Metallurgical Institutes (CMMI), is a grouping of representatives of organizations that are responsible for developing mineral reporting codes and guidelines in Australasia (JORC), Brazil (CBRR), Canada (CIM), Chile (National Committee), Colombia (CCRR), Europe (PERC), Indonesia (KOMPERS), Kazakhstan (KAZRC), Mongolia (MPIGM), Russia (NAEN), South Africa (SAMREO), Turkey (UMREK) and the USA (SME). (https://mrmr.cim.org/en/links/crirSCO/, accessed on 2019-08-27)
About two weeks ago, my husband and I were discussing my column for TPG and how I was struggling with finding the best way to address climate change and navigate reluctance to discuss the issue. And that’s when my husband said the most profound thing, right there while brushing our teeth; “If you aren’t going to talk about it now, then when will you?”

“If not now, then when?” It was the perfect challenge to have the conversation and to develop an organization position on climate change.

For nearly 60 years, AIPG has been the cornerstone of professionalism in the geosciences. But in the past 60 years, there have been a lot of changes to our profession; gentlemen no longer wear suits in the field, and women make up nearly half of all geoscience graduates. We are able to collect terabytes of data from our desk before even putting our first foot into the field, whereas traditional mapping tools and methods required months or years in the field to collect the same information (though I will never discount the value of time well spent in the field, no matter how good Google Earth is). Plate Tectonic theory was defined shortly after AIPG was founded in 1963 and is now the accepted mechanism for most of our basic geologic understanding. If the profession can survive these changes and adjustments, then why can’t AIPG also evolve?

The politicization of climate change has caused a polarization of opinion among our members, making taking a position one way or another a very difficult choice for our leadership for fear of alienating some of our members or ruffling the feathers of partner groups. But as William James said, “When you have to make a choice and don’t make it, that in itself is a choice.” In my opinion, it is time for us to make a conscious choice on climate change.

Growing up and living in Alaska my entire life, I have been fortunate to reside among some of the most majestic and most grand scenery nature can provide: the Chugach National Forest in my backyard, glaciers merely an hour drive away, and world class fishing runs on the wildest rivers. However, there is a very noticeable and real shift in the climate of my home state; increasing temperatures across the state have thawed permafrost and melted glaciers, and caused changes in the seasons that used to arrive in predictable clockwork fashion. I grew up in a temperate region that borders on that of an arctic climate. I remember that in grade school there was snow in the winter, cooler summers with rain and green grass and trees, and snow on the mountains until July; visitors to Anchorage were often (amusedly) spotted wearing sweaters and jackets all summer. But in the last two decades, nearly all of Alaska has been plagued with warm and dry winters, sweltering summers, and incessant wildfires. I’ve witnessed, firsthand, the diminishing extent of the arctic ice pack and the rapid pace of thawing permafrost and the impacts that it has on animals, ecology, and traditional ways of life in the Arctic.

I’m not talking about the pictures of emaciated polar bears clinging to tiny icebergs or giant pieces of ice break-

Continued on p. 37

1. A sandstone is composed of 64% potassium feldspar, 28% quartz, 8% plagioclase feldspar and 4% miscellaneous rock fragments. How should it be classified?
   a) Arkose.
   b) Arenite.
   c) Litharenite.
   d) Dude, I don’t go for sandstones! Evaporites rule!

2. This clay is a 2:1 structure made up of 2 silicon tetrahedra and one aluminum octahedron, where the units are bonded by potassium cations and diagnostic x-ray peaks are seen at about 10.0, 4.5 and 3.3 angstroms:
   a) Illite.
   b) Smectite.
   c) Kaolinite.
   d) None of these “ites” for me! Just give me silly putty and let me play!

3. In geomechanics and structural geology, which type of rock behavior is indicated when the stress required to continue deformation rises as the strain increases?
   a) Ductile.
   b) Brittle.
   c) Work hardening.
   d) Hey hombre, I’ve never heard of rocks behaving (and misbehaving). I think you had one too many adult beverages.....

4. One of these is not a stage of the Cretaceous period:
   a) Aptian.
   b) Toarcian.
   c) Albian.
   d) Dude, I dun’t mimirize this stoff! I are a hololocene xprt miselph!

5. In our studies of geophysics and geodetics, we wish to calculate the velocity at which the Earth moves around the Sun. To a first approximation, if the average distance between the Earth and Sun is about 149,600,000 kilometers and considering a circular orbit, what is this velocity in miles per hour?
   a) 670 mph.
   b) 6,700 mph.
   c) 67,000 mph.
   d) Help!!!!!! Let me out of this column!!!!
Climate change is a reality that we as humans, along with the other species that we share this planet with, are facing. If current trends continue, it will result in a worldwide disruption of our concept of how the world works.

Common topics of concern during the courses of our professional lives are: finding a school, finding that first job, keeping your job, setbacks in the industry, ethics, continuing education, relationships and outreach within communities.

These suggestions are significant and the timing is now. But to move forward on such a significant front requires input and conversation with all our members, young and old. Think about the trends identified in this article and the two suggested actions then ask yourself: Do I want to be a part of something bigger than myself? Success is earned and working together yields meaning to your life and the lives of those you support. I want to hear from each of you. Please share your thoughts and opinion for moving this vision forward. We can do this when the will to advance our science and profession drives the process. Contact me at stevebaker@operationunite.co, or write a letter to the Editor at aipg@aipg.org.

About the Author

Stephen J. Baker serves as a 2019 AIPG Advisory Committee member. He is a California and Washington Registered Geologist and Certified Hydrogeologist and owned and operated his consulting firm, HydroSolutions of California, Incorporated, for 29 years. He now consults and has created Operation Unite that focuses on building public responsibility for water related projects through public and stakeholder outreach programs.

Answers:

1. The answer is choice “a” or “arkose.” The vast abundance of feldspars is indicative of arkose sandstone (see diagram to the right, based on Folk’s classification). Note that arenites are dominated by quartz grains and litharenites have a mixture of rock fragments (lithics) and quartz with little feldspar, in comparison.

2. The answer is choice “a” or “illite.”

Smectite is also a 2:1 structure but the bonding is much weaker, as oxygen atoms of each sheet are opposite to one another and only secondary bonds exist. Thus, in smectite, water and cations can move between the units and force them apart. Diagnostic x-ray peaks occur at about 14-15 and 9.5 angstroms for air-dried samples. X-ray peaks for samples saturated with ethylene glycol occur at about 17.5 and 9.9 angstroms.

In kaolinite, we have a 1:1 structure consisting of one silicon tetrahedron and one aluminum octahedron where the units are held by hydrogen bonding and where diagnostic x-ray peaks occur at about 7.2, 3.57 and 2.33 angstroms.

3. The answer is choice “c” or “work hardening.”

In ductile behavior, rocks experience large amounts of plastic deformation before rupture.

In brittle behavior, elastic deformation is followed by rupture.

4. The answer is choice “b” or “toarcian” which belongs to the Jurassic Period.

5. The answer is choice “c” or “67,000 mph.” The proof follows:

The circumference of the circular orbit is 2πR. Thus, the distance traveled by the Earth around the Sun in one year is:

\[
D_{1\text{yr}} = 2\pi R = (2)(3.1416)(149,600,000) = 939,966,720 \text{ km/yr (1)}
\]

In hours, equation (1) becomes:

\[
D_{1\text{yr}} = 939,966,720/[(365)(24)] = 107,302 \text{ km/hr (2)}
\]

Since 1 km = 0.625 miles, equation (2) may be written as:

\[
D_{1\text{yr}} = (107,302)(0.625) = 67,064 \text{ mph (3)}
\]

Equation (3) is the answer that we seek. The Earth then travels around the Sun at a speed of about 1,000 times greater than an average highway speed of 67 mph! Hold on to your hats and hang on!

67,000 MPH
Morals and Ethics

An observation I heard: “The ethical man knows that cheating on his spouse is unethical while the moral man does not cheat on his spouse.”¹ This observation distinguishes between ethics and morals on the basis of actions. Behaving rightly is not just knowing what the right thing to do is, it is acting that way. This observation is really about integrity, that is not only knowing what the morally/ethically correct thing to do is but acting in conformance with that knowledge.

In my ethical writing and speaking, I’ve distinguished between morals and ethics by stating that morals are informal statements about acting rightly that we’ve all learned, generally informally (following Bernard Gert’s Common morality—deciding what to do (Oxford Univ. 2004)). Ethics are written, codified statements adopted by a particular group such as the AIPG Code of Ethics. This distinction is useful for contrasting common morality from professional ethics.²

More generally, morals and ethics concern themselves with distinguishing right from wrong, with character, with actions or behavior, and the volition involved in the actions of responsible persons.³ Dictionary definitions define “ethics” in terms of “morals” and “morals” in terms of “ethics,” so the terms are quite similar, and the definitions are circular.

Each of the three preceding paragraphs is an important and different statement about moral and ethics. They express some fundamental concepts that are worth periodic re-examination and contemplation.

Professional ethics and the geosciences

Aaron Johnson’s, Mem-2783. “Professional ethics and the geosciences” column in the Jul/Aug/Sep ’19 TPG describes an early career assignment in which a heating oil tank was removed followed by removal of the piping from the tank to the adjacent building. Johnson describes the muddy mess of insulation surrounding the piping that contained increasingly visible gray fibers as things dried out a bit. Johnson was concerned about these fibers, but his supervisor and project manager were unconcerned and wanted the work to continue. Johnson quit that job shortly thereafter. Johnson noted that he had not received any relevant training on working with potentially hazardous materials in college. This was his first experience with potentially hazardous working conditions and the fact that employers are sometimes unconcerned.

I spent two years as a field tech for a mining exploration consulting firm in the late 1960s. A fair amount of my time involved running electromagnetic or magnetometer surveys over properties, primarily in the Colorado mountains. These were one-man surveys. At the end of the day, I’d call the office and let them know what I’d done that day. This call was also the safety check that I hadn’t fallen and broken a leg or met with some other emergency situation. Fortunately, the worst that ever happened was getting a 4×4 stuck in the mud, which involved a 3-hour walk to a phone and another 2½ hours of waiting for someone to come pull me out. Looking back now, I realize that I shouldn’t have been working alone. But that is what everyone did at the time. The only exploration geologist I ever heard of getting in trouble was fishing, rather than working, when he slipped into a stream, broke a leg, and had to wait several hours for rescue while still sitting in cold water. Cell phones with GPS certainly can improve the situation, but they don’t always work in the boonies. The general lack of trouble is not a good justification for working alone in rugged terrain.

Johnson’s story reflects the time at which it occurred. But academic courses still don’t cover many topics that one needs to learn about in one’s professional practice. This fact simply recognizes that there are limits on the amount of topics and time available in formal education. This is why continuing professional education or professional development is an encouraged, if not required, part of many professional ethics codes. The types of emerging problems faced by today’s professionals (young and old) differ in some respects from those of 20–30 years ago. The real lesson here is to be sensitive to potentially troubling situations and don’t be afraid to stop and ask questions. This is where mentors, including those who are outside your organization can help.

1. While I used “man” in the observation because the text flows better, “woman” or other gender-neutral term could be used.
2. See Professional Ethics Fundamentals and Professional Practice Examples: https://www.youtube.com/watch?v=smOZOjTNNA8, 40 minutes.
3. We don’t hold children, the insane, and others with diminished mental functions to the same standards of responsibility and moral behavior.
and ask questions. This is where mentors, including those who are outside your organization can help. Brandy Barnes’s, YP-195, “The impact of an incredible mentor” article and Keri Nutter’s, CPG-11579, “Mentors and mentees” President’s Message in the Jul/Aug/Sep ’19 TPG describe the importance of and the wide variety of mentors available to you. Don’t be afraid to pick up the phone and contact someone you think can help you, even someone you don’t know or know well. I remember talking with many older AIPG members early in my career and the assistance and encouragement I received from them. I periodically get calls about professional ethics issues from folks, some of whom I know and some I don’t. I always enjoy the conversations. And relative age doesn’t matter. I’ve called both Barnes and Nutter about issues they know more about than I do.

Safe harbor for forward-looking statements

Geoscience practice and the securities laws most commonly meet in connection with statements about the potential success for mining or oil and gas ventures and any associated estimates of mineral or oil and gas resources and/or reserves. Shares in a mining venture or fractional undivided interests in oil and gas or other mineral rights are defined as securities in federal and many state securities laws. But investments in proposed real estate ventures or construction of a plant that require geoscience reports on potential geohazards or environmental impacts can also be covered; “investments” is the key word.

The one thing geoscientists all know about any estimates about future potential exploration success, estimates of mineral or oil and gas resources and/or reserves, potential for geohazards or environmental impacts occurring is that such estimates are erroneous, that they are not precisely correct. The precision of such estimates is limited by the number of significant figures that can be used in the estimate, usually no more than 2 or 3 for resource and reserve estimates due to the precision limits of the underlying data. But there are a variety of other reasons why the estimates and statements of potential are wrong. These can be due to unknown geologic factors, price and cost unknowns, and many other factors.

This is where the safe harbor for forward-looking statements in the Securities Act of 1933, as amended, Section 27A (15 United States Code 77z-2) comes into play. The safe harbor provides that an issuer or person acting on behalf of the issuer “shall not be liable with respect to any forward-looking statement, whether written or oral, if and to the extent that the forward-looking statement”

• is identified as a forward-looking statement
• is accompanied by meaningful cautionary statements identifying the important factors that could cause actual results to differ materially from those in the forward-looking statement.

Although geoscientists recognize that estimates of mineral resources and mineral reserves, the potential for geohazards, or environmental impacts occurring, etc. are inherently forward-looking statements, they must be explicitly labeled as such to avoid an attorney’s “client-interest induced stupidity” for whom words like “estimate ≠ forward-looking.”

An example of a statement invoking the safe harbor is, “Mineral resource and mineral reserve estimates are inherently forward-looking statements subject to error. Mineral resource and mineral reserve estimation errors cannot be eliminated. The major expected sources of error in the estimates, in order of importance, include: [list of major sources of error]. These factors are continually being reviewed to determine whether any adjustments are needed. The timing and effect of such changes cannot be predicted.” The list of major sources of error vary by project. Another way of dealing with this issue is the use of a “Risk Factor” section in the project report containing a paragraph or so on each of the major sources of error: this helps provide the required meaningful cautionary disclosure.

Because our professional reports, regardless of subject matter, probably contain estimates of future performance, risk avoidance, etc. getting into the habit of providing a meaningful discussion of why our opinions and interpretations will be in error, identifying the probable sources of error and their impact is a good habit to get into. Even if the securities laws are not involved, the concept of the safe harbor for forward-looking statements can be a potential defense.

Escaping Water World: Future Sea-Level Rise and How to Fix It

“Escaping Water World: Future Sea-Level Rise and How to Fix It” is the title of a lecture presented by Dartmouth College Professor Erich Osterberg on 19 June 2019. This is the most thoughtful discussion of global warming, sea level rise, and what we can reasonably do about it that I’ve ever seen or read. Osterberg is neither a fervent denier nor a climate alarmist; he is pragmatic about climate change and suggests things that we can all realistically do about it. I urge you to take the hour to view it: https://alumni.dartmouth.edu/learn/faculty-lectures/escaping-water-world-future-sea-level-rise-and-how-fix-it. It counts as CPD.
Recent modeling supports this conclusion. Extreme care must be taken in selecting appropriate pumps with wide ranges in pumping rate over wide ranges in head (i.e., head-capacity curves). Additionally, detailed and real-time monitoring and controls are needed to continually optimize reliable production from wells and well fields. With continued increases in demand over the next few decades, importation of water from large regional groundwater and surface water sources will certainly also be viable. Additionally, the Middle Trinity aquifer will provide substantial amounts of water while at the same time waters from the Lower Trinity aquifer may provide a suitable groundwater reservoir for desalination and ASR projects.

References
1. South Central Texas Regional Water Planning Group, 2015, 2016 South Central Texas Regional Water Plan, Volume 1 – Executive Summary and Regional Water Plan. Prepared by South Central Texas Regional Water Planning Group, with administration by San Antonio River Authority, with technical assistance by HDR Engineering, Inc. and Ximenes and Associates.

About the Authors
Raul A. Deju (CPG 4025) received his Ph.D. in Hydrology from New Mexico Tech and serves as Partner in Brightstar Capital Partners and Chair of Texas Water Supply Company. He is the author of the book “Regional Hydrology Fundamentals” and six other books and the recipient of numerous awards as well as being recognized for his charitable work.

Mike Thornhill (CPG-9545) a Professional Geoscientist licensed by the State of Texas with more than 30 years consulting experience, has provided professional consulting services for many projects across Texas as well as several other states, including projects within all the major and most of the minor aquifers of Texas. Since establishing Thornhill Group, Inc, a professional firm specializing in hydrogeology and water resources, Mike has conducted and supervised investigations for developing groundwater supplies ranging from tens of gallons per minute to more than 100 million gallons per day; assisted numerous project engineers with well and well field design; directed projects involving well evaluation and rehabilitation; and provided expert witness services in some of the most high profile groundwater cases in Texas.
On the Art of Teaching Geology

Rasoul Sorkhabi, Ph.D., CPG-11981

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Geology is a science; teaching geology is an art. Both need to be learned and practiced. Every one of us during his or her student years has seen professors who were great research scientists but poor teachers or vice versa, and also professors who had excelled in both research and teaching. Excellence in work comes from learning and experience. Excellent teachers are always remembered and respected because they have life-long impacts on our knowledge, views, and sometimes, our careers too. Geoscience education is important because it trains the next generations of geologists. This implies that the quality of geoscience education directly impacts the students’ employment and work. But geoscience education is also important because it teaches the public about our how our one and only home planet functions, and about its natural environments, resources, and hazards. This public knowledge about geology is critical because informed citizens and leaders influence policymakers in society. This article shares some tips and suggestions for teaching geoscience courses particularly at undergraduate levels. My intention is not to present an all-inclusive paper on the principles and practices in geoscience education but rather some points that may be interesting and important for further thought.

Advantages of Geoscience

Geoscience has certain characteristics and advantages that should be utilized in geoscience education. These points, outlined below, are valuable assets for the teachers to tap into.

(1) Planet Earth is an interesting subject. Even though most people think of science as dry and difficult, they are fascinated by gemstones, rocks, fossils, mountains, rivers, glaciers, seaside, clouds, and other geologic phenomena. People want to know how Earth functions, how the planet has evolved, and how minerals, rocks, mountains, oceans, etc. form. Indeed, a survey of science news stories reveal that discoveries related to geoscience are highly popular and widely covered. A geoscience teacher should utilize this curiosity and fascination about Earth as a valuable asset and try to enrich and deepen it.

(2) Geoscience is an integrative science. Indeed, aside from astronomy, all branches of natural science – physics, chemistry and biology – investigate some particular aspect of Earth – its forces, matter and lifeforms. But geoscience specifically studies Earth as a unified planetary system. In other words, geoscience, in addition to its own methods, utilizes the principles and techniques of chemistry, physics, biology, and mathematics to study Earth as an interlinked and holistic system. Geoscience education, to some degree, is also an education in science, and a geoscience teacher should be familiar with the other branches of science as well.

(3) Geoscience is an applied science. We study Earth in order to mitigate natural hazards, locate economic minerals and energy resources, help solve environmental problems, and construct safe buildings, bridges and dams. Geoscience education has direct economic and safety implications for society and human life.

(4) Geoscience is a regional science. Geoscience is intimately related to the landscape, tectonic setting, and natural resources of the cities and environments where colleges are located. Some years ago in an article I remarked that the traditional disciplines of geology (physical, historical and applied) are mental divisions in order to manage our scientific knowledge, but when we place this knowledge in a regional context it can be better conveyed to students. In other words, geoscience teaching can be most effective if the teacher incorporates the local geology and environment in the lectures on various geologic processes and concepts. Geologist David Goldsmith has documented that a regional case-based curriculum for introductory geology promotes student engagement and inquiry. He cites the Great Salt Lake, the Tibetan Plateau, Iceland, the Pacific Ocean, and East African rift basins as regional examples he used to introduce his students to the various facets of physical geology.

Balanced Approaches

A keyword in successful geoscience education in colleges and universities is “balance” – how to adopt a balanced approach to various components in geoscience teaching. These components may appear to be opposites and hence difficult to reconcile,
but an experienced teacher creates harmony and synergy between them.

(1) Balance between textbook and new information. While college textbooks cover the basics and essentials of their subjects and disciplines, it is sometimes useful to share stories of cutting-edge discoveries and breakthroughs with students. It takes years for most significant discoveries to be included in textbooks. Fortunately, several print and online magazines cover new discoveries and developments in science on a regular basis such as Science News (USA), Science (USA), New Scientist (UK), and Nature (UK). Readers of The Professional Geologist may also be familiar with the weekly AIPG e-News.

(2) Balance between scientific information and science history. Sometimes we describe the concepts and findings of geoscience without explaining how they were actually discovered. Students are usually curious to know: How do we know what we know about Earth? Although a geoscience course is not a course on the history of science, it is sometimes necessary to blend the textbook information with anecdotes from the history of science to show how geoscience works and grows. It is thus imperative that geoscience teachers also study the history of geoscience. Recently I read a new book, A Brief History of Geology (Cambridge University Press, 2018) by Kieran O’Hara, and found it informative and interesting (so much so that I actually wrote a review of the book for Geology Today). Fundamental topics such as uniformitarianism, evolution of life, determining the age of the earth, geologic timescale, and plate tectonics are better taught and learned using their historical contexts and with description of key geological features like Hutton’s Siccar Point, Guadalupe Island, samples from the Moon and meteorites, Vine and Matthew’s magnetic stripes, Benioff-Wadati subduction zone, and so forth.

(3) Balance between plain language and technical jargon. One severe difficulty that most people face in studying geoscience is that the field is loaded with a large number of unfamiliar technical terms historically derived from the Latin, Greek, German, and French languages: Augen gneiss, batholith, Cephalopod, décollement, graben, isotasy, klippe, nappe, ophiolite, phenocryst, serpentinite, Triassic, xenolith, , and so forth. The geoscience teacher is thus faced with the dilemma of how to describe the processes, materials and structure of Earth in plain language without overloading the student’s mind with this strange jargon. Of course, the essential terms need to be used, and students learn them best if the etymology and meanings of the terms are first explained. For example, how the different stratigraphic periods (Cambrian, Permain, Cretaceous, etc.) were named needs to be explained. Or sometimes, we can substitute more familiar words; for example, “left-lateral” for “sinistral” fault; “mountain-building” for “orogenic” events; “failed rift valley” for “aulacogen” and so forth. Too much focus on unfamiliar technical jargon can discourage the students and should be avoided in introductory geoscience courses. Perhaps an analogy helps here. An automobile has hundreds of parts and a car mechanic is expected to know their names and functionality, but an ordinary person only needs a minimum knowledge of car mechanics in order to drive safely. Similarly, a professional geologist is required to have an extensive knowledge of geologic jargon but a non-major student need not. A process-based geoscience education with a reasonable amount of terminology well explained is more suitable and effective in the introductory courses.

(4) Balance between descriptive, graphic, practical, and mathematical presentations. Students learn differently. Some learn better through words and abstract concepts; some prefer images and diagrams; some learn most from hands-on experiences; and others are more comfortable with numbers and equations. Various methods should thus be employed in teaching: Lectures, documentary films, field trips, in-class activities, examining mineral, rock and fossil specimens, report writing, quizzes, calculations, etc. appeal to different aspects of learning.

Here I should add a note on the relationship between geoscience and mathematics. Geoscience is often perceived as a descriptive science as if mathematics has no place in it. It is important to expose the students to simple calculations and equations related to geoscience. Indeed, the ancient Greek science of “geometry” literally means “earth-measurement.” I often ask students to calculate the circumference, area, volume and mass of Earth, calculate the vertical offset (throw) and horizontal offset (heave) of a fault or the true thickness of an inclined or eroded sedimentary layer using simple geometry and trigonometry.

(5) Balance between theoretical and practical learning. Conceptual knowledge has its own significance, but geoscience education should not be limited to bookish information. Indeed, geoscience is about the outdoors. Students should be encouraged to learn through observation and practice: Visiting outcrops, natural history museums or national parks, examining minerals, rocks and fossils, drawing graphs and maps; photography, using Google Earth and GIS for mapping, etc. should be parts of geoscience education. In this way, students are better prepared to use technological and digital tools in their studies and projects.

(6) Balance between hard science and fun learning. Teachers are educators not entertainers; nevertheless, teaching is an art. Science in general can be hard and dry for many people. Students learn better when teachers introduce audiovisual materials, interactive (question and answer) time as well as some wit and humorous stories into their lectures and classes.

**Geoscience education is important because it trains the next generations of geologists. This implies that the quality of geoscience education directly impacts the students’ employment and work. But geoscience education is also important because it teaches the public about our one and only home planet functions, and about its natural environments, resources, and hazards. This public knowledge about geology is critical because informed citizens and leaders influence policy-making decisions in society.**
Teaching Tips

There are several general books on the art of teaching in colleges. One of the most popular ones is *Teaching Tips* by Wilbert McKeachie, a psychology professor at Michigan, who wrote this book in 1951 for his own teaching assistants. However, the book has gone through several editions and is still in print. I read (and still have) its 9th edition but its latest (13th edition) came out in 2013. Such books can be extremely helpful to geoscience instructors.

Our science, technology, planet and society are all changing, so should geoscience education to address the progress, problems and prospects in our field. Digital information technologies are rapidly altering the way people live, work, think and communicate around the world; these technologies need to be incorporated in geoscience education.

Many students take a geoscience course as part of their science graduation requirements and will probably never take another geoscience course in their lives. Some students, on the other hand, may decide to major in geoscience. In either case, a successful course in geoscience plays an important role in college students’ learning and careers. It is said that when the student is ready the teacher appears. This is true but the teacher should also appear as one who is not only knowledgeable but also skillful and caring. Classroom is a valuable opportunity for a geoscience teacher to share his or her profession and passion with society. In this spirit, let us remember and salute our great teachers who taught us the science of geology and also painted in action the art of teaching geology.

Order Extra Copies of the Student Issue

Individuals and sections are encouraged to purchase extra copies of the Student issue to provide to colleges and universities with geology departments. This is a great way to introduce students to AIPG and encourage formation of student chapters. The cost of the Student Issue is discounted from $5.00 to $3.00 for quantities of 10 or more. Amount due ($3.00 x Quantity) + Shipping and Handling.

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Request For Nominations

The 2020 AIPG Awards Committee is seeking nominations for future recipients of the Ben H. Parker Memorial Distinguished Service Medal, the Martin VanCouvering Memorial Service to the Institute Award, the John T. Galey, Sr. Memorial Public Service Award, and Honorary Membership. The qualifications for these awards can be found below. Nominations for these awards, accompanied by supporting statement, should be sent to AIPG Headquarters, c/o Honors and Awards Chrm., 1333 W. 120th Avenue, Suite 211, Westminster, Colorado, 80234-2710.

**Ben H. Parker Memorial Distinguished Service Medal**

The Ben H. Parker Memorial Medal is the Institute’s most distinguished award. It was established by the Executive Committee in 1969 in posthumous honor of a truly great leader, who devoted much of his life to improve the quality of geology and geologists and the services they provide. The medal is awarded to individuals who have long records of distinguished and outstanding service to the profession.

The most important criterion is a continual record of contribution to the profession of geology. A wide variety of contributions can be considered, such as (a) the education and training of geologists, (b) professional development of geologists, (c) services to the Institute, (d) leadership in the surveillance of laws, rules, and regulations affecting geology, geologists, and the public, and (e) activity in local and regional affairs of geologists.

**Martin VanCouvering Memorial Service to the Institute Award**

The Martin Van Couvering Memorial Award was established by the Executive Committee in 1979 in posthumous honor of the first president of the Institute. Martin Van Couvering made the presidency a full-time occupation for the first two years of the Institute’s history. His dynamic leadership, diplomacy, and organizational abilities established the solid foundation from which the Institute has grown. Few, if any, have given so much to the Institute.

The most important criterion for the Martin Van Couvering Memorial Award is service to the Institute. As in other awards, a wide variety of contributions to the Institute may be considered. By far the most important contribution a geologist can make to the Institute is that of time. It is the contributions by individuals to the Section, the committees, and special projects that enable the Institute to enhance the practice of geology.

**Award of Honorary Membership**

Since 1984, AIPG has conferred Honorary Membership to those who have an exemplary record of distinguished service to the profession and to the Institute.

**John T. Galey, Sr. Memorial Public Service Award**

The American Institute of Professional Geologists’ Public Service Award was established by the Executive Committee in 1982 in recognition of one of its primary purposes: service to the public. In 1992, it was renamed the John T. Galey, Sr., Memorial Public Service Award, in posthumous honor of our fourth President, whose long professional career was a continuum of service to both the geological and the general public.

Recognition of public service is important because so many Members have distinguished themselves and the Institute by giving expert testimony to governmental commissions and committees, and by providing geological expertise where it was needed by the public at large.

The application of geology to the needs of the general public may be in many different forms. Recipients of this award have outstanding records of public service on the national, state, or local level well beyond their normal professional responsibilities.

**Outstanding Achievement Award**

The Outstanding Achievement Award was established by the 1989 Executive Committee to honor a non-member of AIPG who is widely recognized as a major contributor to the profession of geology. The award is not necessarily given annually, but only when the Awards Committee recommends an outstanding candidate to the Executive Committee for their consideration.

In 2013, the Executive Committee voted to expand the scope of the award to include candidates engaged in all types of media that inform or enlighten the public on the roles of professional geologists and the geosciences in society. This award may be for work in any media such as visual (television, film, webcasts), auditory (radio, podcasts) or printed (books, articles, websites). The work must have been completed within five years preceding the award nomination and the nominee may be an individual, a group, or a company.

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DEADLINE: Completed nominations must be received by January 15, 2020

www.aipg.org
Severn P. Brown, CPG-1707
Canton, New York
1922 - May 4, 2019

Member Since 1968

Severn P. Brown, a member of AIPG for 51 years (1968-2019), passed away on May 4, 2019, in the 97th year of what he referred to as a "heck of a good run"; he was a Christian gentleman of the old school.

Severn and his two brothers grew up in Evanston, IL, across from Northwestern University. Unlike his brothers, however, he chose to attend the University of Rochester where he was a member of Psi Upsilon and played on the basketball team. Graduating in 1943, as a geologist, he initially received a military deferment that he later resigned to serve as an officer in the military police.

After the war, he did his graduate work at Columbia University where he was elected to Sigma Xi. He then worked for the USGS in Alaska. He worked in Mexico and eventually came to Gouverneur to work as a mining geologist for the then St. Joseph lead company. He began a lifelong association with St. Lawrence University in 1957, serving as an Associate Professor of Geology for four years. Leaving SLU, he and several partners founded a geologic consulting firm where he worked until his retirement.

In retirement, he indulged his passion for travel, enjoyed gardening, and worked to advance the science of geology. Severn was a member of the Presbyterian Church of Canton, serving as a Church Elder. Among his many other activities, he was an active member of Rotary and a founding member of the Canton Community Fund.

While in Gouverneur, he met and married Alita F. (Hunter) Brown. They were married for 41 years until her death. He married Sarah (Sally) Street and they enjoyed some 20 years of marriage. Once asked for a longevity tip, he quipped, "if nothing else, I know how to marry well."

Severn is survived by his wife, a son, and two beloved grandchildren.

In lieu of flowers, the family requests donations to the United Helpers or the charity of your choice.

Dr. Robert “Bob” G. Corbett, CPG-4502
Normal, Illinois
March 13, 1935 - July 27, 2019

Member Since 1979

Robert, "Bob" Guy Corbett, CPG 4502, Martin C. Van Couverying Memorial Awardee in 2007 passed away in Normal, IL, on Saturday, July 27, 2019 at the age of 84. The family suggests memorials to be made to First Christian Church, Bloomington and was a life-long Cubs Fan.

Besides his work at the University he enjoyed leading raft trips down the Grand Canyon for geology students and making several trips to Hawaii National Parks to study the Volcanos. When Bob wasn’t working, he was a member of First Christian Church, Bloomington and was a life-long Cubs Fan.

Ed Nuhfer, CPG 2808, writes: With great sadness, I write this brief memorial for Dr. Robert G. “Bob” Corbett who was past-president of AIPG and recipient of the Martin Van Couverying Award. Bob passed away on July 27, 2019, at his home in Illinois. The geosciences lost one of its most dedicated educators, and AIPG, GSA, Sigma Xi, and NAGT each lost one of their great contributing members. I lost a wonderful mentor for whom I have only happy memories.

My first encounter with Bob was as an undergraduate in Bob’s classes at West Virginia University. Later, he consented to serve as the advisor for my Master’s Degree and guided me in preparing my very first presentations for professional meetings. He was one of those rare professors who not only know their graduate students but also reached to know their families and parents. Happily, Bob and I were able to continue in the College of Arts and Sciences Hall of Fame.

My first encounter with Bob was as an undergraduate in Bob’s classes at West Virginia University. Later, he consented to serve as the advisor for my Master’s Degree and guided me in preparing my very first presentations for professional meetings. He was one of those rare professors who not only know their graduate students but also reached to know their families and parents. Happily, Bob and I were able to continue
Dr. Keith R. Long, MEM-0795

Marana, Arizona
April 30, 1957 - March 29, 2019

Member Since 2005

Born to Walter A. Long and Edith Berridge in Wichita Falls, Texas, Keith grew up in Santa Clara, California and graduated from University of California Santa Cruz with a double major of a B.S. in Earth Sciences and a B.A. in Political Economy (1979). He completed his M.S. in Geoscience at University of Michigan (1984), and his Ph.D. in Mineral Economics at The University of Arizona (1988). He married Kay Ellen Lindley in Tucson on October 2, 1999.

Keith joined the U.S. Geological Survey in Tucson in 1988, to work in the Center for Inter-American Mineral Resource Investigations where he participated in cooperative studies in Central and South America, especially Mexico and Bolivia. Keith devoted his career to studying mineral resources and specializing in the economic aspects of mineral resource assessment. The focus of his research in recent years included work on the economics of porphyry copper deposits, economic filters for evaluating mineral deposits, the environmental aspects of historical mine tailings, and characterization of rare earth element deposits and significant metal deposits of the U.S. He wrote over 100 publications ranging from country-specific studies of the mineral resources of Bolivia and the United States to work identifying and classifying abandoned mines in California (upcoming). Keith also published an English-Spanish dictionary of mining and geologic terms. He ended his career as a Research Specialist in rare earth minerals. He was active in professional societies including the Society of Economic Geologists, Arizona Geological Society, the Mining History Association, and the International Assoc. of Mathematical Geologists where he served as Editor for Natural Resources Journal. He presented numerous, well-researched talks on minerals and mining history. Keith was an intelligent, thoughtful, kind, godly person with a quiet sense of humor. An avid reader, he was interested the natural sciences, history (especially world history, technology, military, mining, Biblical archaeology). He was respected and endeared by his colleagues and friends.

Keith is survived by wife, Kay; his father, sisters, Suzanne Long Huntington (Steve) of San Jose and Karin Long Schubert (Alex) of Granite Canyon, Wyo.; brother, Walter Scott Long (Maria) of Fremont, Calif. Memorial donations in Keith’s name may be made to Tucson Gospel Rescue Mission or the Mining History Association.
Comments on proposed rule: Modernization of Property Disclosures for Mining Registrants

Comments on the U.S. Security and Exchange Commission’s (SEC’s) proposal are available at https://www.sec.gov/comments/s7-10-16/s71016.htm

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Geology of California

AIPG’s 2020 Annual Meeting will be in Sacramento, CA. If you have expertise on any aspect of the geology of California, especially that of the Great Valley, Lassen volcanic field, Motherlode, etc., I strongly urge you to submit a paper to TPG by May 1st, 2020, for the July-Aug-Sept 2020 issue. Papers will be Peer Reviewed and indexed. Go for it!

John Berry, CPG-04032, Editor
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TPG Next Issue:
We are accepting articles for the Jan-Feb.Mar 2020 Student Edition. We encourage student authors to submit articles on research, experiences as a student, and other topics relevant to students. Additionally, we are asking professional members to submit articles on topics relevant to students like resume writing tips, interviewing techniques, how to prepare for joining the workforce, etc....

All submissions are due by November 1, 2019.

CONGRATULATIONS!
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(winningers receive a one year subscription to the TPG.)

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Testing the efficacy of a Cyclops 7 infrared probe by performing a follow up dye trace study at McConnell Springs in Lexington, Kentucky, USA

Author
Trent Garrison, PhD, YP-0259, Northern Kentucky University

Abstract
Dye traces are often performed to identify sinkhole-to-spring connections, delineate groundwater basins, detect leaks, as well as to measure the direction of groundwater travel. Calculating precise dye travel time is only sometimes achieved, due to the limitations of sampling devices. In this study, a new device is introduced to detect more accurate times of travel.

As a precursor to this study, in the fall of 2015, a dye trace was performed during high flow conditions in the Middle Ordovician karst of Lexington, Fayette County, Kentucky in order to measure ground water time of travel between the Campbell House Sinkhole, McConnell Springs, and Preston’s Cave Spring. Using traditional sampling methods at 3 hour intervals, dye appeared in the samples collected 6 hours after injection, and peaked 3 hours later.

The purpose of this project is to replicate that study in similar flow conditions using a newly available infrared probe. This probe\(^1\) is capable of collecting in-situ measurements of dye presence, as well as temperature measurements, at one-minute intervals. The paper will discuss efficacy of the device in more detail, but, in short, the probe performed according to specifications\(^2\) after some troubleshooting. Dye appeared 3.0 hours after deployment on June 18th, decreased, then peaked at 1,200ppb on June 19th, yielding a first-arrival time of travel of 17.88 cm/sec (2,112 ft/hr). A more accurate picture of dye traveling through the system is gleaned from sampling at these intervals.

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2. Fluorometer Specifications.
Introduction and Geology

The dye trace was performed in Lexington, Fayette County, KY, in the Inner Bluegrass Region, which is underlain by highly-weathered, Middle Ordovician limestone (Figure 1).

The study sites are in the Grier Member of the Lexington Limestone Formation. The unit is approximately 55 m (180 ft) thick, containing up to 15 cm (6 in) thick beds of fine- to coarse-grained limestone with interbeds of shale approximately 5 cm (2 in) thick (Blair, 2009). The geology and climate of the region is conducive to the development of karst features, such as sinkholes, springs, and conduits.

The study area is located within a single karst drainage basin area of approximately 12 km² (4.6 mi²) in Lexington, Kentucky (Spangler, 1982; Currens, 1996; Norris, 2016). Project locations include the dye-injection location, informally known as the “Campbell House Sinkhole” and a monitoring location at McConnell Springs (Figure 2).

After briefly surfacing at McConnell Springs before again sinking, water ultimately daylights at Preston’s Cave Spring, where it then flows as surface water to Wolf Run and thus eventually into Town Branch. Though karst drainage basin studies have been conducted in this area (Spangler, 1982), detailed measurements of conduit-flow velocities were not recorded.

In our preliminary study (Norris et al., 2016) we measured the conduit distance from the Campbell House sinkhole to McConnell Springs as 1.9 km (1.2 mi). The topographic relief over the study area is 21.4 m (70’), the highest elevation being 295.7 m (970’) and the lowest at 274.3 m (900’). The difference in elevation between the Campbell House and Preston's Cave Springs is 12.2 m (40’) over the conduit path of 3.2 km (2 miles), making the stream gradient 6 m per 1.6 km, or 20’ per mile. Regional bedrock dip is 3°-5° NE. While no faults are evident directly in the flow path, the study area lies within the vicinity of several major fault systems: the Kentucky River and Lexington Fault systems, the Cincinnati Arch, and the Jessamine Dome (Black, 1989; McFarlan, 1943). Tectonic activity from these geologic structures has resulted in jointing and fracturing in the local bedrock, opening new paths for groundwater to travel freely and quickly: caves and sinks

Figure 1: Geologic map of Kentucky. Note box around study area.

Figure 2 - Sinkhole and spring locations. The thick black lines represent the surface watershed drainage divides. Note that water traveling underground transgresses surface water basins in some locations. Thus Campbell House Springs and Preston’s Cave Spring are in a different surface drainage basin from McConnell Springs, though all aforementioned sites are on the same subterranean flow path.
A higher-than-average amount of dye was added due to flood conditions and the possibility of dilution. Following the injection, data were collected primarily using the probe instead of traditional methods (‘traditional’ meaning activated charcoal dye receptors [CDRs] and water “grab samples” using 8 ml borosilicate glass sample vials – See Norris et al., 2016), though these sampling techniques were used as backups. Precautionary measures (such as gloves and transporting dye separate from the probe and other materials) were used to ensure that there was no dye contamination. Temperature collection on the probe was also set to one-minute intervals.

Results and Discussion

As noted in the introduction, in the two days preceding the injection, Fayette County received 3.61 inches of rain (Kentucky Mesonet, 2019), which is well above the 0.148 in (0.376 cm) daily average for June in Lexington. Discharge recordings at the nearby USGS Wolf Run Gauging Station were consistently above the mean for the year (12 cf/s), peaking up to 873 cf/s on June 18, 2019 the night before the injection (Figure 4). Discharge at the time of injection (11:45am on 6/18/19) was 85.7 cf/s. The excess rainfall occurring before and during sampling, thus facilitated rapid movement of dye through the system.

Dye appeared at McConnell Springs at 3 hours post-injection and increased to 600ppb at 3.75 hours on June 18th, regressed, then again peaked at its highest value of just over 1,200ppb on June 19th before gradually decreasing to background levels over the next two days (Figure 5). Comparison of Figures 4 and 5 suggests that there is a correlation between discharge and dye concentrations due to flushing of the karst system,
especially during the smaller dye spikes on June 19th when dye was actively traveling through the system. Note the lack of data on Figure 5 between June 18th and June 19th: this was due to removal of the probe for safety at the park overnight during flood conditions.

Using the dye arrival time for calculating conduit velocity between the Campbell House sinkhole and McConnell Springs yields a time of travel of 2,112 ft/hr (17.88 cm/s). Or in perhaps more familiar terms, 0.4 miles per hour. However, one could use dye peak time to calculate, yielding slightly different results, but because the probe was removed overnight, we cannot be confident of the maximum peak time. Regardless, these conduit velocities are very fast compared to the hydraulic conductivities reviewed by the author in eastern Kentucky, non-karst aquifers, which range from 10^{-2} cm/sec to 10^{-7} cm/sec (10 ft/day to 10^{-4} ft/day) (Garrison, 2015; Minns, 1993).

As the average groundwater temperature in Kentucky is 12°C (54°F), the daily surface water temperature measurements at each location indicate that the stream water is warmer in high flow conditions at this time of year. Surface water at McConnell Springs measured 18.55°C (65.39°F) when the dye quantity peaked in the first day and fluctuated based upon rainfall and discharge, but gradually decreased to approximately 18°C (64.4°F).

Conclusions

The primary objective of this study was to use the Cyclops 7 infrared probe to more accurately measure dye travel time through the Middle Ordovician karst of Lexington, Kentucky. This was done to refine the numbers found in the Norris et al. study from 2016 and to test efficacy of the probe. Temperature measurements were also collected. Below is a summary of relevant conclusions:

Dye deployed into the Campbell House sinkhole during high flow appeared at McConnell Springs (which is 1.9 km, or 1.2 mi, down gradient) 3 hours after injection and later peaked at a concentration of approximately 1,200 ppm. Using time of first dye arrival, conduit flow velocity between the Campbell House sinkhole and McConnell Springs was calculated 17.88 cm/sec or 2,112 ft/hr (50,688 ft/day). These conduit velocities are fast compared to the non-karst aquifers, which range from 10^{-2} cm/sec to 10^{-7} cm/sec (10 ft/day to 10^{-4} ft/day).

The following observations were corroborated from the previous study: (1) high-flow conditions likely facilitated accelerated dye travel time through conduits due to increased hydraulic head caused by flooding at the Campbell House sinkhole, (2) the regional topographic relief of 21.3 m (70’), stream gradient of 6 m per 1.6 km (20’ per mile), and the structural dip of the bedrock (3°-5°-NE) probably had little influence on the dye’s travel time, and (3) the water temperatures measured at these karst springs in high-flow conditions was warmer due to excess rainfall from the day before the dye injection being forced through the karst system with little time to cool to ambient temperatures.

In addition, dye concentration fluctuations observed after first arrival exemplify (1) the importance of collecting frequent (in this case, 1-minute) measurements and (2) the complexities of karst systems. Without these frequent measurements, the intricacies of peaks and troughs would not be observed. Lastly, it appears there is a weak but noticeable correlation between discharge and dye concentration on June 19th of this study.

According to the manufacturer, the detection limit of the probe is 0.01 ppb, which is the same as the spectrophotometer that used per the traditional method (in water). Therefore, any sensitivity difference has no significant impact on results in this case.

If directions are followed and the Cyclops 7 probe is calibrated accurately, it performs as advertised, with less field work than traditional methods. However, it is recommended to collect water and charcoal samples for backup data.

Other notes: On the probe’s chart readout, there are two lines (battery power and gain) that cannot be removed (this had to be done manually using Microsoft Paint, which took 45 minutes). One also might feel uncomfortable leaving an instrument of this value in a stream overnight, which for us led to a data gap. It is suggested that the device be camouflaged and as well-secured as possible. However, with some relatively minor adjustments and with appropriate security procedures for the device, this could be a tool that hydrogeologists utilize on a regular basis.
Ideally, this is the beginning of the accurate mapping of sinkhole-to-spring times-of-travel. For future studies, it is recommended that dye traces be repeated in both average-flow and low-flow conditions at other sinkholes in the Lexington-greater area.

References
Blair, R. J., et al., 2009, Assessment of Nonpoint Source Impacts on Groundwater Quality in South Elkhorn Creek Basin, Central Kentucky (EMU 1, Round 2), Kentucky Division of Water.

About the Author
Dr. Trent Garrison’s teaching and research interests include: Environmental Geology (Karst Hydrogeology, Coal Fires, Hydrocarbon Movement). Passions include: outreach, science communication, geo-policy, and helping connect students with professionals. Dr. Garrison is the former President of American Institute of Professional Geologists (Kentucky Section), Vice President and Legislative Liaison for the Kentucky Academy of Science, and contributor to Benchtalk (science podcast).
Bedrock Collapse Sinkhole Analysis of Bowling Green, Kentucky

Author
Brittany Paige Moore, SA-7788

Abstract
Warren County, Kentucky is located atop bedrock consisting of karstic Mississippian age limestones marked by sinking streams, caverns, sinkholes and springs. Though sinkholes are common throughout the state, southcentral Kentucky has the highest density. The most common type of sinkhole in Kentucky is the cover (or sediment) collapse which occurs in the soil or other loose material that overlies soluble bedrock. A second type of sinkhole is called a bedrock collapse, which occurs when the ceiling of a cave collapses, exposing the cave passage. This type of collapse is considered rare. The purpose of this study is to determine the increased risk of bedrock collapse sinkholes as a geohazard as a result of human activities in Bowling Green, Kentucky. Methods include the use of remote-sensing, GIS, cave data and maps to interpret areas in Bowling Green that pose the greatest risk of bedrock collapse and, thus, damage and loss of infrastructure. There are over 350 cave entrances in Warren County and more than 30 km of cave passages; among those, bedrock collapse sinkholes are relatively rare. However, preliminary results indicate that bedrock collapse sinkholes can be induced by human activities.

Introduction
The Kentucky landscape stretches 105,000 km², of which 38,000 km² is karst terrain. About 36% of the state has some type of karst development, because its bedrock – commonly limestone – is dissolved by water. Karst in Kentucky occurs in five principal regions (Figure 1). The largest of the karst regions is the Western Pennyroyal, which is home to the longest cave in the world, Mammoth Cave, followed by the Inner Bluegrass region, the Eastern Pennyroyal, and the Carter Caves region (Currens 2002).

Between 4,000 and 6,000 sinkholes collapse annually in the state of Kentucky. The most common type of sinkhole in the state is the cover (or sediment) collapse which occurs in the soil or other loose material that overlies soluble bedrock (Currens 2002). A second type of sinkhole is called a bedrock collapse: this occurs when the ceiling of a cave collapses, exposing the cave passage to the surface. Bedrock collapse is naturally occurring and occurs in all karstic environments. Its development, in relation to its influence on the stability of the bedrock surface, is dependent on the geology of the area, including geologic structures, and the maturity of the solution process in relation to geologic time (Figure 2 on page 10). Collapse of bedrock due to this process can be accelerated or even initiated by imposed loads from sources such as construction and the daily activity that ensues thereafter (Waltham, Bell, and Culshaw 2005).

The purpose of this study was twofold: 1) assess the distribution of natural and anthropogenic bedrock collapse sinkholes and their relationship to known cave passages and infrastructure development within the city of Bowling Green, Kentucky and 2) to locate areas that are at risk of bedrock collapse from infrastructure development and to determine...
County, the city of Bowling Green holds nearly 52% of the county’s population and some of the greatest expanses of cave passages (Figure 3).

The Lost River Cave System drains much of the landscape around Bowling Green proper. Bedrock collapse sinkholes occurring in the Bowling Green area are largely related to the underlying Lost River Cave System and its associated cave passages. Lost River Cave System has five natural entrances and contains approximately 11 kilometers of mapped cave passage (Figure 4).

Study Area

More than 30 km of cave passages lie beneath several major cities of Warren County whose cumulative population is approximately 113,792. While only encompassing roughly 7% of Warren County, the city of Bowling Green holds nearly 52% of the county’s population and some of the greatest expanses of cave passages (Figure 3).

The Lost River Cave System drains much of the landscape around Bowling Green proper. Bedrock collapse sinkholes occurring in the Bowling Green area are largely related to the underlying Lost River Cave System and its associated cave passages. Lost River Cave System has five natural entrances and contains approximately 11 kilometers of mapped cave passage (Figure 4).

1. This report is a condensed version of a Senior Thesis that may be obtained from the author at bittiny.moore00@gmail.com.
4). Primitive uses for the cave included piping into the underlying passageways as septic tank dump stations and public landfills. Greater knowledge of the cave and concern for its ecosystem exists today and has resulted in more conservative developmental endeavors designed to protect the cave and its environment.

Two significant bedrock collapses have occurred within the city limits of Bowling Green, in 2002 and 2014. A third construction equipment-induced collapse occurred in 2016.

According to an investigation report (Crawford, 2002), in February of 2002 a large collapse occurred on a portion of Dishman Lane at its intersection with Mill Valley Road, a newly constructed section of road. The 45m wide sinkhole collapsed into the main passage of State Trooper Cave, lowering the road surface 5m (Figure 5) (Waltham, Bell, and Culshaw 2005).

Before the road was built, a site investigation led by Crawford used microgravity testing to detect the State Trooper Cave passages along a proposed route for Dishman Lane (Crawford 2002). The testing showed that the proposed route would be built directly above a large collapse room in the cave. Further investigation showed the broken rocks associated with collapse extended all the way to the surface, indicating a surface collapse was possible (Crawford 2002). The road was still built on the proposed path, and the collapse was due to exacerbation of pre-existing rock instability by 20 years of additional stress due to significant urban development. All the storm drainage in the area had been directed into smaller sinkholes that were also engulfed by the collapse of the cave roof. There were no injuries, but the catastrophic collapse into the passage directly beneath Dishman Lane led to nine months of repairs costing a million dollars. The Dishman Lane collapse exhibited features of bedrock collapse and soil failure (Waltham, Bell, and Culshaw 2005).

In February 2014, a sinkhole opened up at the National Corvette Museum in Bowling Green, Kentucky. The floor of the Corvette Museum Skydome collapsed into an underlying cave system, creating a 9-meter-deep sinkhole and swallowing eight corvettes. The underlying cave is about 67 meters long and 12 meters wide with an average depth of 20 to 26 meters (Figure 6). The bedrock consisted of thinly interbedded limestone and chert between two impure limestone units. Talus and breakdown, the debris resulting from the collapse, are common on the floor of the cave in which the sinkhole formed, providing further evidence for a lack of long-term structural integrity of the bedrock in the area. The results of an investigation of the collapse revealed that the collapse occurred because of the failure of the cave’s roof which is made up of thinly bedded and impure limestone (Polk, et. al. 2015).

Another cave, By-Pass Cave, which is hydrogeologically connected to the Lost River Cave System is approximately 5
meters below the surface and in several areas, vehicles can easily be heard on the road above. A small stream exists in the cave and has been traced to the Lost River Resurgence at Lampkin Park. During construction of a new apartment complex over By-Pass cave building construction broke into the cave roof, creating a sinkhole. A concrete plug was installed to prevent further collapse (Figure 7) during ongoing building construction. Although the cave system is small, the creation of a sinkhole and the building of further developments could create even greater implications for the area. Any change in the flow of surface water that occurs could impact the potential for flooding and contamination in the area. The cave is now more susceptible to future collapse due to an increase in roof instability.

The 2002 and 2014 collapses described above affected infrastructure and were remediated at great expense. The 2016 collapse was much less extensive and was remediated by the construction company fairly quickly. Despite these incidents, a lack of understanding of karst systems as a geo-hazard exists: thus, there exists a lack of regulations for building over karst terrain as well as a lack of plans to mitigate and prevent potential sinkhole collapse.

Methodology

A combination of field work, analysis of remote sensing data, and GIS were used to identify areas within Bowling Green, Kentucky that are at risk for sinkhole collapse. GIS data and cave maps were acquired from the Kentucky Geological Survey (KGS) and the Kentucky Speleological Survey (KSS). Cave maps were georeferenced and map points and polygons were digitized into feature classes. Orthophotos, photos that detail structure and development, were used to identify areas within Bowling Green, Kentucky that are at risk for sinkhole collapse.

Table 1

<table>
<thead>
<tr>
<th>Cave</th>
<th>Location</th>
<th>Overburden (m)</th>
<th>Width (m)</th>
<th>Cover ratio</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Entrance</td>
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<td>4</td>
<td>0.375</td>
</tr>
<tr>
<td>State Trooper</td>
<td>Entrance</td>
<td>2.41</td>
<td>4</td>
<td>0.6025</td>
</tr>
<tr>
<td>Lost River</td>
<td>Historic</td>
<td>18.3</td>
<td>4</td>
<td>4.575</td>
</tr>
<tr>
<td>State Trooper</td>
<td>Dishman Lane</td>
<td>&lt; 0.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8 - Warren County has a karst aquifer system that influences the flow of groundwater and cave development. Warren County caves are connected to this system and sinkhole development within the system can greatly impact water flow and drainage. Understanding the system and knowing where cave streams exist makes it easy to indicate areas prone for future collapse.
Figure 9 - Bedrock collapse sinkhole potential depends on several parameters. Areas in Bowling Green where more of those parameters exist, or where some exist in excess, will exhibit a higher risk potential for collapse. These parameters include existing cave passages that create underground voids, groundwater flow and any disturbance in flow, the amount of existing overburden, and areas where imposed load and drainage diversion is created by activities.

Figure 10 - An initial risk assessment depicts areas in Bowling Green where future bedrock collapse is likely. The red boxes indicate areas with a high probability for collapse – these areas are most at risk. The orange box indicates areas with a moderate probability for collapse, and the yellow box indicates areas where, although possible, collapse is least likely to occur.
opment at the surface, were also collected for Warren County. Sinkholes and cave entrance locations were ground-truthed using GPS. Field measurements were conducted to collect overburden measurements at cave entrance locations and were extrapolated to represent the overburden of the entire cave system. Known cave entrances were field-checked and collapse type characterized, inventoried, and georeferenced. Overburden and epikarst, the upper and most permeable boundary of a karst system, were measured at each bedrock collapse using standard geologic mapping methods. The ratio of cave passage width to overburden thickness was calculated to assess the relative stability of cave passages known as cover ratios. The cover ratio for the Dishman Lane collapse was taken from Crawford (2002).

Digital and field data were compiled within a GIS to assess geological and hydrological controls on sinkhole locations and development (Figure 8). Extent of sinkhole drainage, cave locations, overburden and major and moderate karst development zones were analyzed to identify sinkhole risk potential (Figure 9). Based on a series of derivative maps produced, including an overburden isopach map showing the overburden thickness above known cave passages and existing bedrock collapses, a bedrock collapse geohazard map was made in order to identify areas at risk for bedrock collapses (Figure 10).

Discussion
All the largest sinkholes in Bowling Green, Kentucky area are associated with conduits that currently drain the surface topography of the city or were paleo-drainage conduits that are currently not active. The active conduits are passages associated with the Lost River Cave System. The Corvette Museum collapse occurred within an inactive drainage conduit not associated with the Lost River Cave System.

GIS analysis of the previous bedrock collapses show that construction activities and the redirection of flood waters into the epikarst create an imposed load over an underlying cave passage, causing the weakened cave roof to collapse. Collapses could have been avoided had more detailed information about the subsurface cave features been available.

The maps produced during this study not only elucidate the subsurface of the City of Bowling Green, but also provide tools with which to assess the stability of the landscape and the potential risk of sinkhole development. The bedrock collapse geohazard maps are a proactive means for informing future infrastructure development in Bowling Green, Kentucky. They have the potential to help with risk assessment in sinkhole-prone areas. The maps would also serve as a good resource for public education and outreach.

The structural integrity of different parts of each cave system will evolve differently. While one site may exhibit a structurally sound roof with relatively intact rock, another site in the same cave or same passage may have areas exhibiting breakdown or stopping, breakdown of a cave roof in a series of steps or layers. Such conditions are common in a karst environment and can be mapped to reduce the difficulty they present for developers during construction. However, in order to avoid the damage caused by bedrock collapse sinkholes, careful site investigation, which includes the use of tools such as the maps created in this project, is required for every construction within a terrain of cavernous karst.

Kentucky annually incurs $20 million in damages due to karst subsidence and sinkhole collapse (Weary 2015). There are approximately 22,735 households in Bowling Green, Kentucky, leaving thousands of citizens at risk for sinkhole damages. The potential for sinkhole collapse increases as the rate and scale of development in this city increases. Although bedrock collapse is considered to be less frequent than cover collapse, its mitigation is more costly.

Correspondingly, land values in sinkhole-prone areas can suffer, impacting landowners, as well as counties and municipalities that are dependent on property tax revenue (Weary 2015). Many citizens are not aware of the hidden costs, in the form of higher taxes and an increased cost of living, that are imposed by the need for the remediation of sinkholes. Sinkholes also serve as drainage points for surface water to reach the subsurface. This creates significant issues in groundwater quality and often leaves structures vulnerable to flood damage (Currens 2002).

Conclusion
While some Kentucky cities have recognized a need for planning when building on karst, there are no building regulations relating to sinkholes in Bowling Green or Warren County. Many planning regulations currently in place have no provision for sinkholes, but certain ordinances that do provide guidelines for sinkholes are limited to the protection of water quality. This is the typical practice for managing construction in karst terrain across the country (Fleury 2009). While no formal practices for building on karst exist, both the Kentucky Geological Survey and the National Cave and Karst Research Institute offer guidelines for government agencies to work from or adopt. The Bowling Green Public Works Department claims that sinkholes do not pose a threat to the Warren County area, and that best management practices are currently being used in the city. However, recent sinkhole events, and the rapid increase in sinkhole development due to imposed loads from construction seem to suggest otherwise.

Maps that provide an in-depth look at the subsurface environment would aid in the avoidance of poor construction planning and enhance preparation and remediation tactics where imposed loads currently exist. Education about the Bowling Green area subsurface will allow for better management practices to be implemented, including, but not limited to, the passing of ordinances and guidelines for building on karst. Continued efforts to map the subsurface and karst environments in Bowling Green will make available more data to map larger expanses of the city and allow for better risk assessment.

References
Cori Hoag, CPG-11205, writes: I was his 100th graduate student and he had a profound impact on my life and professional development.

Spence presented me with a copy of his 1982 Advances in Geology of the Porphyry Copper Deposits (AKA green Titley volume, green Bible) when I graduated as his 100th graduate student in 1991 (M.S. Economic Geology). I referred to the comprehensive deposit articles in both publications countless times working as an Arizona-based exploration, mine development, and environmental geologist in the copper mining industry.

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