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Justin LaBrozzi
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Remnants of Austin Dam. This 50-ft high, 540-ft long concrete dam failed on September 30, 1911, killing 78 people and destroying a paper mill and much of the town of Austin, PA. The dam was designed to be 30-ft thick, but was built to only 20-ft thick, which led to substantial bowing due to the pressure of the retained water.
LARSSSEN INTERLOCK, WIDER, LIGHTER, and made in the USA

NZ SHEET PILES from NUCOR-YAMATO

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President’s Letter
By Allen Cadden

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COREBITS STUDENTS

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Look Who’s a D.GE
An interview with Ronald J. (Ron) Ebelhar

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What’s Coming in September/October 2015 GEOSTRATA

GeoPoem: Seismic Design
By Mary C. Nodine
We Have BIG News!

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President’s Letter

Cooperation – Ideas for the Future

So far, my presidency has been very exciting and challenging. As I mentioned in a previous column, and as Billy Camp remarked in this space last year, a key focus of the G-I is serving you better by facilitating cooperation within the industry. I’m very happy to report that over the past few months this goal is advancing and building momentum.

The most notable area of concentration is one you’ve heard about extensively over the past few months: the International Foundation Conference and Equipment Exposition 2015 (IFCEE 2015), a cooperative effort, years in the making, between Geo-Institute of ASCE (G-I), International Association of Foundation Drilling (ADSC), Deep Foundations Institute (DFI), and Pile Driving Contractors Association (PDCA). Without the cooperation of these four organizations, we would never have been able to gather nearly 3,500 geoprofessionals in one place to exchange ideas, review recent experiences, and discuss what the future has in store for us.

I also recently attended the Geoprofessional Business Association’s (GBA) spring meeting in Miami, FL, where I spoke to the association’s membership about the recently signed memorandum of understanding. What an exciting initiative! The Memorandum aims to bring GBA content and information related to the business of geoprofessionals to our G-I members, both locally and nationally.

The next opportunity I had to advance the goal of collaboration was when I attended the Technical Region Board of Governors (TRBG) meeting a month later. Here, ASCE gathered the leadership from each institute together to exchange ideas, find out how each is serving its membership, and provide feedback to the technical region Directors of ASCE. This cooperation between Institutes is leading us toward the 2016 Geotechnical & Structural Engineering Congress – a joint event between the Geo-Institute and the Structural Engineering Institute (SEI). It is time we gather with our structural compatriots to collaborate and learn from each other. I am confident that this will bring new ideas and new ways we can grow as professionals and serve our clients better.

Most recently, Kord Wissmann (Vice President of G-I) and I attended the GeoCoalition meeting. A major purpose of this meeting is to build relationships between the executives and the volunteer leaders of seven geoprofessionals’ organizations. The agenda included reviewing current activities of each organization, brainstorming ideas for future IFCEE-type events, coordinating calendars, strategizing about ways that educators and practitioners might collaborate, and discussing a possible joint Crystal Ball/Futures Workshop. While these are all admirable goals, what’s more impressive is witnessing the relationships that have grown as a result of these GeoCoalition meetings. The International Society for Micropiles (ISM) leverages the ADSC and DFI organizations to facilitate their international efforts to advance micropile technology, and several sidebar conversations were held to advance this effort. The cooperative efforts between GBA and G-I were particularly highlighted, since this cooperative effort is a means of bringing diverse content to local chapter events. The discussion led to encouraging all of the cooperating organizations to take advantage of, and form relationships with, the G-I Chapters and Graduate Student Organizations, which can deliver worthwhile content to the local level. Even as the meeting wrapped up, everyone was scrambling to have one last conversation and coordinate another cooperative effort — exactly why GeoCoalition was created.

Many of you traveled to San Antonio to participate in G-I technical committee meetings and activities. Again, cooperation was key. At the GeoCoalition meeting, we discussed the importance of committees and how many of the organizations have overlapping missions. Some of these committee-overlaps involve the same volunteers across the organizations, while others bring in fresh new faces. Regardless of the committee makeup, if the initiatives are important for the profession, we need to close the gaps and leverage cooperative efforts.

I’ll leave you with a couple examples of recent successes. PDCA, led by Dale Biggers, has produced a model cooperative venture across at least four organizations that will propose changes to the International Building Code Chapter 18 on soils and foundations. And for years, the ADSC’s and DFI’s micropile committees have worked cooperatively leading code development, research and development, and educational activities. Like them, we must continue to seize the many opportunities that can leverage our joint strengths for the betterment of the future of the geoprofession.

Let’s all open our minds to the new opportunities presented by cooperation. We do it for our clients when we come together as teams of various talents to solve issues on projects. It’s now time to cooperate in our professional societies and cultivate our profession.

Allen Cadden, PE, D.GE, M.ASCE Geo-Institute President acadden@schnabel-eng.com
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This issue revisits geotechnical disasters, which has been a popular theme for past issues of GEOSTRATA, including: Geo-Hazards and the Natural Environment (Fall 2004), Lessons Learned from Fantastic Failures (March/April 2006), Hurricanes - Geotechnical Lessons Learned (January/February 2007), Earthquake Geotechnics (September/October 2011), and most recently, Post-Disaster Geotechnics (July/August 2012). As someone who has always had a keen fascination for a variety of natural disasters, it is not surprising to me that this would be a popular topic. We as geo-professionals may learn from each occurrence of a geo-disaster. The combination of variability (both physically and in some cases, temporally) in geomaterials and the earth’s environment (climate, weather, etc.) continues to present impressive, often unexpected disasters to our natural and built environment, as well as to the people who inhabit affected regions.

Jonathan Bray, chair of the GEER (Geotechnical Extreme Events Reconnaissance) organization, describes the goals and objectives of GEER through reconnaissance of earthquakes, floods, hurricanes, landslides, etc. The importance of collecting perishable data, and the ability to learn and foster new research are but a few of these goals. One of the recent GEER efforts is detailed in an article by Keaton et al. on the investigation and conclusions of the Oso Landslide that occurred in Washington State in March 2014. This article describes the data that has been pieced together to tell the story leading up to that disaster.

Two articles describe recent advancements in data collection technology that may aid in rapid and meaningful inspection and monitoring of surface and subsurface features. Sandiford and Munfah’s article describes leveraging digital scanning for rapid inspection of tunnels, as was done following Super Storm Sandy, which inundated underground transportation facilities in the New York metropolitan area. An article by Bouali et al., discusses advancements in the use of satellite-based remote monitoring techniques to detect and monitor landslide activity, and potentially forecast future landslide occurrence.

David Rogers provides an historical view of integrated flood control planning following the Dayton flood of 1913. The article describes development of the concept for flood control by evaluating flooding potential of an entire watershed. This concept involved the use of ‘dry’ embankment dams constructed with the primary purpose as flood control structures.

An additional article by Gray and Elton is a discussion of the human perception of risk from landslides, but could also relate to the education and awareness (or lack thereof) of the general public to the risks of natural geo-hazards that surround them.

We sincerely hope you will enjoy this collection of works by our friends and colleagues in the geo-profession, and that you will take away something new to ponder in the days ahead.

This message was prepared by PETER G. NICHOLSON, PhD, PE, D.GE, F.ASCE. He can be reached at peter.hawaii@gmail.com.
GeoNet is a battery powered wireless data acquisition network compatible with all of Geokon’s vibrating wire sensors. It uses a cluster tree topology to aggregate data from the entire network to a single device - the network supervisor. GeoNet is especially beneficial for projects where a wired infrastructure would be prohibitively expensive and difficult to employ.

The network consists of a Supervisor Node and up to 100 Sensor Nodes. Data collected at each node is transmitted to the supervisor. Once there, it can be accessed locally via PC or connected to network devices such as cellular modems for remote connectivity from practically any location.

GeoNet Wireless network is self healing and will reconfigure itself to tolerate disturbances to the physical environment. This topology is more flexible than star networks because it allows data communication to be established over longer distances and around obstructions.

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Uses worldwide 2.4 GHz ISM band.

Self configuring, easy installation.

GeoNet will automatically route data around obstructions.

Nodes separated from network will continue to collect and store data autonomously.

When network connectivity is re-established the data collected while offline will be transmitted to the supervisor.

All data collected and sent to the supervisor is also stored on each respective node.

Long battery life. Most applications measured in years.

*Environmental factors also affect battery life.
To Use or Not Use Geosynthetics

In response to the “As I See It” question and the question posed by some of your authors in the March/April 2015 GEOSTRATA, “Why Not Use Geosynthetics?”, readers would not be so tempted to respond in the affirmative had you and your other authors included our negative experience with this miracle material.

The Industrial Fabrics International Association (IFIA) hosted a panel in February 2015 that included some of your authors that dealt with the state of practice of Mechanically Stabilized Earth (MSE) walls. Quoting from the program description, “…trends indicate that the state of the practice in geosynthetic-reinforced retaining wall design is alarmingly poor.”

Moreover, Dr. Robert Koerner has an ongoing webinar describing forensic evaluation of 171 MSE failures. A quote from that synopsis is as follows: "Unfortunately, there have been many failures; some with excessive distortion while others have actually collapsed in whole or part.” With the Yeager airport embankment slope failure (Charleston, WV), it’s now 172. Dr. Bob Holtz includes this gruesome topic in some of his lectures.

As the first chair of the Transportation Research Board Committee on Geosynthetics (1990-97), a group that included major participation by several of your authors, and a committee now chaired by Dr. Christopher, I was instrumental in developing the first design protocols for MSE systems. As manager of geotechnical research for the Colorado Department of Transportation, my team (including Al Ruckman and Dr. Jonathan Wu) went on to discover flaws in MSE designs and create an alternate technology we call Geosynthetically Confined Soil (GCS). Al and I have used GCS for hundreds of walls and bridge abutments, beginning in about 1992. Our GCS technology was adopted by FHWA and renamed GRS for their abutment system. This nuance was omitted from the article by Mr. Alzamora and Dr. Nicks. Conceptually, GRS/GRS has a factor of safety of about 2.0. (No kidding.) MSE with a few more inclusions can be differentiated with the title like Mechanically Stabilized Earth – Improved, or MSEI.

Generic MSEI would rebuild our trust in geosynthetics.

Bob Barrett, President
TerraTask, LLC
bob.barrett33@gmail.com

In response to Bob Barrett’s letter, I agree with him that there are entirely too many failures of geosynthetic-reinforced slopes and very steep GRS slopes (aka “GRS walls”), but then his solution for all those failures is to use more geosynthetics (his GCS and the GRS-IBS systems)! Bob knows as well as I do that the majority of those failures have very little to do with the geosynthetics. Rather they are due...
to construction problems, inappropriate backfill, poor drainage, unexpected surcharges, inadequate global or external stability, poor training for workers, lack of proper inspection and often no control of construction by the designer, "value-engineered" or "contractor-supplied" designs, where no money is available for checking the alternates by competent professionals, the disconnect between the wall designer, geotech of record, and site civil, a relationship complicated by wall designs supplied by material suppliers and distributors, and jurisdictions that require a GRS "wall" design to be stamped by a registered structural engineer. And I’m sure Bob knows of other causes of poor GRS performance.

Secondly, his suggestion is surprising because he has long been a strong advocate for the use of geosynthetics in highways, not only the CDoT research he mentioned, but also for using geosynthetics for rockfall barriers, low-cost roadway and embankment construction, and many other applications.

Finally, I cannot resist pointing out a small "nuance" in Bob’s letter — he was not the first chair of the TRB Committee on Geosynthetics, but its second. Bob surely remembers "Old Grand Dad," Verne McGuffey of NYSDoT, who was the first chair of that committee. In about 1980, Verne convinced TRB to set up a task force on geosynthetics. That task force was so active that after a few years, TRB agreed geosynthetics deserved to be a full-fledged committee. Both Verne and Bob were excellent leaders, and their hard work laid the foundation for what has become one of the most active of all the TRB technical committees.

Bob Holtz, PhD, PE, D.GE, Dist.M.ASCE
Professor Emeritus
University of Washington
holtz@uw.edu
I write regarding the article titled “Geosynthetic Materials Help Build Optimized Infrastructure” by Bryan C. Gee in the March/April 2015 issue of GEOSTRATA.

As an Organizational Member of the Geo-Institute and a frequent advertiser in GEOSTRATA, TenCate was very disappointed to see the aforementioned article published, apparently, as an independent analysis rather than as an advertisement as it appeared to be.

Although the article did have some good information, it was largely a marketing piece that focused on geogrids, which Mr. Gee’s employer manufactures. That same company does not manufacture or market a geotextile in roadway reinforcement applications, thus calling into question whether or not the article is based on relevant experience, expertise, and free of a bias toward one manufacturer’s technology.

Regrettably, the article contained false and misleading information about geotextiles that are also successfully used in pavement optimization applications around the world. Of considerable concern is the comment in the article “in order for a geotextile to provide additional support to a pavement structure, it is necessary to place it into tension, like the surface of a trampoline.” A fair-minded geosynthetic expert should know that the geotextiles being used today for roadway reinforcement are different than those that are used to manufacture trampoline mats. In fact, many independent and widely distributed research reports have shown results showing geotextiles perform better than geogrids, in direct conflict with the comments made in the article about geotextiles.

TenCate Geosynthetics, the world’s largest manufacturer of civil engineering geosynthetics, is committed to growing the market for geosynthetics ethically. GEOSTRATA’s decision to run such an article, apparently without peer review, is both troubling and contradictory to TenCate’s belief that a professional article should be free of negative and misleading marketing information of products that compete with those of an author’s employer.

TenCate requests a written response to answer our concerns as well as to address GEOSTRATA’s criteria for publishing articles, advertisements, and editorials.

Brett Odgers, PE
Director of Roadway Reinforcement
TenCate

Thank you for writing to us in response to Bryan Gee’s article in the March/April 2015 issue. I respond here to your closing comment about “GEOSTRATA’s criteria for publishing articles...and editorials” in the magazine.

Since GEOSTRATA’s first publication more than 16 years ago, the editors have strived to solicit and select articles that are technically valid and non-promotional, either in content or tone. To meet these objectives, we have been fortunate to draw from a volunteer group of geoprofessionals with diverse backgrounds in practice, education, and government service, and as technology suppliers. Each and every article is reviewed twice (draft and final versions) by one of the current 10 members of the magazine’s Editorial Board, our content coordinator, and me, as editor-in-chief. Unlike ASCE’s Journal of Geotechnical and Geoenvironmental Engineering or a GSP, GEOSTRATA is not a peer-reviewed publication, nor has it ever been. We rely solely on volunteer writers and our volunteer Editorial Board — and, until now, have never received a criticism like yours. I can assure you that we make every effort to review and edit articles we receive in accordance with the principles outlined above. We appreciate your concerns and, as in the past, will review and edit articles to limit promotional biases as we review articles for publication going forward.

I’ll leave it to the author and readers to comment on the technical criticisms you raise.

James L. Withiam, PhD, PE, D.GE
Chair, GEOSTRATA Editorial Board
jwithiam@dappolonia.com

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It’s Our Nature.”
Fred H. Kulhawy, PhD, PE, GE, Dist.M.ASCE (1943-2015)

Fred H. Kulhawy, PhD, PE, D.GE, F.ASCE, passed away on May 12, 2015, in Ithaca, NY. He was known around the world for his research, project consulting, and academic achievements.

Dr. Kulhawy was born in Topeka, KS, and grew up in New Jersey, where he received his bachelor’s and then master’s degrees from Newark College of Engineering (NCE). In 1969, he received his PhD from the University of California, Berkeley; his dissertation was one of the very early applications of finite elements in nonlinear geotechnical construction problems. After completing his PhD, he joined the faculty at Syracuse University. In 1976, he moved to Cornell University.

While he was completing his graduate work, Dr. Kulhawy worked as a project engineer with Storch Engineers, where he worked on projects including the foundations for the Boston Aquarium, rehabilitation of portions of the Jefferson Memorial, and embankments and bridge foundations for the interstate highway system. He continued consulting during his academic career at Syracuse and Cornell, completing more than 400 assignments across six continents.

As an academic, Dr. Kulhawy was a prolific and influential researcher, authoring or co-authoring more than 370 publications. He made major contributions to foundation engineering, the development of reliability-based geotechnical design, the mechanics of soil-structure interaction, and geotechnical property evaluation. John Turner, PhD, PE, D.GE, a former student, remembered him as a dedicated and rigorous teacher who kept things in perspective with “his wry sense of humor and the wildest wardrobe (especially his ties!).”

Dr. Kulhawy was an active member and leader in ASCE and the Geo-Institute, and was elected to Distinguished Membership in 2005. He was named a G-I Hero in 2014. He served as the president of the Syracuse Section of ASCE and as a Student Chapter advisor. He was an active member and a past chair of the G-I’s Deep Foundations Technical Committee, and he was also active on the Rock Mechanics Technical Committee. He received the Kapp Foundation Engineering award in 2014, the Norman Medal in 2005, and the Karl Terzaghi Award in 2005. A Geotechnical Special Publication, *Foundation Engineering in the Face of Uncertainty* (GSP 229), was prepared in his honor in 2013.
Edward Nowatzki, PhD, PE, D.GE, F.ASCE (1936–2015)

Edward A. Nowatzki, PhD, PE, D.GE, F.ASCE, passed away on May 4, 2015, in Tucson, AZ. In his long and fruitful career, which spanned over 45 years, he touched the lives of thousands of students and engineering practitioners as a professor and as an engineering consultant.

Dr. Nowatzki grew up in New York City and earned his bachelor’s degree in civil engineering at Manhattan College. He completed his master’s and PhD at the University of Arizona, Tucson. His first position was at Grumman Aerospace Corporation. An aircraft engineering defense contractor might seem an unusual place for a civil engineer with a specialization in geotechnical engineering; Dr. Nowatzki’s research there was also very unusual: geotechnical engineering aspects of the design of the first lunar lander. He later wrote, “I consider myself very fortunate to have been a part of that historic event…” His article about his experiences on this project is available at http://tinyurl.com/NowatzkiLM.

Dr. Nowatzki served as an associate professor at California State Polytechnic University (Cal Poly) – Pomona and then at the University of Arizona, Tucson. He served as professor and department chair at Cal Poly – San Luis Obispo, and then returned to the University of Arizona as an advisor to the vice provost and as a professor. At the same time, he worked in the private sector as a consulting and principal engineer. A colleague, Jay S. Natale, PhD, PE, remembers him as able to move “seamlessly” between the private sector and academia. Dr. Nowatzki was a recognized expert in the areas of soil nailing, soil nail wall systems, and...
and soil-tire interactions. Over the course of his career, he published more than 100 technical papers and reports, including an authoritative book on off-road vehicle mobility. In 2013, he published a memoir, I Can Hold My Own.

Throughout his career, Dr. Nowatzki was involved in a number of professional organizations, including ASCE. He served as president of the Southern Arizona Branch in 1980–81 and also the Arizona Section in 1986–87. He was active in the Geotechnical Engineering Division—the predecessor of the Geo-Institute—and served on the Division’s Publications and Soil Dynamics committees. He also served as an advisor for student chapters of ASCE. In 1988, the ASCE Southern Branch named him Civil Engineer of the Year and awarded him a Commendation for Professional Contributions. He was elected a Fellow of ASCE in 1990. In 1999, he received the John C. Park Outstanding Civil Engineer Award from the Arizona Section. In 2007, he was named Engineer of the Year by the Arizona Society of Professional Engineers. He was named Outstanding Teacher of the Year four times by the students at the University of Arizona. In 1992, he received the James M. Robbins Excellence in Teaching Award from the Chi Epsilon National Honor Society. In 2005, he received the Centennial Professor Award from the University of Arizona’s Department of Civil Engineering and Engineering Mechanics, one of only four such awards.

Fox Named Head of Civil and Environmental Engineering at Penn State

Patrick J. Fox, PhD, PE, D.GE, F.ASCE, has been named the John A. and Harriette K. Shaw Professor and head of the Department of Civil and Environmental Engineering within Penn State’s College of Engineering. His appointment is effective August 1, 2015.

Dr. Fox, a member of the G-I Board of Governors, comes to Penn State from the Department of Structural Engineering at the University of California – San Diego, where he is a professor of geotechnical and geoenvironmental engineering. His research awards include the Arthur Casagrande Professional Development Award and the...
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Whatever you’re facing, we’ll help you face it.
Thomas A. Middlebrooks Award from ASCE. He has also received the Chandra S. Desai Medal from the International Association for Computer Methods and Advances in Geomechanics, the IGS Award from the International Geosynthetics Society, and best paper awards from several professional journals. He recently stepped down as chief editor of the Journal of Geotechnical and Geoenvironmental Engineering.

**Grubb Named Vice President**

Dennis Grubb, PhD, PE, M.ASCE, has joined Phoenix Services International LLC as its vice president of research, development, and technical sales. He will be developing new and enhanced beneficial uses for slag and other steel mill products, overseeing Phoenix Services’ global slag services and the quality assurance and control testing of the produced material, and serving as primary liaison for environmental affairs.

Dr. Grubb has more than 25 years of academic, research, and engineering consulting experience in environmental remediation, beneficial use, stabilization/solidification, mine waste issues, and environmental forensics. He holds a master’s and a PhD in geotechnical engineering from the University of California at Berkeley, a master’s in environmental engineering and science from Stanford University, and a bachelor’s in civil engineering from Drexel University. His research and academic experience includes launching the environmental geotechnics program at Georgia Tech and serving as senior research associate/consultant in the Center for Environmental Systems at the Stevens Institute of Technology.

He has published more than 40 journal articles. His article “Aging Effects in Field-Compact Dredged Material: Steel Slag Fines Blends,” won the 2014 Samuel Arnold Greeley Award (best industry paper) from the Environmental and Water Resources Institute of ASCE. This work focused on using steel slag to enhance the properties of dredged material so that it could be used as a competent geotechnical fill for earthwork construction in highway embankments, airport runway and ocean port fills, and other large-scale uses.

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**COREBITS STUDENTS**

**2015 IFCEE Student Competition Results**

Congratulations to all of the student teams that participated in this year’s GeoChallenge during IFCEE 2015. Sponsored largely by the Geo-Institute, the student competitions challenge and encourage graduate and undergraduate geotechnical and civil engineering students. Photos of the first-place teams are shown in each column.

**GeoWall**

Teams of four students designed and built a model mechanically-stabilized earth wall.

1st place and recipient of the coveted Atterberg Cup for the second year in a row: Cal State Fullerton
2nd place: University of Texas, Arlington
3rd place: University of Arkansas

**GeoPoster**

Students had the opportunity to present their research findings and to receive achievement recognition.

1st place: Nasser Hamdan of Arizona State University
2nd place: Alejandro Martinez of Georgia Tech
3rd place: Ashly Cabas of Virginia Tech

**GeoPrediction**

Students predicted the behavior of a ‘real world’ geotechnical system. The winning team most accurately matched the actual field performance.

1st place and recipient of the Mohr Circle Trophy: Raju Acharya and Minh Tran of University of Texas, Arlington
2nd place: Shaymaa Kadhim and Rand Khalil of University of Kansas
3rd place: Peter Demshar and Jacob Erickson of University of Minnesota, Duluth

**GeoVideo**

New to the competitions this year was the GeoVideo, in which students developed short videos explaining various geo-technical concepts accessible to a variety of educational levels.

1st place: Pugazhuel Palanivelu, Jesus Esquivel, and Miriam Woodley of Arizona State
2nd place: Jun Guo and Xiaohui Sun of University of Kansas
3rd place: Abiy Ghirmay and Cyrus Garner of University of Arkansas

**ABOVE:** GeoWall; Cal State Fullerton Team with Bill Kitch on Right. GeoPoster; Nasser Hamdan (left) with Scott Merry. GeoPrediction; Left to Right: Eric Stewart, Raju Acharya and Minh Tran. GeoVideo; Left to Right: Eric Stewart, Jesus Esquivel, Pugazhuel Palanivelu, Miriam Woodley, and Scott Merry.
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As I See It

Geotechnical Extreme Events Reconnaissance – Turning Disaster into Knowledge

By Jonathan D. Bray, PhD, PE, NAE, F.ASCE

Extreme events can impact thousands of lives and destroy cities. The tsunami generated by the Tohoku, Japan M9 earthquake washed away thousands of people and buildings and reshaped global views of nuclear power. A large landslide devastated the community of Oso, WA, killing 43 people. The storm surge from Hurricane Sandy disabled the subway system in lower Manhattan. The central business district of what was New Zealand’s second-largest city was crippled due to a few seconds of intense earthquake shaking. The lasting effects of Hurricane Katrina has forced us to rethink how we design, construct, and maintain levee systems.
Major natural and human-made disasters have the potential to reshape the landscape. It’s incumbent upon us to strive to understand the underlying mechanisms of each hazard, to characterize its effects on the ground and our infrastructure, and to develop strategies to mitigate its damaging effects. We cannot allow society to ignore extreme events, just because they occur infrequently. Their potential for doing great harm within a matter of seconds — and often without warning — requires us to be vigilant.

When it comes to instructing us and guiding our technical advancements, geotechnical engineers are keenly aware of the importance of observing performance in the field. In his 1936 presidential address to the First International Conference on Soil Mechanics and Foundation Engineering, Professor Karl Terzaghi stated: “Our theories will be superseded by better ones, but the results of conscientious observations in the field will remain as a permanent asset of inestimable value to our profession.” Geotechnical engineers must always address the challenge of engineering with materials created by nature. No theory or experiment will be sufficient. The inherent heterogeneity of soil deposits and rock formations cannot be easily captured by a computer or in the laboratory. Thus, case histories remain the cornerstone of geotechnical engineering.

In fact, it was a grass-roots movement that led to the formation of the Geotechnical Extreme Events Reconnaissance (GEER) Association. Several geotechnical engineers who had participated in ad hoc, post-earthquake surveys of damage realized that through a coordinated, coherent response of a diverse group of professionals employing advanced sensing technologies, they could do better. This collaborative effort was funded by the U.S. National Science Foundation (NSF), through the geotechnical engineering program administered by Dr. Richard Fragaszy.

Of course, carefully capturing observations in the field under normal conditions presents challenges. Documenting the performance of the ground and infrastructure under the tumultuous and pressure-filled conditions created by an extreme event is especially demanding. Much of the data generated by an extreme event is short-lived and therefore must be collected within a few days of the event. Fortunately, geotechnical engineers are familiar with working safely and efficiently under stressful field conditions. Coupling this experience with their firm commitment to develop case histories to advance the profession, GEER’s geotechnical engineers are well equipped to address these challenges. Moreover,

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they realize that each major disaster potentially provides critical lessons that can save lives in a future event.

Our profession has a rich tradition of understanding the necessity to develop and to apply new technologies and techniques that capture field observations. This is a time of unprecedented advancement in the technologies available to document damage. GEER teams have quickly moved from taking pictures on film and recording observations on paper, to the ubiquitous use of GPS devices, digital cameras, and tablet data collection applications. Ground-based and airborne LiDAR mapping technology provides an unparalleled capability to document damage in great detail before reconstruction efforts erase physical evidence. Google Earth™ and other spatial data management and analysis technologies have revolutionized the way we see the earth and share information. New technologies, such as unmanned autonomous vehicles, coupled with various sensing systems, will provide even greater data collection possibilities.

As soon as feasible after an extreme event, it is crucial to identify the primary opportunities that the event presents for collecting data that can advance the profession. Once areas to investigate more extensively are identified, Google Earth™ is used to coordinate and record GEER team member activities and their field observations. Teams must also remain flexible to respond to unanticipated phenomena. The willing participation of volunteer geo-professionals in GEER post-event reconnaissance surveys has enabled important advancements in our understanding of hazards and their impacts. GEER team members work under challenging conditions to capture the data that enable the development of robust design procedures. They document cases of good and poor
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Documenting the performance of the ground and infrastructure under the tumultuous and pressure-filled conditions created by an extreme event is especially demanding.

performance so that key factors can be identified. Their work provides the underpinnings of follow-on research studies that transform the manner in which we prepare for future events. Unanticipated observations often define new research directions. As an example, recent studies of the liquefaction of fine-grained soils have been largely motivated by observations documented by NSF-sponsored GEER reconnaissance efforts after earthquakes in Turkey and Taiwan. The careful documentation of liquefaction following the 1999 Kocaeli earthquake provided much of the data that advanced the profession’s understanding of liquefaction/cyclic ground softening of fine-grained soils. It also led to new criteria for evaluating the liquefaction potential of these soils.

GEER accomplishes its goals through the dedicated service of its volunteer members. They are committed to seizing these opportunities to develop well-documented case histories that inform engineers and direct research. Consider joining GEER and sharing your talent and passion with your profession and the world. GEER members can turn disaster into knowledge.

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GEER Response to the Oso Landslide

Documenting Perishable Details Helps Turn Disaster into Knowledge

By Jeffrey R. Keaton, PhD, PE, PG, D.GE, F.ASCE, Joseph Wartman, PhD, PE, M.ASCE, Scott A. Anderson, PhD, PE, M.ASCE, Jean Benoît, PhD, M.ASCE, John deLaChapelle, LG, LEG, Robert B. Gilbert, PhD, M.ASCE, and David R. Montgomery, PhD

Mud line on an in-place tree trunk documents vector of debris flow movement; head of Oso Landslide in background. (Photo by Jeffrey R. Keaton, May 25, 2014.)
News of the deadliest landslide in the conterminous U.S. prompted the NSF-supported Geotechnical Extreme Event Reconnaissance (GEER) Association (www.geerassociation.org) to spring into action. The GEER team turned “disaster into knowledge” by sending representatives to observe those features that otherwise may have been obscured or obliterated by rescue, recovery, and restoration activities, as well as weather and time. The disaster struck on March 22, 2014, with collapse of a portion of an unstable slope 6 km east of Oso, WA, in Snohomish County, which is about 80 km north of Seattle. The resulting landslide devastated the Steelhead Haven community and took 43 lives.

In the early days following the landslide, emergency response teams had searched for survivors in extremely difficult conditions. The landslide on the north side of the North Fork Stillaguamish River had mobilized into a debris avalanche and debris flow that blocked the river and effectively bulldozed the floodplain to the south, where residential development had existed since 1962. The landslide dam created a lake, hampering search efforts and resulting in the urgent need to drain it to prevent establishment of a new channel along the south margin of the valley, which was the focus of the search efforts. The river channel was reestablished, with assistance from the U.S. Army Corps of Engineers, across the landslide mass in approximately its pre-landslide position.

After the GEER team was formed, it began coordinating with local authorities to gain access. Online resources and discussions with key personnel allowed the team to get an understanding of the situation while search and recovery efforts were still underway. Two months following the disaster, the GEER team was granted access by local emergency

Figure 1. Historical aerial photos of the Oso Landslide slope.
management officials. This article is based on the report generated by the team and was posted on the GEER website four months after the disaster.

**Overview**

The Oso Landslide occurred at approximately 10:37 a.m. local time on a sunny Saturday morning. The area of the Steelhead Haven community on the floodplain across the river from the base of the unstable slope was immediately buried by a portion of about 8 million m$^3$ of debris that encompassed an area exceeding one km$^2$. Approximately 35 single-family homes were destroyed, and about 1.5 km of Highway 530 was blocked for two months by landslide material that locally exceeded 25 m in thickness. Damages were estimated to exceed $150 million.

The slope where the landslide originated was adjacent to a meander bend that had cut into the toe of the slope to the north of the river. The slope has a long history of movements, dating from at least the late 1940s. The river is a local fishery resource, and the primary concerns about landslides had historically related to sediment yield degrading the fishery quality. Historical aerial photos taken in 2005, 2013, and 2014 show evolution of the slope, including the two most recent landslides in 2006 and the disastrous 2014 event (Figures 1A, 1B, and 1C, respectively).

The 2005 photo shows the river channel meander north of the Steelhead Haven community and vegetation contrasts north of the meander bend that mark landslide conditions at that time. A landslide occurred on this slope in January 2006, evidence of which is visible in the 2013 photo. The vegetation contrast and river channel position in the 2005 and 2013 photos show significant differences. Linear features on the north bank of the river within the toe area following the 2006 landslide, which also are visible in the 2013 lidar hillshade image (Figure 1D), include erosion control measures installed in 2007. The primary feature of the erosion control was a log revetment consisting of tree trunks lashed together with wire rope and anchored to concrete blocks.

**Geologic Setting**

The Oso Landslide occurred in the Northern Cascade Range at about 48.3° N latitude and approximately 35 km east of Puget Sound. The Puget Lobe of the Cordilleran ice sheet dammed the west-trending valleys creating lakes in which glacio-lacustrine silt and clay were deposited. Ultimately, the landscape was overridden by ice as thick as 1.2 km, compacting recently deposited glacio-lacustrine, advance outwash, and till sediments. Meltwater from receding ice subsequently deposited recessional outwash on top of glacial till. Most recently, drainage from the Northern Cascade Range reoccupied the ice-dammed valleys, again flowing into Puget Sound.

The glacio-lacustrine silt and clay deposits were over-consolidated by the ice sheet. The melting ice relieved some of the stress in the glacio-lacustrine deposits, allowing them to expand and fissures to develop. Meltwater, initially, and then stormwater and snowmelt incised the glacio-lacustrine deposits as the river systems regained equilibrium with sea level. Meandering channels cut into the toes of valley slopes, setting the stage for landslides. The Stillaguamish Valley is relatively narrow; therefore, the meandering river created a dynamic situation of cutting into the slope toe at one location until a landslide occurred and pushed the river to the opposite side of the valley, where it again cut into the slope toe. The valley slopes in the vicinity of the Oso Landslide are nearly continuous landslide deposits, including one landslide adjacent and remarkably similar to the Oso Landslide.
Landslide Features

The stratigraphy and geomorphology of the Oso Landslide suggests two stages of movement that produced six zones or features (Figure 2). Zone A is the main scarp and back-rotated block; it was subdivided into four sub-zones, the most prominent of which is Zone A2, a block covered by mature, second-growth trees that have been felled in a uniform direction. Zone B is a rotational block field of till and glacial-lacustrine materials. Zone C is debris flows along the left margin. Zone D is sheared glacio-lacustrine sediments exposed in a blocky debris field. Zone E is a block field consisting of high-standing blocks that diminish in size to the south. Zone F is the debris flow runout.

Field observations of superposed landslide zone features support several stages of landsliding, whereas seismograph records indicate two main episodes of landsliding separated by a few minutes. The GEER hypothesis of landslide mechanics is that the Oso Landslide occurred in two main stages (Figure 2). Stage 1 is interpreted to be remobilization of the 2006 slide mass and included part of the forested head of the ancient slide (see 2013 lidar image in Figure 1D). It mobilized into a debris flow, traveling rapidly across the valley and causing the destruction. The leading edge of Stage 1 became a turbulent flow that traveled a great distance. Little of its original ground surface was preserved as interpreted from first-responders’ photographs.

Stage 2 most likely occurred in response to the unsupported scarp created by Stage 1. It retrogressed into Whitman Bench (Figure 2) by nearly 90 m horizontally from the ancient slide scarp. The Stage 2 landslide mass moved rapidly on the existing Stage 1 slip surface until it impacted the more intact blocks at the trailing edge of the Stage 1 slide mass (Zone E), where it came to rest. Vibrations recorded by nearby Puget Sound Seismic Network seismographs show two pulses of energy about four minutes apart.

Perishable Data

Immediately following an extreme event that produces geotechnical effects, GEER tries to mobilize teams with appropriate expertise to collect perishable data that
can be used to advance understanding, but is likely to disappear quickly. The GEER team was able to access the Oso Landslide area two months after it occurred. Pieces of asphalt pavement section from Highway 530 were among the features documented by the team (Figure 3). The left part of Figure 3 is the location utility in the FieldNotesPro application for smart phones displaying the latitude and longitude of an Oso observation on a georeferenced aerial photo image. The right part of Figure 3 is a photo taken at that location.

The asphalt pieces documented in Figure 3 contain the entire pavement section, from base course to pavement stripe. The original pavement and two overlays are visible in the photo. Sediment accumulations on the pavement appear to be plane-bedded, silty sand that represent hyperconcentrated sediment flow material deposited as the leading edge of the debris flow sequence. The debris flow had sufficient power to push residential buildings and forest trees across the flood plain.

The slabs of pavement are imbricated toward the north-northeast, an orientation that points to the only location in the landslide area where Highway 530 was elevated on fill and had guard rail. Pieces of guard rail were found in the same area, but farther from the highway.

These details aid in documenting the trajectory of movement of the distal part of the debris flow. In addition to pieces of asphalt pavement, unmistakable pieces of the log revetment constructed along the river in 2007 were observed at several locations on the north side of the highway. Unique features observed in some logs were wire rope in holes drilled through the trunks and inventory number identification tags tacked to the ends of some of the logs. The entire area where these features were documented by the GEER team has since been thoroughly cleaned up so that no landslide debris remains for additional observation.

**Precipitation and Hydrology**

Newspaper headlines and websites proclaimed that 2014 had the “Wettest March in Seattle History,” suggesting that precipitation must have been the trigger for the landslide that occurred on March 22. However, the Oso Landslide was the only major landslide that occurred in the Seattle region in the spring of 2014. Therefore, something else must have been involved.

The region in Snohomish County where the Oso Landslide occurred has a history of higher precipitation than regions to the north or south. This can be attributed to a weather phenomenon known as the Puget Sound Convergence Zone: air flow patterns split by the Olympic Mountains come together over Snohomish County. Some statistical analyses have been performed using data from the Darrington Ranger Station (RS) gauge, located 19 km east of the Oso Landslide. The GEER team used that gauge and others, along with NOAA NEXRAD Doppler radar data, to assess precipitation accumulation and variability in March 2014. March precipitation contains substantial variability, as can be observed in the NEXRAD radar data (Figure 4).
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The NEXRAD scene in Figure 4 is near the end of a two-day storm. The strength of the returned radar signal (reflectivity) is taken from NOAA, and rain rate equivalency is derived from online NOAA guidance. Warmer colors indicate higher rainfall intensity. The NEXRAD scene shows a strong storm cell at Oso with rain rates from ~ 25 to > 50 mm/hr. This scene also shows the Darrington RS gauge location with light rain. Typically, NEXRAD scenes are collected every five minutes, so cumulative precipitation from rain rate can be calculated with reasonable resolution. The week prior to the Oso Landslide, the Darrington gauge recorded about 116.8 mm of rain, whereas the calculated NEXRAD precipitation was just over 101 mm. However, the calculated NEXRAD precipitation at the Oso Landslide for this week was just over 228 mm. The first 21 days of March produced about 401 mm of rain at the Darrington gauge, whereas the radar estimate at Oso was over 762 mm. Perhaps the wettest March on record at the Darrington RS, the nearest rain gauge to Oso, was even wetter at the Oso Landslide. This variability may have contributed to local conditions that, in turn, contributed to triggering a major landslide at Oso, but not at other locations.

**Preventing Future Disasters**

The Oso Landslide disaster points to the need to better assess and communicate landslide risks in the Pacific Northwest. Managing the threat of landslide damage requires knowledge of the frequency with which such landslides have occurred in the past, what might trigger them in the future, and how far they may run out if they do occur. The GEER response has combined perishable observations from the field, observations that will improve our understanding and ability to model mechanics and runout, with many new tools and approaches to identify the locations, frequency and triggers, such as the use of aerial lidar and NEXRAD data. In this way, it helps us better understand the risk of similar disasters in the future. We may not be able to prevent landslides, but we can reduce landslide disasters if the lessons from Oso are understood completely, communicated clearly, and applied wisely.

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**Figure 5.** Precipitation at Oso and Darrington and NF Stillaguamish River hydrograph.

Figure 5 contains the hydrograph of the North Fork Stillaguamish River at a position 21 km downstream from the landslide (see Figure 4). The hydrograph shows the effects of the March 19 storm, as well as the effects of the landslide dam. The river distance divided by the time difference between the occurrence of the landslide and the drop in the hydrograph corresponds to a flow velocity of 2 m/s.

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Landslide Risk Perception

Consequences of Failure to Reconcile Contradictory Beliefs

By Donald Gray, PhD, M.ASCE, and David Elton, PhD, PE, FASCE
In the 8th Terzaghi Oration (Oration), Protecting Society from Landslides - The Role of the Geotechnical Engineer in 2013, Suzanne Lacasse presented selected case studies of landslides and examples of landslide risk management. She discussed at length the significance and use of safety factors. She also described the role of the geotechnical engineer, which has evolved from simply evaluating the degree of hazard via calculation of safety factors to conveying a sense of vulnerability and risk associated with landslides.

While the basis for geotechnical safety is important, public perceptions of risk and its apparent willingness to ignore or discount hazard warnings should also be considered. Why does this problem continue to exist despite huge losses of life and property from landslides the past few decades, and published hazard warnings? What quirk of human nature and circumstances allows this to occur?

Selected case studies are used to explore these questions. In addition, the role of “cognitive dissonance” is examined as a possible explanation for this unfortunate state of affairs. Simply defined, cognitive dissonance is the rationalization of unwise beliefs and actions. Cognitive dissonance has no influence on the occurrence of landslides; however, it has a huge influence on the consequences. As such, it affects risk.

Consequences of Landslides — The Human Toll
Like earthquakes and floods, landslides constitute a major threat to human life and property. European statistics for natural disasters during the past century are shown in Table 1. The landslide frequency of about 20 major events per year in Europe is the highest compared to the frequency of floods and earthquakes. However, the number of fatalities and the quantity of material damage is far greater for earthquakes. In terms of risk, which is a function of both frequency of occurrence (return period) and consequences (loss of life and economic damage), landslides fall somewhere in the middle.

Developing countries tend to be more severely affected than developed countries, especially in terms of lives lost. Table 2 shows data for the decade 1991-2000. A massive landslide in western India in 2014 was attributed to deforestation and resulted in 25 confirmed deaths. The connection between landslides and deforestation in Asia was investigated and documented in a technical report issued in 2013 by the World Food and Agriculture Organization.

More recently, the dangerous consequences of ignoring landslide risks were highlighted for the 2014 Oso Landslide in WA in a report by the Geotechnical Extreme Events Reconnaissance (GEER) team (see “GEER Response to the Oso Landslide” on p. 28 of this issue). The landslide resulted in 43 deaths and serious economic losses. This is one of several landslides reviewed in this article — particularly with regard to the role played by cognitive dissonance.

Figure 1. 2005 La Conchita landslide with breached retaining wall visible at bottom center of photo. (USGS Open File Report #2005-1067, photo by R.W. Jibson.)
“Cognitive dissonance” is defined as the psychological conflict that occurs when beliefs or assumptions are contradicted by new information. The term was introduced by the psychologist Leon Festinger in the late 1950s. He and later researchers showed that, when confronted with challenging new information, most people seek to preserve their current understanding of the world by rejecting, explaining away, or avoiding the new information — or by convincing themselves that no conflict really exists.

Landslide-related examples of cognitive dissonance include:

- A landslide occurred here previously; landslides don’t occur twice in the same place.
- The authorities wouldn’t let us build here if the location was unsafe.
- Landslides are basically unpredictable.
- The risk is worth it: less painful than moving away.
- A retaining wall can keep us safe against a landslide.
- A landslide warning system is adequate to alert us to danger.

**Case History No. 1 – La Conchita Landslide, La Conchita, CA**

**Description**

In January 2005, a catastrophic landslide/debris flow, originating from the edge of a coastal marine deposit, struck the community of La Conchita. The slide killed 10 people and destroyed approximately 30 homes (Figure 1). While it’s useful to examine the 2005 failure, it is essential to note it is part of a much larger, ancient slide complex called the Rincon Mountain slide.

**Landslide History**

The 2005 landslide occurred in virtually the same location as an earlier slope failure in the spring of 1995 (Figure 2). The earlier landslide destroyed homes,
but did not cause deaths due to its short run-out distance. The slope that failed in 1995, and again in 2005, is near the seaward edge of a prehistoric landslide that has produced historic slides, slumps, debris, and mudflows.

Community Response to Landslide Threat and Warnings
One response to the 1995 slide was to build a retaining wall at the bottom of the slope (Figure 3). As a temporary structure, the main purpose of the retaining wall was to facilitate reopening of a road at the base of the slide. The retaining wall was breached and overturned by the 2005 landslide. The remains (trace) of the retaining wall are also visible in Figure 1. Another response was to place notices on every home warning that the area was a “Geologic Hazard Area” and that residents should “Enter at Your Own Risk.” No attempt was made by public agencies to require that vulnerable homes be relocated a safe distance away from the base of the slope. The deaths and property damage that occurred in the subsequent 2005 landslide can be attributed, at least in part, to the following examples of cognitive dissonance:

- A landslide occurred here previously; landslides don’t occur twice in the same place.
- The authorities wouldn’t let us locate here if the area was unsafe.
- Landslides are basically unpredictable.
- A retaining wall can keep us safe against a landslide.

A likely consequence of the retaining wall, notwithstanding its purpose as a temporary fix, was that it gave residents a false sense of security.

Case History No. 2 – Oso Landslide, Oso, WA
Description
The Oso Landslide struck the community of Oso, in Snohomish County, WA, just before noon during a clear, sunny day in March 2014. It killed 43 people, making it the second deadliest landslide in U.S. history. The Oso Landslide completely destroyed the Steelhead Haven residential neighborhood and several homes near State Highway 530 (Figure 4). Approximately 600 m of the highway was buried under deep debris, closing this major east-west transportation route for over two months.

The landslide originated from the edge of the Whitman Bench, a plateau that borders a relatively narrow valley. The failure initiated within a steep slope comprised of unconsolidated glacial and colluvial soils. The Oso failure mass transitioned into a rapidly moving and catastrophic debris flow that traveled across the Stillaguamish River and rapidly inundated Steelhead Haven, a neighborhood of homes across the river (Figure 4). The Oso Landslide was approximately 7.6 million m³, making it one of the largest mass movements that have occurred in WA in recent decades. The slope morphology and stratigraphy of the Oso and La Conchita landslides resemble one another in some important respects, namely (1) both originated from the edge...
of relatively flat, steep-sided benches, and (2) both were slopes comprised of prior landslide debris and deposits.

**Landslide History**
The slope at the location of the 2014 landslide has slid several times since the 1930s and is also the site of ancient landslides. The most recent prior activity was in 2006, when the Hazel Landslide occurred and temporarily blocked the North Fork Stillaguamish River. This 2006 landslide traveled over 100 m laterally, but unlike the 2014 landslide, came to rest before reaching the Steelhead Haven neighborhood.

**Community Response to Landslide Threat and Warnings**
Many of the same responses (typical of the earlier La Conchita landslide) also characterized the Oso landslide. The most egregious examples were those pertaining to disregard of a history of prior landslides in the area and the issuance of additional building permits in the Steelhead Haven neighborhood following the 2006 slope failure. Local residents have been reported to refer to the steep hillside above them as “Slide Mountain.”

**Case History No. 3 – Rockfall in Tramin, Italy**

**Description**
In January 2014, a large, 300-year-old barn at the base of a steep mountain near Tramin, in northern Italy, was flattened by a 7.6-m boulder. The boulder rolled down the mountain, delivering a fatal blow to the barn. The property, known as the Freisingerhof, is owned by the Catholic Servite Order. Surprisingly, no one was hurt. Figure 5 shows the guilty boulder and the flattened barn.

The boulder in question was joined by about 4,000 m$^3$ of its fellows from the cliff face, including one 9-m monster that stopped a meter short of the farmhouse. Had it traveled one more diameter, it would have killed all inside. The damaging boulder, and several others, dislodged from the cliffs high above the farm.

**Landslide History**
The site is at the base of a steep, wooded mountain. The mountain is topped by cliffs, surrounded by talus. The cliff rock formation, apparently limestone, is somewhat fractured, and weathers into rounded shapes.

Is this boulder unique? No. It came to rest in the vineyard immediately below the farmhouse, less than 7 m from another boulder, which came down the same exact path on the mountain before the 300-year-old property was established (Figure 6). Even the most cursory examination of the largely wooded mountain above the farmhouse shows the path of this current boulder, and the ancient boulder – the clear stripe of exposed rock shown in the background of Figure 6. The best analogy for this site is: the barn is (was) at the end of the barrel of a gun that continues to discharge.
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Community Response to Landslide
Fortunately, there were no human injuries. Immediately after this rockfall, the area was temporarily evacuated by geologists over concern for other immediate falls. Amazingly, a webpage was set up to solicit money to assist the owner and repair the building to its former state... in its present location. The original property owner, surrounded by evidence of rockfalls, built directly in the path of future rockfalls, perhaps believing "it can't happen again" or "it won't happen in my lifetime.”

Lessons Learned
There are several lessons to be learned from these examples. The greatest is: many of the landslide-related deaths could have been avoided had the humans involved been fully aware. While there is no telling the thoughts of the individuals killed, it seems reasonable to conclude that they ignored the risks of living at the base of a landslide that had repeatedly failed. That is, the victims acted like “it won't happen again,” when, geologically, the first slide is compelling evidence that there will be a second.

Government construction zoning seems to have been led by those who did not understand — or choose not to understand — geology. Landslides that fail once are likely to fail again in the same location, in human time, not just geologic time. Zoning should account for this. Unfortunately, poor governmental judgment abets the unfortunate victims’ cognitive dissonance (they wouldn’t let us live here if it was unsafe). Finally, the role of “economics” should be noted in promoting unwise perceptions and acceptance to high levels of risk. Regulators may be tempted to allow people to live in unwise places because of intense development pressures and economic interests. But as these and countless other landslide case histories demonstrate, the outcomes can be damaging and deadly.

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Editor’s Note: References are available from the authors.
Slope Stability Analysis by the Limit Equilibrium Method

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by Yang H. Huang, Sc.D., P.E.

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The LEAME software can be used on any PC with Windows 95 or higher. Multi-user/multisite licenses are available by inquiring at ascelibrary@asce.org or calling 1-800-548-2723.
Figure 1. Map showing the confluence of four rivers that converge on Dayton, OH, and the 10 square miles that were inundated in the Great Ohio Flood of 1913, which included most of the city’s central business district.
Before 1913, most civil engineers evaluated floods solely upon stage levels and employed a singular approach to flood response. Their solutions for providing increased flood protection usually focused on heightening earthen dikes or retaining walls. Such improvements were normally undertaken by private property owners, usually in the wealthier commercial centers along America’s principal watercourses, like Pittsburgh, Cincinnati, Louisville, St. Louis, Memphis, or New Orleans.

The first modern attempt at integrated flood protection was the Miami Conservancy District (MCD), in the wake of the Dayton Flood. The district’s visionary, Arthur Ernest Morgan, combined scientific assessments of antecedent moisture, rainfall, runoff coefficients, and peak flow coincidence between tributaries to attempt a rational assessment of relative frequency of occurrence—something we all take for granted today. He then assembled multidisciplinary teams to undertake cost–benefit analyses of potential mitigation measures, which was another first. The remedial measures included every possibility recognized at that time, such as widening and deepening channels, checking channel downcutting with hardened weirs, robust energy dissipation devices, innovative bank stabilization measures (including structural elements and vegetation schemes), and sediment entrapment, monitoring, and
management. They also considered a graduated tax based on risk-of-inundation and the largest flood retention basins ever conceived up to that time. The project envisioned a system of checks-and-balances on operations and maintenance, which included establishing a permanent engineering staff with specific responsibilities, periodic inspections, a board of external consultants that periodically convened on site, and a system of public education focused on educating business leaders, politicians, and the general public about the importance of maintaining the district’s infrastructure.

Morgan and his advisory board concluded that engineered flood control should include every property owner within a given watershed, as all stood to benefit or to suffer from the action or inaction of their upstream neighbors. These mandates resulted in numerous court challenges, but the district’s legal authority was sustained in court decisions that went as far as the U.S. Supreme Court. The result was civil engineers engaging in proactive land use planning, and the establishment of an ad valorem tax scheme for every inch of the Great Miami River’s watershed. These monies funded the construction of a robust and redundant system of civil works improvements, which were designed to function without human or mechanical intervention, in order to be “fail-safe.” The project took nine years to complete and changed the way American engineers treated flood control problems.

A hundred years ago, sub-disciplines involved in flood control included surveying, hydrology, structural engineering, sanitary engineering, transportation engineering, soil science, horticulture, erosion control, county farm agents, railroad and utility interests, industries situated along the principal watercourses, and local political bodies having jurisdiction within the watershed. The geotechnical aspects of the project pre-dated the introduction of soil mechanics, which occurred 15 years later, but it sported some of the largest embankment dams and railway excavations of the times in the U.S., and all of these have performed remarkably well.

Today, we recognize the MCD as the prototype systems engineering project. Systems engineering is concerned with the overall process of defining, developing, operating, maintaining, and ultimately replacing quality systems. Systems engineers often organize and coordinate the activities of the sub-disciplines, serving as the primary interface between management, suppliers, customers, and specific engineering disciplines in the planning and development, design, construction, and operations and maintenance processes.

A Flood like No Other

To better understand the circumstances that led to the creation of the Miami Conservancy District, it’s important to know some details about the 1913 Dayton Flood.

Since its founding in 1796, Dayton, OH — where four rivers converge within one mile of each other (Figure 1) — has averaged about one major flood every decade. The Great Miami River watershed encompasses 3,937 mi², emptying into 115 lineal miles of channel, which feed into the Ohio River. In the early spring of 1913, the greater Ohio River Valley area was inundated by a significant storm, which dumped 4 to 10+ inches of precipitation in just three days. The rain began falling on Dayton on Easter Sunday, March 23. During that evening, the precipitation intensified. By 7 a.m. the next morning, the Great Miami River reached its annual flood stage at 11.6 ft above normal flow and continued rising. By 5:30 a.m. on Tuesday the 25th, the river’s flow reached an unprecedented 100,000 cfs, and the streets of downtown Dayton began flooding. By 1:30 p.m. that afternoon, the flood waters crested with a flow estimated to have been 250,000 cfs. The City had designed its levee systems to withstand a peak flow of 90,000 cfs; as a result, 10 mi² of the Dayton area were inundated.
Twenty thousand homes were destroyed, mostly along the Great Miami River Valley. The City of Hamilton was actually the hardest hit, with Dayton second. More than 700 people died in the event, including 467 in Ohio and the rest in surrounding states. The depth of flood water in the downtown area was about 11 ft, trapping many people in their attics, where they were later rescued. Many of those living in homes of insufficient height perished, with most of the casualties being elderly couples, and children or infants. Fourteen hundred horses and 2,000 other domestic animals also died in the flood.

Martial law was declared, and the U.S. Army was brought in to prevent looting and supervise distribution of aid to the civilian populace. Prominent local business leaders came together to form a Citizen’s Relief Commission that raised $2 million for relief and reconstruction efforts. The Commission vowed that such a catastrophe of human suffering should never occur again.

Public Outcry and Demands for Action
Several individuals became deeply involved in the mission to protect Dayton from future calamities like the 1913 flood. Arthur E. Morgan, mentioned earlier, was one of them. In 1910, he had resigned his position as supervising drainage engineer for the U.S. Department of Agriculture’s Office of Drainage Investigation to set up the Morgan Engineering Company in Memphis, TN. The firm specialized in water resources development, irrigation, and flood control for a wide range of clients, from railroads to government agencies. He was able to attract many solid and capable civil engineers to work on an array of challenging problems. In each case, Morgan would reward these men by making them partners in his young firm, a most unusual practice at that time.

Another major player was Dayton’s newly appointed city manager, Henry Matson Waite, an 1890 civil engineering graduate of MIT. He had recently arrived in Dayton, after having served as city engineer for Cincinnati from 1911-13. Dayton’s city engineer, Gaylord Cummin, had worked for the Morgan Engineering Company in Memphis before accepting his position. Cummin and Waite convinced the Relief Commission to interview Morgan about developing a reliable system of flood protection for Dayton, which served as one of the nation’s emerging centers of technology at that time. (Dayton had established prowess in the manufacture of bicycles, cash registers, paper products, electrical devices, and aviation — remember the Wright Brothers!)

Two months after the flood, the Morgan Engineering Company was retained to develop a plan of “fail-safe flood control” for Dayton. Arthur Morgan realized that flood protection could only be accomplished by examining the entire watershed tributary to the city. Morgan then established the Morgan Engineering Company of Dayton to carry out the work of making all of the principal cities in the Great Miami River Valley safe from future flood hazards — an unprecedented challenge. He thrust himself into the research, design, and construction of a resilient flood control system, involving the entire watershed.

Morgan began by hiring the best engineers he could find, including many who went on to stellar careers with the MCD, the Corps of Engineers, and the Bureau of Reclamation (Ivan
Hoek, Barton Jones, Charles H. Paul, Emory W. Lane, J. H. Kimball, and Gerard H. Matthes, to name a few. He charged Hoek with reviewing all of the climatologic information, while dispatching an army of surveyors to carefully ascertain flood heights across the Great Miami River watershed.

**Integrated Plan of Flood Control**

Morgan’s major contribution to civil engineering practice was his championing of an integrated plan of flood control, which encompassed evaluations of the entire 3,937 mi² watershed of the Great Miami River and recommended improvements to the entire system of runoff collection and discharge. Morgan recommended that the main channel be made capable of conveying 40 percent greater volume of water than the March 1913 flood, or 350,000 cfs. Today, this is viewed as a 500-yr flood, with a 0.2 percent chance of exceedance.

In 1914, Morgan drafted the Ohio Conservancy Act, which was quickly passed and signed into law. The Conservancy Act allowed local governments to establish “conservancy districts” for flood control. After much debate regarding the act’s constitutionality, the MCD was established in June 1915, and Morgan was appointed as its first president. The MCD was the first significant public works project funded by a local improvement agency established by the citizens of an affected area. The new district withstood 61 legal challenges — all the way to the U.S. Supreme Court. It also ushered in a modern era of earthmoving and earthen structures construction before the advent of modern soil mechanics.

Morgan’s forces began physical improvements by enlarging the principal channels, laying back side-slopes, and armoring the slopes on bends, as well as installing a control weir in downtown Dayton. The structural removals were significant and without precedent; in one case, an entire paper mill was razed to widen the main channel in Hamilton.

**“Dry Dams” with No Moving Parts**

The kingpin structures of Morgan’s novel scheme were five embankment dams serving as mammoth retention basins. These were named the Englewood, Huffman, Germantown, Taylorsville, and Lockington dams. The embankments varied between 65 and 120 ft high, were up to 4,700 ft long, and incorporated fill volumes between 865,000 and 3,500,000 yds³.

The only realistic means of handling a potential 350,000 cfs flow through downtown Dayton and Hamilton was to mollify the flow using retention basins of unprecedented size, as shown in Figure 2. The critical elements of the five dams/detention basins were intended to function without human intervention. The effectiveness of these mega-basins has been borne out over the last 95 years. During this time, none of the facilities has spilled excess storage over their service spillways, and all of the discharge has been carried through the concrete outlet conduits passing beneath the structures. Morgan’s team also devised an innovative plan that made the project more “fail safe” by eliminating any moving parts that would require human intervention to operate correctly during a flood.

Morgan presented his scheme for “dry flood control dams” to the public 3½ years after the flood, making five days of presentations in October of 1916. His earth dams were constructed using the hydraulic filling technique common to that era. These operations were before the advent of most mechanized earth-moving machinery, as shown in Figures 3 and 4, and these were some of the largest embankment dams in the United States at that time. Figure 5 shows the scale of the construction, and a large cut implemented on the project.

**No Multi-Purpose Reservoirs**

The mammoth dams were not intended to serve as “multiple use” reservoirs, which Morgan considered an anathema to good engineering. Morgan believed the competing forces of recreation and hydroelectric generation would likely result in the diminution of flood storage capacity to enhance short-term profits. Morgan recognized that infrequent events, such as floods, are rarely appreciated by politicians or the general public unless they have “lived through the horrors of such
Thank you to the generous donors who celebrated the Foundation’s 20th birthday with contributions during 2014. To view a complete listing of supporters, download our Annual Report at www.ascefoundation.org/annual-report.
a catastrophe.” Morgan envisioned dry basins upstream of the great embankments that could be utilized for agriculture during years of normal precipitation, with farmers paying a much–reduced, flood-protection fee to work lands that could be expected to flood more easily.

A Project without Precedent

The Miami Conservancy District established American engineering prowess in flood control engineering on an unprecedented scale, encompassing the entire watershed of a sizable Midwestern river. The Dayton flood control project included a number of firsts:

- It was the first project to attempt a credible scientific assessment of flood recurrence frequency, then designing the project for a frequency of one-in-1,000 years. This was without precedent at the time.
- It was the first time in American history that a government agency succeeded in condemning large commercial and industrial parcels, dismantling valuable properties, such as factories, which had encroached on the 100-year flood channel. These same sorts of issues would be revisited in the late 1920s and 1930s with the establishment of the federal Mississippi River & Tributaries Project after the 1927 flood of the lower Mississippi River, and the establishment of the Tennessee Valley Authority (headed by Arthur E. Morgan from 1933-38).
- The project introduced the nation to flood retention structures, or “dry dams.” The five embankment dams were among the largest earthen structures ever completed in the U.S. up until that time. These were of the hydraulic fill type, which dominated the pre-war era, up through 1940.

Predating the establishment of the Corps’ soil mechanics lab at Vicksburg, MS, by about a year, the first soil mechanics laboratory and QA/QC field work by the Army Corps of Engineers were for the Muskingum Watershed Conservancy District in Ohio in 1933, which was modeled on the Miami Conservancy District established by Morgan. This soils laboratory was established by Theodore Knappen, who went on to found his own geotechnical firm in 1942, based in New York City. After his death, that firm became Tippetts-Abbett-McCarthy-Stratton, known today as TAMS.

Today’s Miami Conservancy District is overseen by a chief engineer, a board of directors, and a board of consultants, which for more than three decades included Ralph Peck. The members periodically convene in Dayton and review the district’s activities. Since 1922, the system of flood protection has worked as intended, thanks in large measure to ongoing maintenance and upkeep, which includes periodic mucking of accumulated sediment behind the dry dams. For more information, see web.mst.edu/~rogersda/levees/Rogers-Morgan-MiamiConservancyDistrict-May2013.pdf.

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![Figure 5. The largest cut for the project was for a railroad relocation adjacent to the left abutment of Huffman Dam, seen here in September 1920. Note men standing on mid-slope drainage bench for scale.](image-url)
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How Interferometric Stacking of SAR Can Mitigate Geo-Disasters Along Transportation Corridors

By El Hachemi Bouali, PhD, Rüdiger Escobar-Wolf, PhD, and Thomas Oommen, PhD, M.ASCE
Landslides, debris flows, and other types of ground movements are among the most common hazards to humans and infrastructure (Figure 1). According to the United States Geological Survey, annual domestic losses caused by landslides in recent years range between $2B and $4B. Even worse, they kill between 25 and 50 people each year. The 1983 Thistle landslide in Utah, considered the most expensive landslide in U.S. history, required more than $400M (adjusted to current value due to inflation) in repairs to road and railroad infrastructure, plus the cost of damage to a nearby town. In 1998, the San Francisco Bay area experienced damage due to landslides in excess of $210M. More recently, on March 22, 2014, a landslide in Oso, WA, killed 43 people and destroyed 30 houses and almost a mile of State Route 530.
Landslides can be hard to predict and control once underway, but monitoring and potentially forecasting their occurrence can be crucial in the efforts to reduce their impact. Information about the imminent threat of a landslide can lead authorities to evacuate people at risk, or close transportation routes that otherwise may expose travelers to the hazard. In some cases, early intervention on an unstable slope can slow down the instability process, or even stop it, if done timely. And long-term planning for human settlements, transportation routes, and building of other critical infrastructure and human activities can also benefit from the knowledge of potentially unstable slopes.

**Slope-Monitoring Techniques**

Monitoring landslides can involve a variety of different methods, including in-situ testing of the slope material properties and modelling of the stability conditions of the slope. However, these methods can be very labor intensive and costly, and may not be affordable when applied to extensive areas. Alternatively, remote-sensing technologies, especially those based on satellite platforms, offer data with extensive aerial coverage at a reasonable cost. In the case of landslides and other terrain stability problems, surface deformation over time can be a crucial indication of a future potential failure, and satellite-based Interferometric Synthetic Aperture Radar (InSAR) offers the possibility to detect millimeter-scale displacements of the land surface.

In cases where there is no a priori knowledge of the potential location of a landslide, but the general conditions of the terrain make such a possibility a real concern, satellite-based InSAR can be used with the hope of pinpointing the location of those potentially problematic areas. Once a zone of movement has been identified, the more detailed and costly in-situ methods can be justified and applied more efficiently and, of course, satellite-based InSAR can continue to be used at those sites as well. An example of such cases could involve transportation corridors, like roads, railroads, pipelines, power lines, etc. Identifying subtle slope movements adjacent to hundreds of miles of road would be virtually impossible to do using in-situ methods, but can be readily accomplished with satellite-based InSAR.

**Multi-Pass Interferometry vs. Interferometric Stacking**

Synthetic Aperture Radar (SAR) images incorporate amplitude and phase information of incoming radar waves. Amplitude is a measure of the amount of radar signal received compared to the amount transmitted (how much signal has been reflected back to the sensor), while the phase is assigned a value between 0 and 2π describing the incoming radar wave position. Put more simply, each point along one radar
(sinusoidal) wavelength is assigned a unique phase value. InSAR is a technique that measures the phase change between multiple SAR images.

A change in phase over time can be caused by up to five variables: (1) topography, (2) atmospheric effects, (3) satellite location, (4) instrumental errors, and (5) ground deformation. The goal is to eliminate causes 1 through 4, which can be accomplished with a variety of additional input datasets, such as a digital elevation model (eliminates topography), water content or weather data (reduces atmospheric effects), and precise orbital files (avoids errors due to inexact satellite location). The remaining product is one that clearly illustrates the deformation across the area of interest.

The traditional way to display ground deformation results obtained via multi-pass InSAR processing is through an interferogram (Figure 2). Interferograms spatially show the phase change through a color wheel, where a phase change of $2\pi$ equals one full color cycle (cyan-yellow-magenta), which forms a color band called a “fringe.” Each fringe, or $2\pi$ phase change, is equal to half the wavelength of the transmitted radar wave. In the case of Figure 2, each complete fringe indicates 2.8 cm of ground deformation, which transmitted radar waves at a wavelength of 5.6 cm. Regions that appear gray exhibit low coherence and do not yield deformation information.

The best-case scenario would be to have radar images acquired before and after the deformation period so that an interferogram can be generated without areas of information loss due to low coherence. Because displacement calculations require continuous fringes across an interferogram, large areas of low coherence may interrupt these fringes.

Multi-pass InSAR is highly dependent on image pair quality; factors such as variable soil moisture, snow cover, vegetation, and large geometric variability may yield portions of the study area unusable for interferogram generation. A disruption in fringe continuity makes the interpretation process quite difficult.

One way to combat the limitation of fringe continuity is to use many more scenes, spread out over a longer period of time, and process these scenes as one stack. This method is aptly named “interferometric stacking” and includes a family of algorithms that serve various purposes. Just like in other geophysical techniques (e.g., refraction seismology or ground-penetrating radar), stacking allows for an increase in the signal-to-noise ratio by averaging out causes of random noise. Unlike multi-pass interferometry, this technique processes the phase change across the stack at the
pixel-level. Therefore, interferometric stacking is not as constrained by spatial continuity. Other benefits include the ability to detect deformation that occurs over longer timeframes (1 mm/year) and to be able to measure these rates at the pixel scale.

Persistent Scatterer Interferometry (PSI) is an interferometric stacking algorithm that searches the radar images for individual pixels with consistently high coherence. A pixel with a coherence value less than the user-defined coherence threshold will be excluded from interferometric calculations and, therefore, will result in a null value. The remaining pixels will yield a wealth of data, including cumulative displacement, average velocity, coherence, and relative displacement between the reference image and all other radar images.

Prior to illustrating the many uses of PSI for landslide detection and monitoring, two inherent constraints must be discussed. The first is that all ground motion measurements (displacement and velocity) are in the satellite line-of-sight (LOS) direction. For most satellites, this ranges from 20°-35° from nadir. The second is that total displacement measurements have an upper limit on the radar wavelength. For example, the ENVISAT satellite, which has a wavelength of 5.6 cm (C-band), has difficulty measuring fast deformations (>4 cm/year). This is regardless of the number of radar images within the processing stack (multiple stacks may be processed individually and then patched together to avoid this problem). It is important to understand these limitations. Fortunately, PSI is still a useful tool for landslide observations.

**Applications in Landslide Detection and Monitoring**

Unstable slopes can be detected and monitored using PSI-derived deformation results. Two types of analyses can be performed on these results: temporal and spatial. A temporal analysis allows for an in-depth assessment of cumulative displacement trends on a pixel-by-pixel basis over the entire timespan of radar images used in the processing stack. A spatial analysis allows for the geographic distribution of pixels to be studied. Interpretations of landslide type and potential processes can be made by examining temporal and spatial information.

Figure 3 displays PSI results for a stack of radar images acquired by ENVISAT between 2003 and 2010. The image shows an unstable slope within a railroad corridor in southeastern Nevada. Each point represents the average velocity within a pixel. Velocity values in the red-yellow-green color spectrum indicate movement away from the satellite (AFS), which may be interpreted as downslope movement or subsidence; blue-colored values indicate movement toward the satellite (TS), which may be interpreted as slope toe formation or uplift. The inset in Figure 3 shows the displacement time-series – a plot which shows the total displacement over time relative to the first radar image, with negative displacements indicating AFS.
movement – for two points: the arrow color coincides with the plot color.

Downslope displacements measured along the slope in Figure 3 indicate deformation rates from 1-4 mm/year AFS. The displacement time-series plot illustrates a relatively linear displacement trend over seven years. An initial hypothesis as to the type of landslide can be ventured without having to set foot into the field. PSI allows for the preliminary categorization of landslides based on spatial point distribution and temporal information. For example, the unstable slope in Figure 3 may be a case of continuous creep, where the slow, steady downward movement may be imperceptible to unsuspecting crews on the ground.

PSI may also be used for preliminary landslide detection. This is beneficial because landslide investigations may be performed prior to any field work. A preliminary working hypothesis may be created before anyone has to set foot onto the study site. An example initial interpretation can be performed on the PSI velocity results in Figure 4. The points in the red polygon exhibit downslope rates of displacement, while most of the points in the blue polygon show upward (or stable) rates of displacement. An interpretation to this spatial velocity signature is that perhaps the red polygon is a zone of ablation, and the blue polygon is a zone of accumulation. Field investigations may confirm or disprove this hypothesis.

InSAR techniques have been successfully implemented to measure landslide movement across the world. These examples illustrate the many types of landslides that are detectable using InSAR. Of course, actual detection of these landslides depends on a handful of critical variables. Slope orientation and geometry are obviously important, as the landslide must be visible from the satellite LOS direction. The actual slope displacement is also important, as very quick movements are nearly impossible to detect. In these cases, slope geometry changes too drastically, and coherence between image pairs drops substantially, leading to decorrelation (loss of information). Decorrelation also occurs on slopes with dense vegetation. A way to work around these two decorrelation problems is to use radar images obtained from satellites using longer wavelengths, which are able to measure faster deformations and can penetrate vegetation.

The benefits of InSAR toward landslide monitoring go beyond just measuring displacements and velocities. Interferometric stacking techniques like PSI offer pixel-scale resolution which, in theory, would allow users to target individual features or structures within or around landslide-prone regions. Anthropogenic infrastructure, such as buildings and bridges, could yield a large number of points, each with high-resolution velocity information that could be used to measure strain across the asset. Not much work has yet been done on secondary measurements (calculations based on observations), such as differential velocity and stress/strain. High-resolution data provide the potential to extract much more information from spatial and temporal InSAR results.

Future Possibilities
Much research is currently being performed on widening the application scope of satellite-based InSAR. Algorithms used for interferometric stacking are being updated and refined annually. Recent algorithms take temporal coherence fluctuations and the presence of vegetation into account, increasing the coverage area of satellite-based InSAR products. Additionally, the ever-increasing variety of future satellite missions offer many opportunities for landslide monitoring — e.g., by 2020, there will be at least one satellite transmitting radar waves with wavelengths ranging from Ku-Band (1.1-1.7cm) to L-Band (24cm) simultaneously — and there is no telling what may be accomplished.

One thing is clear, however: the future for satellite-based InSAR is bright and holds great promise for geotechnical engineering and monitoring. More powerful analysis algorithms and extensive datasets will expand the field of application for this technology. This expansion will offer a wider range of possibilities to monitor terrain instabilities along transportation corridors, even at a regional, state, or national scale, and contribute to preventing catastrophic and costly disasters.

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Figure 1. 3-D representation of scan cloud.
A large number of transit and vehicular tunnels in the New York Metropolitan area were inundated by the tidal surge caused by Super Storm Sandy on October 29, 2012. The storm created major disruptions to the region’s transportation network and resulted in tens of billions of dollars in damage and lost economic activity. Public agencies were hard pressed to restore vital services, and much of the region’s citizenry had to cope with lost or damaged residences, power and utility outages, and the loss of much of the public transportation system. Following the storm, one of the highest priorities was the rapid restoration of these transportation facilities. This was essential to getting the regional economy moving again. However, the expedited restoration process did not provide adequate time to perform comprehensive condition surveys of these tunnels, and thus required that surveys be conducted after service restoration.
The logistics associated with inspecting highly trafficked transit tunnels is challenging and led to a rethinking of conventional inspection routines. Traditionally, tunnel inspections are performed first using visual and tactile methods, and then quite often followed by LiDAR (Light Detection and Ranging) scanning and perhaps infrared scanning. The time required to visually map tunnel features can be extensive in long tunnels. By reversing the sequence — scanning first, and then performing the visual inspection — the data from the scans could be leveraged to reduce the time for visual inspections and the associated tunnel outage time. This method has been used successfully in a number of tunnels in New York City (NYC).

**Tunnel Environment**

The transit tunnels in NYC were constructed between the later part of the 19th century and the middle of the 20th century. Typically, the under-river sections were built using tunnel shield technology with the initial (outer) lining consisting of heavy cast-iron segments. In most, but not all of the tunnels, a concrete lining was placed inside the cast-iron to provide both protection and weight to counteract buoyancy. The rail systems within the tunnels vary and are either traditional track, tie and ballast system, or, for the newer generation of tunnels, direct fixation track systems. Because the trains are powered by high-voltage electricity, these cables are housed in concrete bench walls that run the length of the tunnels. Other electrical utilities, such as signals, communications, lighting, and auxiliary power, are also housed in the bench walls. There are a number of other utilities in the tunnels, including fire stand pipes, radio and Wi-Fi antennae, compressed air lines, pumps, and drainage lines. All of these systems and features are susceptible to varying degrees of damage due to saltwater exposure. The challenge is to find a methodology that provides a rapid means to inventory and assess the damage to these features.

**Scanning Technology**

LiDAR scanning has been widely used for over a decade and has proven to be invaluable for precise surveys of complex geometries, and, if time has
lapsed, progressive movements. For tunnel inspection, the value lies in its ability to detect and record defects as small as 3 mm. Recent advances in data processing and display software have greatly facilitated the analysis of the LiDAR data such that vast numbers of defects can be rapidly located, identified, measured, and categorized. The ability to pre-process the tunnel defects greatly facilitates the inspector’s work and transforms what appears to be an insurmountable volume of information into a manageable and visible set of data (Figure 1).

High speed, digital photogrammetry provides a visual record of the scanned areas and complements the dimensional data provided by the LiDAR scan. Although photogrammetric scanners provide images in the visual range, many defects and features are only apparent beyond the human visible spectrum. Fortunately, many of these defects can be detected using scanners tuned to the near-infrared frequency range, e.g., thermal range (8-12 μm). Using false color imagery, these “invisible” infrared readings can be presented within the visible color spectrum, with black representing the coolest condition and white representing the warmest condition (Figure 2).

A multi-purpose scanner (TS-3), produced by SPACETEC Datengewinnung GmbH, was used for many of the NYC tunnel inspections (Figure 3). The scanner’s mirror rotates at a rate of 155 cycles per second and records data at a rate of 10,000 readings per second. By advancing the scanner at a speed of approximately 1 km/hr, the sampling interval for a typical 6-m-diameter transit tunnel is approximately 2.5 mm. This is adequate fidelity to detect the typical defects found in the structure.

**Data Interpretation**

The three-channel scanner provides a dimensional, photographic, and temperature record of the scanned subject. The value of each type of information is different. The dimensional information serves multiple purposes, the first being the documentation of physical defects, such as cracks, spalls, and other structural damage (Figure 4). The second is the longer-term value of providing a three-dimensional record of the tunnel’s structural dimensions, exposed utility services, and track features (Figure 5). Having this information imported into BIM software, or other 3-D programs, allows designers to develop very accurate and complete drawing sets for future tunnel repairs or reconstruction.

The photographic log provides a means to visually identify many of the more obscure tunnel features that are detected by the LiDAR scanning. It’s especially valuable for the identification...
of spalls, efflorescence, equipment, and location stationing.

The infrared data provides a thermal “third eye” record of the tunnel. The scanner’s infrared imager has the ability to discern temperature differences as small as 0.5°C. The scanner’s high sampling rate results in a high-resolution image of the tunnel’s temperature variations (Figure 5). These variations provide a means to identify not only visible water leakage, but areas of permeable concrete and, to a lesser extent, areas of delamination.

The volume of data that is generated by the scanner is truly enormous. However, data processing software can interpret these data and highlight specific defects, such as crack widths and lengths, and features such as infrared anomalies, stalactites, and cold joints. This “pre-processing” of the data greatly facilitates the follow-up inspection planning process and is essential for tunnels of any considerable length (i.e., longer than 1 km).

**Inspection Process**

Prior to scanning, a system of highly visible station markers was secured in the tunnels at 60-m intervals. The station markers are used to verify and correct the scanner’s wheel-based odometer, if necessary. The data processors are then able to adjust the cloud data to match the actual longitudinal stationing and to tie the tunnel scan with the global positioning. The tunnel outage time used for the installation of station markers was precious, in that this time could not be used for other critical maintenance activities. To make the most out of this tunnel time, pre-scanning reconnaissance was performed by technicians to help facilitate the later data processing.

A high-rail truck was retrofitted to support the scanner and transport it through the tunnels. The actual scanning process took less than two hours and was accomplished during nighttime outages, between midnight and 4 a.m.

The data processing came next. Although this required approximately one week per tunnel, it provided a very detailed preview of the tunnel conditions as well as the ability to pre-determine where more detailed visual inspection was required. The LiDAR and photogrammetric images were used to map cracks and other structural defects. Several features were identified for future visual inspection. The thermal scan images were then used to identify active leaks and also to identify areas of possible delamination or hidden defects. The pre-inspection analysis produced a series of tables indicating at what station and position defects were detected, and where more detailed inspections were required.

The visual inspections and other field tests were conducted during nighttime outages. Using the defect stationing information developed previously, inspectors were able to rapidly advance through the tunnels and were generally able to complete the inspections in two nighttime shifts per tunnel. The work included visual examination, hammer...
testing to detect laminations and voids behind the liner, and echo sounding testing, as well as core sampling of concrete.

Limitations
The data obtained from the scanner was generally extremely detailed and reliable. The one exception was the ability to detect delaminations. Specifically, the use of thermal images to identify delaminated concrete resulted in a number of false-positive results. Areas identified as delaminated were tested using an echo-sounding device and in a number of instances were found to be intact. Inspectors were able to test the suspect areas rapidly by rolling a knobbed roller device across the area and listening for changes in pitch (Figure 6). High technology aside, the human ear is still a finely tuned instrument, able to detect changes in pitch from intact concrete to concrete with shallow delamination.

The Potential
Modern scanning technologies have the potential to not only facilitate tunnel inspections, but also provide a means to document and measure other geotechnical features. Advances to the technology are being made continuously, and these are improving scanner resolution, making it faster and easier to process data, and simplifying the data interpretation. Scanning has an additional value-added feature: the ability to use the data cloud in either 3-D CADD or BIM programs. This allows for further processing, visualization, and, if needed, the production of contract drawings. This technology is in its early stages of development, so as its usage increases, so will its capabilities and its ease of usage.

The Outcome
The damage caused to the various transit tunnels varied in scale and intensity; however, major restoration work was required in all tunnels. Much of this work is either underway or planned in the near future. The most obvious damage was related to the electrical systems, (e.g., traction power, signals, lighting, etc.) and the benchwalls and ducts that house them. Typically, these have all been replaced or thoroughly cleaned and restored. The damage to the tunnel structures themselves was limited. The loads imposed by the flood waters were significant; fortunately, the tunnel structures are robust and were able to sustain these loads without damage. The real damage was caused by the intrusion of saltwater residue into cracks and into and behind concrete delaminations. In terms of structural repair work, the highest priority has been the removal of the remaining saltwater residue from exposed surfaces. This is being done using high-pressure power washing. Unfortunately, power washing is not a viable means for removing this residue from ducts housed in benchwalls, embedded steel members, deep cracks, or delaminations. In a number of tunnels, especially tunnels built at the turn of the 20th century, the benchwalls that house the tunnel electrical systems have sufficient defects that the addition of damaging salt residue requires their entire demolition and reconstruction. On a slightly brighter note, in some instances, the benchwall reconstruction has provided transit systems the opportunity to modify their replacement bench wall configuration to meet current patron evacuation standards.

Client Perspective
The transit systems that experienced the monumental onslaught of Sandy have almost fully recovered. On balance, the transit systems are up and running, and the NYC economy has recovered. Long-term repair and/or reconstruction work has been completed in some of the tunnels. However, a number of tunnels still need to undergo significant rehabilitation. This work is once again hindered by the lack of access to the tunnels. Taking a page from the LiDAR experience, studies are underway to develop rapid and efficient means to affect these repairs with minimal disruption to rail service.

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“Those who cannot remember the past are doomed to repeat it.”

You no doubt agree with George Santayana’s famous observation, but what if the history involved was never documented? How could you learn? In fact, you couldn’t. That’s why, in the early 1970s, one of the first steps taken by the Geoprofessional Business Association (GBA) – then named Associated Soil and Foundation Engineers (ASFE) – was to present and then publish case histories of its member firms’ loss experiences and the lessons they taught. And the more case histories GBA reviewed, the more certain patterns emerged, resulting in extensive lists of “do’s and don’ts.” One of the most important “don’ts” is to refrain from suing clients that owe you a comparatively small amount of money. All too often, such clients will use the money they owe you to retain an attorney and a hired-gun expert to trump up charges and accuse you of negligence, and then seek to settle for a sum that exceeds what they owe you or, at best, is far less than what you’ve earned.
Not everyone believes in the lessons of history (or the law of averages), especially when ignoring them seems to achieve positive results. Consider the case of a firm we’ll call GWA Associates, an outfit that, over the years, had taken nonpaying clients to small-claims court 60 times and won every case... except the one that began when a developer retained GWA to perform a phase-one environmental site assessment (ESA). The developer planned to buy the property involved for construction of a small office building. The property’s owner—a heating-oil-distribution company—was using the property for truck maintenance. The previous owner used the property for a service station and had installed underground tanks to store diesel fuel, gasoline, and waste oil. Reportedly, the previous owner had removed the tanks, but no documentation was available to prove it.

The developer accepted GWA’s proposal and signed its agreement as presented.

GWA’s initial assessment indicated that the site’s use as a gas station and the undocumented removal of underground storage tanks presented significant risks. GWA recommended a phase-two study, including subsurface exploration and soil and groundwater analysis. GWA submitted a second proposal, which—as the first—the client accepted without change.

GWA set to work and soon detected oil globules in one of the observation wells it had installed. Analysis revealed the presence of heating oil or diesel fuel at levels slightly exceeding the “reportable concentration” under state law. A second round of sampling indicated concentrations just under the reportable threshold, but that didn’t matter: State regulations required the property owner to report conditions. GWA therefore recommended that the developer notify the property owner of its reporting requirement, and that GWA perform additional characterization to assess the extent of contamination and the need for remediation.

Concerned by GWA’s findings, the property owner asked the developer to conduct more sampling, but the developer refused. Therefore, with the developer’s blessing (in writing), the owner retained GWA to resample the affected well and conduct laboratory analysis. The owner signed GWA’s contract, the general conditions of which were identical to those the developer had accepted as presented.

Results of the additional sampling, testing, and analysis affirmed the presence of contamination slightly below the reporting threshold. Nonetheless, the owner still was required to report the above-threshold level initially encountered.

Its services complete, GWA billed the owner $1,200. The owner ignored the bill until four months later, when its CEO wrote to GWA saying it would pay the bill immediately if GWA would provide a copy of the report GWA had prepared for the developer. The developer okayed the request, and the Member Firm provided the report. But the owner still refused to pay. Instead, it retained a second environmental firm, with no licensed professionals on staff, to review GWA’s work and resample the observation well. The new consultant concluded that the owner had no regulatory-reporting requirement, unambiguous regulatory language notwithstanding.

After more than a year of repeated billings, calls, and office visits, GWA decided to take its client to small-claims court. Three days before the court date, the owner sued GWA for $20,000, claiming the firm had contaminated its property when diesel fuel leaked from its drilling rig. GWA
retained counsel who was confident GWA would prevail at trial. Counsel estimated that his fees and expenses would come to $5,000 or so.

GWA’s lawyer asked the owner to discuss the matter, per GWA-contract wording requiring mediation before court action. The owner refused, requiring attorneys for both sides to gather and review files and interview participants. While that process was ongoing, GWA’s attorney moved to deny action based on contractual language. He also moved for summary judgment. The judge denied both motions, because she “needed to know more about the case.” As a result, the case moved into the discovery phase, requiring preparation of documentation, interrogatories, production of expert witnesses, depositions, motions, negotiations, and conferences.

Depositions of the owner’s CEO were eye-opening. He openly acknowledged that he had fabricated the drilling-rig fuel-leak claim and that the expert he retained had no evidence that GWA had at any time acted negligently. Based on these revelations, GWA’s attorney again moved for summary judgment and also moved to bar the owner’s expert from testifying, because he had no relevant testimony to offer and, in any event, lacked qualifications. At this point, the owner offered to settle if GWA would pay it $4,000. GWA refused, and both sides then appeared before a pretrial-conference judge. The judge indicated that he probably would bar the owner’s expert and might even accept an abuse-of-process claim if GWA wanted to file one.

Immediately after the conference, the owner offered to settle if GWA would pay it $2,000. GWA rejected the offer, however, because its attorney said the firm would “do really well” with an abuse-of-process claim. Accordingly, GWA countered with an offer to settle if the owner paid the original $1,200 fee, plus attorney and expert fees totaling $51,000. The owner offered $2,000, but GWA, believing it could recover all its legal fees, decided to go to trial. That’s when GWA’s attorney explained that, even if the firm won its abuse-of-process claim, the owner would be obligated to pay no more than one-third of GWA’s legal costs. So, just before trial, GWA offered to settle for $25,000. The owner responded with a check for $16,000, which GWA accepted.

What a dreadful outcome! GWA invested close to $100,000 in out-of-pocket expenses and staff time to collect $1,200. The client’s $16,000 settlement reduced the net cost to $84,000, not including the value of lost morale, lost opportunity, and lost sleep.

Commenting on the case, GWA’s COO said, “I knew the lessons of history [taught by GBA], but I tended to ‘pooh-pooh’ them. The firm had taken clients to small-claims court 60 times and won on almost every occasion. The money we lost on this one case exceeded all the money we collected on all prior claims....” Then he added, “Of course, when you think about it, if we had to use the small-claims court so often, we must have been doing something wrong.”

And “something wrong” was not just going to small-claims court. The best slow- and no-pay client preventive is a comprehensive “go/no-go” decision-making process that includes a comprehensive background check. If the project is so small that you don’t have the time to do that, reject the commission. Many firms’ reluctance to do that is one of the principal reasons why project risk is inversely proportional to project size. (Somewhat ironically, when GWA’s COO began to tell his tale of woe to a colleague, the colleague stopped him mid-sentence: “Don’t tell me you actually accepted a project from that guy,” he said. “He never pays, and he always sues!”)

**Bottom line:** Now that you know where to find the lessons of history, are you going to learn from them...or just repeat them?

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*John P. Bachner* is the executive vice president of the Geoprofessional Business Association (GBA), a not-for-profit association of firms that develops programs, services, and materials to help its members and their clients confront risk and optimize performance. GBA-Member Firms provide geotechnical, geologic, environmental, construction-materials engineering and testing (CoMET), and related professional services ([en.wikipedia.org/wiki/Geoprofessions](en.wikipedia.org/wiki/Geoprofessions)). Contact GBA at info@geoprofessional.org.
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Ronald J. (Ron) Ebelhar, PE, D.GE, F.ASCE, F.ASTM

Ronald (Ron) J. Ebelhar, PE, D.GE, FASCE, FASTM, is currently a senior principal with Terracon in Cincinnati, OH. After earning his bachelor’s and master’s degrees in civil engineering from the University of Kentucky in Lexington, Ebelhar joined McClelland Engineers in Houston, TX, as a staff engineer in 1977. There, he worked in various roles in the geotechnical laboratory, information technology, and marine geosciences groups. From 1987 to 1996, he served as division manager and vice president for Rust Environment & Infrastructure (and its predecessors, S&ME, Westinghouse, and SEC Donohue) in Cincinnati, OH, before taking the position of vice president with H.C. Nutting in 1996. He assumed his current role when Terracon purchased H.C. Nutting in 2007.

As a project manager for geotechnical and environmental engineering projects worldwide, Ebelhar has provided design, consulting, and forensic engineering services for commercial, industrial, transportation, waste disposal, and public utility projects; geotechnical engineering design and construction, including site soil response under seismic, cyclic, and dynamic loading; and marine geosciences and engineering field explorations. He is a registered professional engineer in eight states.

Ebelhar is a fellow for ASTM International, one of the largest voluntary standards developing organizations in the world. He is currently serving as the 2015 chairman of the board. In the past, he has served as chairman of the ASTM Committee D18 on Soil and Rock and several D18 subcommittees, and he is also the 2003 Award of Merit recipient. Ebelhar is also a fellow and member of the American Society of Civil Engineers and a Diplomate, Geotechnical Engineering, in the Academy of Geo-Professionals.

What was your most fun class while in school?
I particularly enjoyed my Soil Dynamics and Advanced Soil Mechanics classes taught by Vince Drnevich and Bobby Hardin, respectively. In the “fun” category, I also would have to include several semesters playing guitar in the Jazz Ensemble directed by Vince DiMartino, with the chance to perform live with Clark Terry, Phil Woods, James Moody, and other jazz greats.

What was the most fun project you worked on?
It’s usually the current project I’m working on. There are literally too many to count. If I could point to a few, though, it would probably include field CPT work offshore Brunei, India, and Norway, dynamic pile testing offshore Saudi Arabia, several international hazardous waste landfill design/construction projects, and the Lake Bridges Project in western Kentucky.
What was something you always wanted?
A better golf game.

What is your favorite song and artist?
My favorite songs are Over the Rainbow, This Masquerade, and The Long and Winding Road. My favorite Artists include The Beatles, Little Feat, and Steely Dan.

What is your favorite movie or television show?
Instead of movie or television, I would have to go with the Broadway musical “Wicked.” We have seen it 10 times in five different cities on three continents, and I performed several of the songs with some Broadway veterans in various settings. The musical works well on so many levels for audiences from young to old, with a plot that can be entertaining superficially, but also with a commentary on discrimination and political satire, if you care to dig deeper. The musical score has many memorable moments, both in lyrics and melodies.

Where did you spend most of your childhood? What was it like for you growing up there?
I was born and raised in Owensboro, Kentucky, where barbeque, basketball, and car racing were the high-profile passions. My dad was in marketing with the Bell companies, and both Mom and Dad were very active in our church, sports, and extracurricular activities. We grew up on the park playgrounds, playing baseball, football, and basketball with my brothers and neighbors. I remember riding bikes to serve early Masses, to school, to ballgames, delivering papers, etc. It was all the great things about living in the Midwest in the 1960s.

How do you feel about the state of Civil Engineering and the profession as it is today?
Civil engineers continue to make strides in the improvement of daily life for our general population, primarily through infrastructure development and the built environment. We (civil engineers) also play a big role in the development of natural resources (mining, oil and gas exploration, manufacturing, commercial, etc.). By nature, most civil engineers are not self-promoters. We have to learn to help the general public and politicians understand why civil engineering is important: to develop and maintain infrastructure for economic viability and quality of life. It’s also important to attract our young people into this noble profession.

What do you personally feel are the biggest challenges that are on the horizon for the profession?
On the technology side, promoting the use of integrated geoscience and geoenvironmental tools and studies, and integrating instrumentation technologies and data management into construction and constructed facilities. On the human resources side, attracting young, talented people to science and engineering is a huge challenge.

Why are you certified as a D.GE, and what made you choose to become a Diplomate in the Academy?
I was invited to apply by colleagues whom I respected. I had already assembled most of the required material for the Member and Fellow status applications, so it wasn't difficult to pull together. I realized that it was a natural progression of my career to become certified in this specialty, and I highly recommend that readers of this article also look into it.
**Schnabel Engineering’s Gordon Matheson, PhD, PE, PG, to Serve as GBA President 2015-2016**

Schnabel Engineering, Inc. (Schnabel), Glen Allen, VA, is pleased to announce that Gordon M. Matheson, PhD, PE, PG, will serve as president for the Geoprofessional Business Association’s (GBA) 2015-2016 year. Gordon will succeed Steven D. Thorne, PR, D.GE, who served for the 2014-2015 year.

Gordon is president and CEO of Schnabel Engineering, Inc., and has more than 35 years of experience nationally and internationally, meeting a wide variety of geo-engineering challenges. He is the author of more than 35 publications and has been active in industry and professional societies for many years.

Prior to joining the GBA Board, Gordon was chair of the GBA Business Practices Committee and helped develop numerous GBA programs. He is also a past chairman of the ASCE Engineering Geology and Site Characterization Committee, has served as adjunct faculty at several universities, has served on several university faculty advisory boards, and actively supports local community charitable activities.

Gordon received his bachelor’s degree from Virginia Polytechnic Institute and State University, his master’s from the University of Missouri at Rolla, and his PhD from the Colorado School of Mines.

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**Demand Spurs Geotechnology, Inc. to Open New Offices**

Geotechnology, Inc., a leading provider of geotechnical and environmental engineering, geophysics, water resource management, materials testing, and drilling services, has opened two new offices, one in Oxford, MS, and one in Jonesboro, AR.

The company, whose corporate offices are in St. Louis, expanded its operations in 2010 to Memphis. It also has offices in Fairview Heights, IL, and Overland Park, KS.

President and CEO Ed Alizadeh, PE, JD, says the decision to open these new offices was based upon the success of the company’s Memphis operations, the region’s opportunities, and the demand for specialized geotechnical and construction materials testing services.

The new Jonesboro office is already involved with the Arkansas Highway and Transportation Department’s Route 63 from Blackrock to Portia project, as well as a project on the Craighead Forest Park Trail in Jonesboro.

The Oxford office is also busy with several projects, including work with Baptist Memorial Hospital-North Mississippi and the University of Mississippi Vaught-Hemingway Stadium’s south endzone upgrades.
The Geo-Institute Organizational Member Council (OMC) invites your organization to join us. Enjoy the numerous benefits that G-I organizational membership offers, including the following:

- Up to a 50 percent discount on the G-I annual Geo-Congress for one person.
- A 5 percent discount for advertising in GEOSTRATA magazine.
- Forty percent ($400) of your annual G-I OM dues goes directly to fund G-I student activities. A portion of that money finances student travel to the annual Geo-Congress and the OM/Student Career Fair.
- Each year during the annual Geo-Congress, the OMC hosts an OM Career Fair/Reception. Two OM members from each OM firm are invited to participate, along with 45-50 students carefully chosen by the OMC.
- Opportunity to publish news about your company, including awards, new staff and promotions, company projects, awards, etc.
- Your company name listed in Organizational Member News in each issue of GEOSTRATA magazine.
- Opportunity to display the G-I logo on your website and on printed materials.
- Opportunity to display a G-I Organizational Member placard at your exhibit booth.
- For more information, visit the G-I website at www.asce.org/geotechnical-engineering/organizational-members where you can download the Organizational Membership application.
GRL Opens 10th Branch Office in the Houston Metropolitan Area

GRL Engineers, Inc. has announced the opening of its 10th branch office, in the Houston metropolitan area. “We will be opening this office to better serve the needs of our growing client base in Texas,” said Pat Hannigan, president of GRL.

The office will be staffed by Brandon Phetteplace and managed by Camilo Alvarez, who together will bring more than 22 years of experience in dynamic testing and quality assurance methods for deep foundations to the Texas market. Both Phetteplace and Alvarez hold Master-level certificates on the PDCA/PDI Dynamic Measurement and Analysis Proficiency Test.

Alvarez, who has a master’s in civil engineering from Case Western Reserve University, is well published and a registered professional engineer in multiple states. Alvarez will manage the Texas office in addition to the Colorado and California offices. Phetteplace has a bachelor’s degree in civil engineering from Case Western Reserve University, is well published and a registered professional engineer in New York and Fredonia.

Miskimon Brings Marketing Expertise to Gannett Fleming

Gannett Fleming welcomes Maria “Ree” Miskimon as its Mid-Atlantic Region business development manager. Based in the firm’s Baltimore, MD, office, Miskimon is responsible for directing Gannett Fleming’s high-level business development efforts in MD, VA, DE, and NC. In this role, she provides leadership for the region’s capture and proposal management initiatives, leads the development and execution of winning strategies, manages the activities of the region’s capture and proposal teams, and works in partnership with the firm’s executive leadership to achieve the company’s business development and financial goals.

An accomplished professional, Miskimon brings 17 years of engineering industry experience in marketing, business development, and proposal management to Gannett Fleming. Her dynamic career includes several engineering and construction management firms in the Baltimore area, where she honed her skills in identifying, developing, and evaluating marketing strategies based on overall objectives and market characteristics. An effective leader and manager, Miskimon excels at serving in key roles for complex pursuits.

Active in professional associations, she is a member of the Society of American Military Engineers – Baltimore Post, the Maryland Association of Engineers, and the Society for Marketing Professional Services (SMPS). Miskimon serves as secretary of the SMPS Maryland Chapter, which named her Board Member of the Year for her outstanding support. In addition, she volunteers for the National Multiple Sclerosis Society and was honored as Big Sister of the Year by Big Brothers/Big Sisters of Baltimore.

Stare Named Stockholder of Gannett Fleming

Daniel P. Stare, PE, was named a stockholder of Gannett Fleming. Based in the corporate headquarters in Harrisburg, PA, Stare serves as a senior geotechnical engineer in the firm’s Earth Sciences and Hydraulics Group.

With more than 16 years of industry and geotechnical experience, Stare has been involved with geotechnical aspects of environmental, water resource, dam, mine subsidence, highway, and structural projects. He specializes in dam engineering projects with an emphasis on foundation seepage remediation applying advanced grouting methods throughout the U.S. Stare regularly manages grouting operations on large dam projects, including the Penn Forest Dam, Hunting Run Dam, Patoka Lake Dam, Mississinewa Dam, Clearwater Lake Dam, Center Hill Dam, Wolf Creek Dam, and Lyman Run Dam.

A registered professional engineer in PA, Stare holds a bachelor’s degree in civil engineering from Virginia Polytechnic Institute and State University. He was a contributor to the design of the IntelliGrout® System and a contributing author for a comprehensive revision and update of the EM 1110-2-3506 Grouting Technology Manual for the U.S. Army Corps of Engineers. Stare resides in Mechanicsburg, PA.

Terracon Expands Presence in El Paso; Plans to Grow Texas Client Services

Terracon is pleased to announce the ownership of a new office in El Paso, TX. The El Paso operation was previously owned by Raba Kistner Consultants, Inc., and has transitioned its employees, equipment, and current projects to Terracon to serve clients locally and nationally.

Terracon offers environmental, geotechnical, materials, and services facilities from 150 offices across the U.S. Raba Kistner’s complementary service offerings will transition seamlessly into Terracon.

“We are excited to expand our strong Texas presence into the city of El Paso,” said David Gaboury, PE, president and CEO of Terracon. “The depth of experience for this office will bring great value to our clients locally and nationally.”

Raba Kistner was founded in 1968 and will continue to operate its office locations across the Southwest, other areas in the U.S., and in Mexico. Raba Kistner specializes in environmental, geotechnical, and facilities engineering, as well as program management and construction quality assurance services.
Jonathan J. Pickering Named Senior Project Manager for GZA GeoEnvironmental, Inc.

GZA Geo-Environmental, Inc., a leading environmental and geotechnical consulting firm, announces that Jonathan J. Pickering, PE, of Washington Court House, OH, has been named a senior project manager in the Cincinnati office.

Prior to joining GZA, Pickering, whose areas of specialization are geotechnical engineering, water resource engineering, civil site engineering, and engineering site inspection, was a senior geotechnical engineer/senior project manager with Barr Engineering, Inc. His extensive industry background also includes tenure as an engineering manager with TesTech, Inc. and as a design/senior engineer with CESCO, Inc.

Pickering received a bachelor's degree in civil engineering from Ohio Northern University. He is a licensed professional engineer in OH, IN, MI, KY, and MO.

Pickering is an active volunteer with the Washington Court House Little League and Fayette County Pony League Football.

"We are very pleased to welcome Jonathan to the firm," said William Hadge, president and CEO of GZA GeoEnvironmental, Inc. "He joins a growing team of people in Cincinnati for GZA and brings a strong background in geotechnical engineering to complement our capabilities in environmental and air quality engineering."

Terracon Celebrates 50th Anniversary

Terracon, a leading provider of environmental, facilities, geotechnical, and materials consulting engineering services, was honored to be celebrating its 50th anniversary in April.

Founded on April 22, 1965, Terracon traces its roots to a small engineering firm in Iowa. The firm, which brings together a staff of engineers, scientists, and technicians, has expanded into a nationwide operation with more than 150 offices and 3,400 employees.

"This anniversary is about honoring our clients who have put their trust in us," said David Gaboury, PE, president and CEO, "and our employees who work hard every day to give back to their communities. We’re just getting started and are excited about the next 50 years."

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Engineering Seismology with Applications to Geotechnical Engineering

ÖZ YILMAZ

This book is about the theory and practice of near-surface seismology applied to engineering problems.

Site investigations for civil-engineering structures require multidisciplinary participation by the geologist, geophysicist, and geotechnical and earthquake engineers. A key objective of this book (SEG Investigations in Geophysics Series No. 17) is to encourage the specialists from these disciplines to apply the seismic method to solve the many challenging engineering problems they face. This book includes a comprehensive review of the seismic wave theory and methods for seismic modeling of the soil column based on a prolific number of elastic wavefield simulations and field experiments. Additionally, the book includes a total of 21 case studies on all applications of engineering seismology.

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G-I Launches New Website

The Geo-Institute is proud to announce the launch of its new website! With the same URL as before, www.geoinstitute.org, the website strives to support and communicate the value and dynamism of the geoprofession, serves as a news and event resource, and communicates activities of the Geo-Institute.

Our easy-to-use website features efficient navigation and search, making our most popular and newest content easy to find. The appealing, new design allows GEOSTRATA articles to be easily accessed and indexed by subject.

The G-I website also hosts autonomously maintained “microsites” for individual committees, chapters, and student organizations. This fosters communication within the G-I community.

Jean-Louis Briaud Chosen as 2015-2016 Cross-USA Lecturer

Please join the Geo-Institute in congratulating Jean-Louis Briaud, PhD, PE, D.GE, Dist.M.ASCE, of Texas A&M University, on being selected the 2015-2016 Cross-USA Lecturer! In the coming months, Professor Briaud will travel to five different Chapters and Graduate Student Organizations (GSOs) as part of this ongoing program that not only enhances the prestige and visibility of the geoprofession, but also brings dynamic and engaging lectures to local G-I groups and members across the U.S.

GI-GBA Memorandum of Understanding

Because the Geo-Institute of ASCE (G-I) and the Geoprofessional Business Association (GBA) share common purposes and interests, on March 16, 2015, the two organizations formalized their relationship by signing a Memorandum of Understanding. The document states that the groups will advance their mutual interests in confronting risk, optimizing performance, and presenting technical topics within the geotechnical profession. Both G-I and GBA look forward to working together as they strive to meet the following goals:

- Encourage continuing dialogue to identify mutual interests and collaboration opportunities between GBA and the G-I at the national, state, and local levels to advance engineering, science, continuing education, and public understanding of the geoprofession.
- Seek to collaborate and understand the needs of both organizations to act in mutually supportive ways to efficiently serve the needs of their mutual customers. Seek to engage both boards in active discussions if and when differences arise and work together to amicably resolve those differences.
- Collaborate in areas of mutual interest that will benefit both organizations and the geoprofession.
- Encourage both memberships to be actively involved in each other’s organization and conferences to efficiently seek technical-focused content from the G-I and business-focused content from GBA.
- Seek to leverage the distribution channels of each other’s organization to efficiently provide services to each group’s mutual customers.
- Seek to provide services and content to each other’s organization using deliverables that are in accordance with the receiving organization’s needs.

G-I Welcomes New Committee Chairs

The G-I is pleased to congratulate its new committee chairs:

- **Luis Garcia**, Deep Foundations Committee Chair
- **Paolo Gazzarrini**, Grouting Committee Chair
- **Dimitrios Zekkos**, Geoenvironmental Engineering Committee Chair
- **Adrian Rodriguez-Marek**, Earthquake Engineering and Soil Dynamics Committee Chair
- **Ron Yeung**, Rock Mechanics Committee Chair

Please join us in welcoming these individuals to their new roles.
GeoCoalition Meeting to Further Collaboration

The GeoCoalition members held their annual meeting on May 18-20 in Leesburg, VA, to discuss collaboration topics for the geo-industry. The mission of the GeoCoalition is to create a sense of geo-community by encouraging communication, cooperation, and collaboration between its members as products and events are publicized and promoted. The GeoCoalition will identify opportunities for members to endorse common positions and provide a powerful, common voice to influence the geo-future.

During the meeting, members participated in networking activities and shared key initiatives, events, and needs for each organization and the geoprophession.

Outcomes included:
- Ideas for linking researcher and practitioner research needs
- Exploration of industry safety needs
- Discussion of structural engineering licensing issues
- Continued building of technical committee collaboration
- Identification of need to assess future trends in the geoprophession
- Identification of need to support existing infrastructure lobbying efforts

GeoCoalition members are: ADSC: The International Association of Foundation Drilling; AEG - Association of Environmental & Engineering Geologists; GBA – Geoprophessional Business Association; DFI - Deep Foundations Institute; G-I - Geo-Institute of ASCE; PDCA - Pile Driving Contractors Association, and USUCGER - United States Universities Council on Geotechnical Education and Research.

Geoprophessional Business Association News

Kenneth R. Johnston has been appointed to the GBA board. His term began May 1, 2015. Johnson is a principal at GZA GeoEnvironmental and is the firm’s chief administration officer.

GBA has released a new publication titled Getting Paid. The guide, in 19 pages, contains 21 techniques to achieving prompt payment, including tips for recognizing reliable clients and writing effective contracts.

Did you know the GBA has an app? It’s not just for conferences – the GBA app brings news, coming events, a member list, and more to your mobile device. Visit www.tinyurl.com/gbamobile from your device to download and install the app.

New Scholarship Fund for Engineering Students

The Deep Foundations Institute (DFI) Educational Trust and Langan Engineering & Environmental Services announce the establishment of the Langan Engineering & Environmental Services Legacy Scholarship Fund. The fund was started with a $200,000 donation from Langan Engineering & Environmental Services and an additional contribution of $102,000 by many principals of Langan. In 2015, it will award $15,000 in scholarships.

The fund will provide scholarships to civil engineering students who are focusing on geotechnical and/or environmental engineering. Within the fund, three standing scholarships honor former distinguished members of Langan: The Bernard F. Langan Scholarship at Purdue University, the Dennis J. Leary Memorial Scholarship at the University of Illinois at Urbana-Champaign, and the Donald J. Murphy Memorial Scholarship at NYU/Polytechnic School of Engineering. More information on the fund is available at www.dfi.org/trust/scholarships.asp?langan.

The DFI Educational Trust was established in 2006 to support individuals in fields of study related to the deep foundation industry through providing scholarships and opportunities to meet and work with leaders in the deep foundations industry.
Internships Available Are you looking for an internship? Explore the positions listed on the ASCE website to help you obtain the experience you need to further your career path. New opportunities are added all the time, so start your search today: careers.asce.org/jobs

ASCE/G–I Co-Sponsored Online Webinars Note: All posted webinars offer 1.5 professional development hours (PDHs).

- Underpinning and Strengthening of Foundations July 15, 2015 11:30 AM – 1:00 PM (ET)
- Ethics: The Road All Engineers Must Follow July 16, 2015 11:30 AM – 1:00 PM (ET)
- Pipeline Condition Assessment using Broadband Electromagnetic (BEM) Testing July 21, 2015 11:30 AM – 12:30 PM (ET)
- Development, Detection, and Containment of Elevated Temperatures in Landfills July 24, 2015 12:00 PM – 1:00 PM (ET)
- Design of Foundations for Equipment Support July 28, 2015 11:30 AM – 1:00 PM (ET)
- Geotextile Filter Failures July 31, 2015 11:30 AM – 1:00 PM (ET)
- The Seismic Coefficient Method for Slope and Retaining Wall Design August 6, 2015 11:30 AM – 1:00 PM (ET)
- Design of Roof Structures: Avoiding Common Errors August 7, 2015 11:30 AM – 1:00 PM (ET)
- Load and Resistance Factor Design (LRFD) for Geotechnical Engineering Features: Earth Retaining Structures: Fill Walls August 10, 2015 11:30 AM – 1:00 PM (ET)
- Interceptor Condition Assessment and Sustainability August 17, 2015 12:00 PM – 1:00 PM (ET)

ASCE/G–I Seminars Note: All posted seminars offer continuing education units (CEUs).

- Earthquake-Induced Ground Motions July 16–17, 2015 Charlotte, NC
- Risk-Based Seismic Design and Evaluation August 13–14, 2015 San Francisco, CA
- Design and Installation of Buried Pipes September 10–11, 2015 San Diego, CA

For more information about webinars, seminars, and on-demand learning, visit the ASCE Continuing Education website: www.asce.org/continuing_education.
The Geo-Institute Seattle Chapter held its annual Short Course and Spring Seminar from May 1-2, 2015. The Short Course, titled “Soil Liquefaction During Earthquakes – Recent Developments,” was presented on May 1 by Dr. Ross Boulanger, Dr. Jason DeJong, and Dr. I. M. Idris of the University of California – Davis. Topics covered included updates to SPT- and CPT-based liquefaction triggering procedures, emerging procedures for characterizing gravelly soils, updated characterization and testing guidance for evaluating softening of soft clays and plastic silts, and discussion of recommended practices for site characterization and soil property selection for liquefaction analyses.

The Chapter’s 32nd Annual Spring Seminar, titled “Geotechnical Earthquake Engineering,” was held the following day at the University of Washington (UW) campus. Topics included recent and future trends in liquefaction evaluation, effects on pile foundations, seismic earth pressures, and a focus on local projects. The Spring Seminar was attended by more than 170 geoprofessionals and included more than 20 exhibitors.

These annual programs are the Chapter’s signature events, providing revenue to support its local activities and sponsorships.

**Robert D. Holtz Endowed Fellowship**

The members of the Seattle Chapter strongly believe in the development of the University of Washington’s (UW) geotechnical engineering program. In the mid-2000s, the organization partnered with local practitioners to create the Robert D. Holtz Endowed Fellowship to support graduate student education and research in geotechnical engineering. Over 70 individuals and firms contributed to raise the initial $100,000 needed several years ago to establish a fully funded fellowship. The State of Washington contributed an additional $25,000 at that time. The Seattle Chapter has subsequently contributed funds to the fellowship on a regular basis and was pleased to contribute an additional $20,000 in 2015. The fellowship currently generates about $9,500 annually for scholarships, helping UW attract talented graduate students to strengthen the geotechnical program and local professional community.

The fellowship honors Dr. Robert Holtz, an esteemed member of the local chapter and an individual who is well known for his research, educational, and professional achievements. Professor Holtz served as the liaison between the Seattle Chapter (formerly the Geotechnical Group of ASCE) and UW engineering faculty and staff. Dr. Holtz is a promoter of excellence in geotechnical engineering. He has had a distinguished career as a geotechnical engineering professor, researcher, author, and consultant and served on the Civil & Environmental Engineering faculty at UW for nearly 20 years. This fellowship honors him and his significant contributions to the field.

**Seattle Chapter Receives 2014 Chapter of the Year Award from Geo-Institute**

The Seattle Chapter was honored to receive the Geo-Institute’s 2014 Chapter of the Year Award in recognition of its many activities and ongoing success supporting local geoprofessionals and the community.
INDUSTRY CALENDAR

ASCE Pipelines Conference
August 23-26, 2015
Baltimore, MD
pipelinesconference.org

14th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst
October 5-9, 2015
Rochester, MN
sinkholeconference.com

ASCE Convention
October 11-14, 2015
New York, NY
asceconvention.org

28th Central Pennsylvania Geotechnical Conference
November 4-6, 2015
Hershey, PA

Geotechnical & Structural Engineering Congress 2016
February 14-17, 2016
Phoenix, AZ
geo-structures.org

Geo-Chicago 2016: Sustainability, Energy and the Geoenvironment
August 14-18, 2016
Chicago, IL

4th GeoChina International Conference
July 25-27, 2016
Shandong, China
geochina2016.geoconf.org

Geotechnical Frontiers
March 12-15, 2017
Orlando, FL
geotechnicalfrontiers.com

For more seminar information:
www.asce.org/Continuing-Education/Seminars/Face-to-Face-Seminars
By Mary C. Nodine, PE, M.ASCE

Seismic Design

As an engineer working along the East Coast,
Where the autumn leaves glow
And the blizzard winds blow,
I feel that, when the seismic load case controls,
I’m designing my structure for the forces of ghosts.

An MSE wall is the source of my plight.
Are my calculations right?
They reveal that despite
A reinforcing length 70% of its height,
If an earthquake shoved with all of its might,
Away it would slide, soil resistance too small.
It makes no sense at all
That this practical wall
Should have strips twice as long as its facing is tall,
To resist eerie forces that want it to fall.

What’s more, beneath the wall is a giant sand lens
With blowcounts of ten.
Dr. Youd and his friends
Predict that its strength will disappear when
The thousand-year earthquake haunts us again.

Don’t get me wrong – I know ‘quakes are for real.
Without enough steel
Sturdy buildings will keel.
Right over, crushing people and automobiles
In their wake. I cannot take this lightly, I feel.

Planned wall sits on stone columns, sand densified.
But I won’t tell a lie:
As my stamp is applied,
I pray that this ominous Magnitude Five
Won’t occur – though I trust that my wall will survive.

MARY C. NODINE, PE, M.ASCE, is a
geotechnical poet and a project engineer with GEI Consultants, Inc. in
Woburn, MA. She can be reached at
mnodine@geiconsultants.com.

Author’s Note: This poem reveals that earthquake engineering is
slightly outside my wheelhouse. I
humbly thank the engineers who contribute to the seismic codes,
with all their mysterious probabili-
ties, variables, and coefficients. You allow me to sleep at night!
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Wendell Strode, Executive Director, National Corvette Museum

National Corvette Museum | Bowling Green, Kentucky

Micropiles

At 5:44 a.m. on February 13, 2014, the world fell out from under the National Corvette Museum. A 40-foot-wide by 60-foot-long sinkhole with a depth of over 35 feet collapsed within the museum’s Skydome swallowing eight very valuable and historic vehicles. Hayward Baker was quickly called and onsite within hours. The owner retained Hayward Baker to design and construct micropiles to stabilize the structure, allowing salvage crews safe access to retrieve the cars and fill the sinkhole.

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