*Fast*TIMES

Special Issue:

Environmental Geophysics

March 2017

Volume 22, Number 1

The current issue of *Fast*TIMES is focused on environmental geophysics, with four articles, three in the "Success with Geophysics" section and one in the new "Student's Corner" section.

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*Fast*TIMES

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ABOUT EEGS

The Environmental and Engineering Geophysical Society (EEGS) is an applied scientific organization founded in 1992. Our mission:

"To promote the science of geophysics especially as it is applied to environmental and engineering problems; to foster common scientific interests of geophysicists and their colleagues in other related sciences and engineering; to maintain a high professional standing among its members; and to promote fellowship and cooperation among persons interested in the science."

We strive to accomplish our mission in many ways, including (1) holding the annual Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP); (2) publishing the Journal of Environmental & Engineering Geophysics (JEEG), a peer-reviewed journal devoted to near-surface geophysics; (3) publishing *Fast*TIMES, a magazine for the near-surface community, and (4) maintaining relationships with other professional societies relevant to near-surface geophysics.

JOINING EEGS

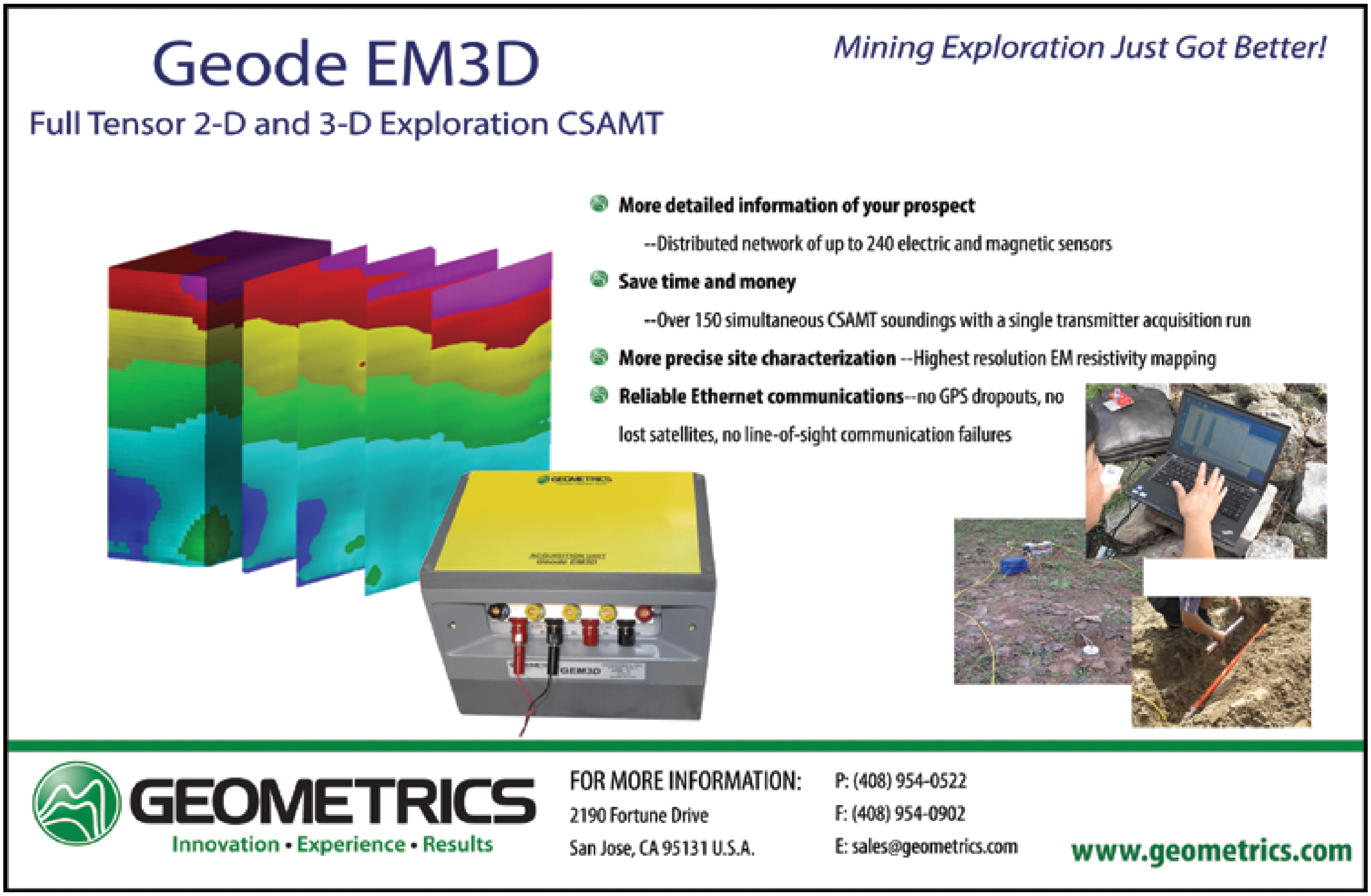
EEGS welcomes membership applications from individuals (including students) and businesses. Annual dues are $105 for an individual membership, $50 for introductory membership, $50 for a retired member, $50 developing world membership, complimentary corporate sponsored student membership - if available, and $310 to $4010 for various levels of corporate membership. All membership categories include free online access to JEEG. The membership application is available at the back of this issue, or online at www.eegs.org.

SUBMISSIONS

To submit information for inclusion in *Fast*TIMES, contact a member of the editorial team:

To advertise in FastTIMES, contact:
Jackie Jacoby
staff@eegs.org
303.531.7517

*Fast*TIMES is published electronically four times a year. Please send contributions to any member of the editorial team by July 15, 2017. Advertisements are due to Jackie Jacoby by July 15, 2017.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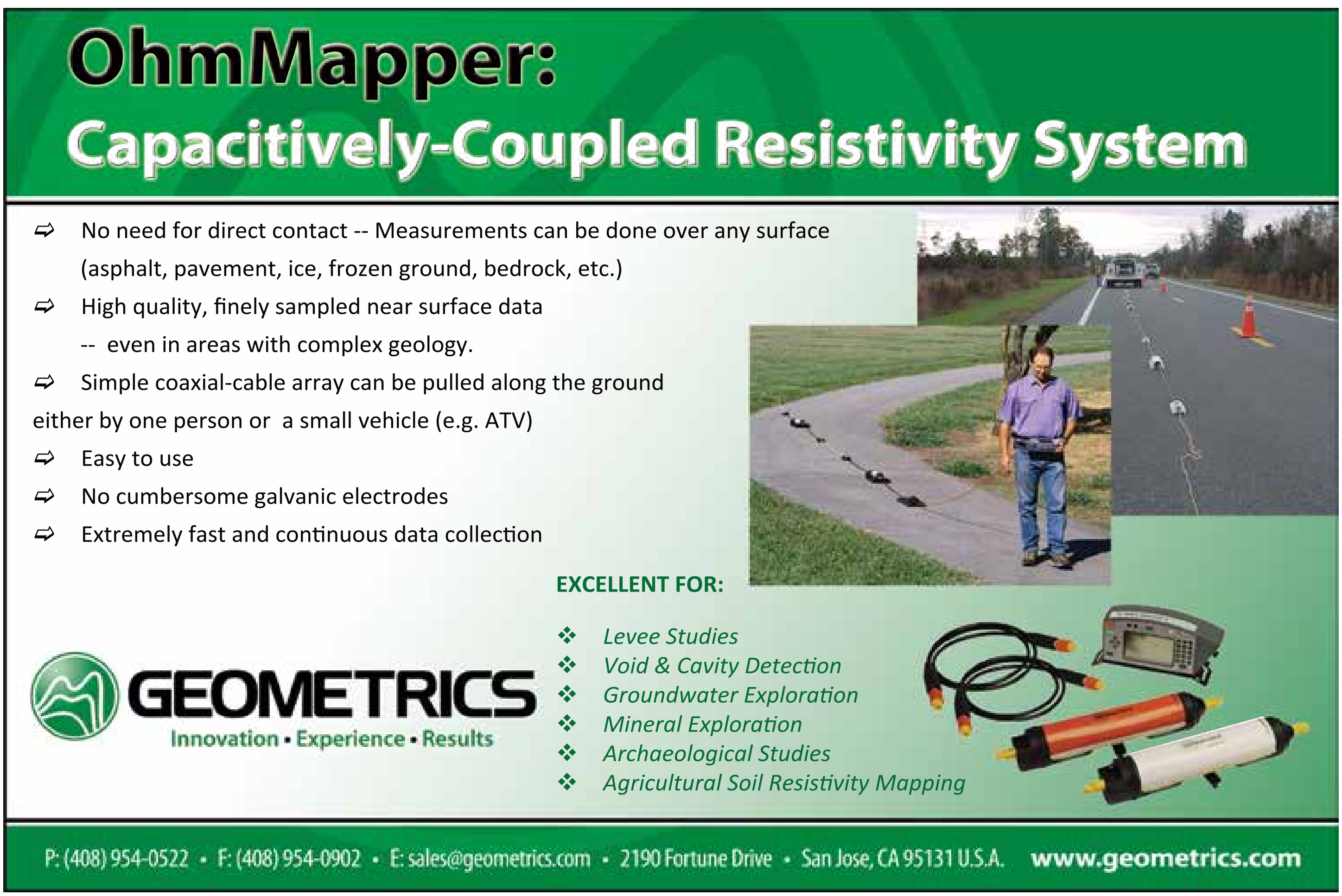
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CALENDAR

2017

July 24 - 27	AGU-SEG Hydrogeophysics Workshop - Imaging the Critical Zone Stanford, California, USA http://workshops.agu.org/hydrogeophysics/
August 14 - 15	19th International Conference on Engineering Geophysics (ICEG 2017) Venice, Italy https://www.waset.org/conference/2017/08/venice/ICEG
September 3 - 7	EAGE 23rd European Meeting of Environmental and Engineering Geophysics Malmö, Sweden http://www.eage.org/event/index.php?eventid=1516
September 14 - 15 Nov. 30 - Dec. 1	SurfSeis - Multichannel Analysis of Surface Waves (MASW) Workshop Lawrence, Kansas, USA http://www.kgs.ku.edu/software/surfseis/workshops.html
September 24 - 29	Society of Exploration Geophysicists (SEG) Annual Meeting Houston, Texas, USA http://seg.org/events/annual-meeting
October 9 - 12	SEG International Conference on Engineering Geophysics (ICEG2017) Al Ain, United Arab Emirates http://seg.org/Events/ICEG2017
November 22 - 24	GELMON 2017 - 4th International Workshop on Geoelectrical Monitoring Vienna, Austria https://www.geologie.ac.at/en/about-us/conferences/gelmon/
December 11 - 15	American Geophysical Union (AGU) Fall Meeting New Orleans, LA, USA http://fallmeeting.agu.org/2017/

2018

March 19 - 23	Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) Nashville, Tennessee, USA http://www.eegs.org/sageep-2018 (Note: See page 64 for additional information.)

Please send event listings, corrections or omitted events to any member of the *Fast*TIMES editorial team.

PRESIDENT'S MESSAGE

Bethany Burton, President

(blburton@usgs.gov)

We've just concluded a successful and productive 30th anniversary Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) held in Denver and co-located with the National Ground Water Association's (NGWA) Conference on Hydrogeophysics and Characterization of Deep Groundwater. I'd like to extend a hearty thank you to the planning and technical committees, chaired by Dale Werkema and Elliot Grunewald, respectively, for their hard work in making this conference a success. We are already looking forward to next year's SAGEEP in Nashville, Tennessee!

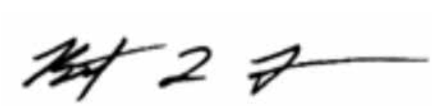
Barry Allred, editor-in-chief of FastTIMES, has announced that he will step down to an associate editor role after the June 2017 issue. Since his first issue in September 2013, Barry has established a successful associate/guest editorship model that has culminated in technically strong issues covering a wide range of topics. EEGS is extremely grateful for Barry's dedication to FastTIMES, and we are currently seeking qualified applicants to serve as the next FastTIMES editor-in-chief.

With SAGEEP also comes the transition to the new EEGS Board of Directors. I'd like to introduce and welcome our incoming 2017 – 2018 Board members:
Rick A. Hoover, Quality Geosciences Co., President-Elect
Michael Kalinski, University of Kentucky: VP-elect Committees
John Stowell, formerly Mount Sopris Instrument Company Inc: VP-elect SAGEEP
John M. Jackson, U.S. Army Corps of Engineers: Board Member at Large
Peeter Pehme, Waterloo Geophysics/G360 University of Guelph: Board Member at Large

I'd also like to thank our outgoing Board members for their time and service to EEGS:

Lee Slater, Rutgers University: Immediate Past President
Mark Saunders, Applus RTD: VP Committees
Charles Stoyer, Interpex Ltd., VP SAGEEP
Rick A. Hoover, Quality Geosciences Co.: Board Member at Large

As my final message as EEGS President, I'd like to close with encouraging you to consider becoming more involved in EEGS, whether through committee, Board, or SAGEEP participation. As I wrote in my first letter, we are a member-driven, volunteer-centric organization that depends on the efforts of its members to be the society that we want it to be.



Bethany L. Burton, EEGS President

EEGS Foundation News

March 2017 by R. Bell (rbell@igsdenver.com

Guiding Technologies Today.
Preparing for a World of Needs Tomorrow.

- **SAGEEP 2017 – Best Ever!!**
- **SAGEEP Silent Auction and Student Event**
- **Richard J. Wold Memorial Scholarship**
- **On-line Silent Auction to Benefit EEGS Foundation**
- **Musician's Workshop & Music Industry Tour for SAGEEP 2018**
- **Geophysical Instruments for Humanitarian Projects**

SAGEEP 2017 was the ***best*** Environmental and Engineering Geophysical Society (EEGS) Annual Meeting event in the 30 years since the SAGEEP came into being. Arguably, the success of the conference was the direct result of several positive changes to SAGEEP, not the least of which was the co-location of the ***NGWA Hydrogeophysics and Deep Groundwater Conference.*** The two (2) day, one-track conference was seamlessly integrated into the traditional SAGEEP format of three (3) days of oral and poster presentations about the developments and "real world" applications of environmental and engineering geophysical technology.

Standing Room Only during the NGWA Hydrogeophysics and Deep Groundwater Technical Presentation

In addition, the conference program included timely and thought provoking talks by notable industry leaders at Keynote Presentation as well as the luncheons. There was a brilliant new layout for the exhibition hall allowing for the obvious increase in number of exhibitors along with a dynamic outdoor demonstration of geophysical equipment and methodologies. Complementing the traditional program were short courses on geophysical methods and creating hydrogeological models from geophysical data. In addition to the strong technical program and educational content, there were two well-attended networking events cleverly presented as receptions along with a unique Student Event.

A "***Bravo!!! and Heartfelt Shout Out***" to Dale Werkema and Elliot Grunewald as well the SAGEEP 2017 Steering Committee (Bruce Smith, Rick Hoover, Lia Martinez, Burke Minsley, Alastair McClymont, Oliver Kuras, Carole Johnson, Jim LoCoco, Beth Burton, Jeannie Norton, John Jansen, and Bill Doll) and EEGS Staff (Jackie Jacoby & Jacey File) for injecting new life into the venerable SAGEEP. The SAGEEP 2018 Steering Committee will have to work very hard if they wish to achieve, much less improve on, the success of SAGEEP 2017.

The EEGS Foundation supported two events at SAGEEP 2017: The Silent Auction and the Student Event.

The Silent Auction

For readers who are new the EEGS Foundation, The Silent Auction is a fundraiser to support of the EEGS Foundation programs. The SAGEEP 2017 Silent Auction raised $200 for the Foundation. Even though the proceeds from the auction were a bit less than hoped, the EEGS Foundation Board of Directors are sincerely grateful to everyone donating items to the Silent Auction as well as everyone who participated in the auction. Your support is essential in order to continue the mission The EEGS Foundation. Thank you.

The inspirational mood permeating the air throughout the SAGEEP 2017 was so uplifting to some members of the EEGS Foundation Board of Directors that planning for the SAGEEP 2018 Silent Auction commenced immediately. If you wish to learn how to contribute items to the Silent Auction ***or*** if you wish to know more about becoming involved with the auction, please contact Doug Laymon (doug@collierconsulting.com).

A special note for US taxpayers: The EEGS Foundation is a non-profit organization as defined by the Internal Revenue Service. Thus, the fair market value of your donations is deductible from your federal income tax in the tax year that you donate the item or cash. Although the 2016 tax season is becoming a faded memory, it is never too early to begin implementing your tax strategy for 2017. Start today by donating an item to The Silent Auction for SAGEEP 2018.

The Student Event

It is almost a tradition for the EEGS Foundation to sponsor the Student Event at the SAGEEP. Keeping with "tradition", it did so for SAGEEP 2017. Carole D. Johnson constructed a non-traditional program that included

- a presentation by Joshua Noel*, a Program Coordinator in the Aviation and Aerospace Science school at Metropolitan State University,
- an Industry – Academic – Research Panel Discussion about establishing and furthering a career in geophysics, and

- a drone demonstration and fly about.

In addition, at the end of the formal program, Laura Sherrod, the incoming EEGS President, spoke to the gathering of approximately 75 that consisted of students, professors, leading industry geophysicists and business professionals, as well as a multitude of government researchers.

The Unmanned Aerial Systems (UAS) Club at MSU set up a drone cage and furnished several radio controlled quadcopters. Folks were encouraged to try their hand at piloting a drone. Those that accepted the challenge quickly learned that avoiding crashes is a skill requiring practice and patience. Networking ensued which no doubt led to numerous stimulating discussions about drones applied to the acquisition of geophysical and geoscience data. All of this high-flying activity fueled by the availability of free pizza and beer resulting in the perfect combination of innovative technology and social interaction tinted by the distinctive desire to apply geophysical methods to map and explore the subsurface.

Top Left: Joshua Noel speaking about the offerings at Aviation and Aerospace Department of Metropolitan State University.
Top Right: Students learning how to operate the drone.
Bottom Left: Beth Burton, EEGS Immediate Past President, flying the drone.
Bottom Right: Networking while watching Beth and others fly the drone.

The EEGS Foundation provides financial support for the Student Event at SAGEEP in order for EEGS to fulfill its mission by encouraging interaction between those beginning their careers in E&E geophysics and those with years of experience applying geophysics to engineering and environmental problems while enduring the vagaries of uncertain economies. Clearly, transforming the application of technology into a sustainable business model and engaging profession requires investment in the youth destined to become the respected practitioners and industry leaders. The Student Event is one way that the EEGS Foundation is *preparing for a world of needs tomorrow*.

Joshua Noel - Program Coordinator
Aviation and Aerospace Science
Metropolitan State University
Denver, CO
email: jnoel@msudenver.edu
website: msudenver.edu/aviation

Richard J. Wold Memorial Scholarship

It comes as no surprise to anyone involved in the application of geophysical methods to real world environmental and engineering problems that drones offer significant advantages when investigating the surface and subsurface of the earth. As a direct result, the demand for lightweight and low power sensors or/and new approaches to making geophysical measurements is growing. There is an obvious need for funding to support academic research and development in this arena. Thus, I am working through the EEGS Foundation to establish a scholarship in the name of Richard J. Wold to support Masters and PhD students in geophysics or engineering who are working on the development of new sensors or innovative methods for making geophysical measurements.

A former President of EEGS, Dick Wold passed away in 2015. Dick began his geophysical career in the 1950's and obtained a PhD for the development of the first digitally recording airborne magnetometer. Throughout his long and varied career, Dick always maintained a keen interest in better ways to make geophysical measurements. He was instrumental in helping many geophysicists and engineers in their respective efforts to develop and commercialize innovative geophysical technologies. He often did so by connecting the researcher to sources of funding. It is all together fitting to create a scholarship in Dick's memory.

My goal is to present one or more $5000.00 scholarships on an annual basis to qualified MS or PhD candidate in geophysics or engineering or related field of study. I plan to award the first scholarship in the Spring of 2018 at SAGEEP 2018.

A candidate selection committee comprised of qualified scientists and industry donors will evaluate applicants and recommend award recipients. Donors contributing a donation of $25,000 or more will have the privilege to participate in the candidate review and selection process. I am seeking one or more individuals willing to assist with the development and guidance of the scholarship fund.

If you wish to support this initiative, simply designate your donation to the EEGS Foundation be applied to the Richard J. Wold Memorial Scholarship Fund. If you wish to learn more about this initiative, please call me at 303-462-1466 or email me at rbell@igsdenver.com.

On-line Silent Auction to Benefit EEGS Foundation

We are exploring the concept of an On-Line Auction as a fundraiser. The proceeds from the auctioned off item would go to the EEGS Foundation to support a specific program such as the Student Event or placed in a general fund to support programs initiated and administered by EEGS. The core of the idea is to auction off geophysical or geoscience relevant items on a regular basis, perhaps through the EEGS Foundation website (http://www.eegsfoundation.org/). The auction may be a standalone event or held in conjunction with the traditional Silent Auction conducted during the SAGEEP.

We are seeking your comments and suggestions.

- *Do you see merit in the idea?*
- *Would you participate through an item donation or as a bidder?*
- *Do you have suggestions on how to implement it?*
- *Are there other fund raising ideas for the foundation to consider?*

Please email any comments or suggestions:
Doug Laymon (doug@collierconsulting.com) or
Ron Bell (rbell@igsdenver.com).

Guitar Workshop and More at SAGEEP 2018

In 2018, the SAGEEP will be located the self-proclaimed ***Music City, Nashville Tenneesee.*** http://www.visitmusiccity.com. Thus, we see a unique opportunity to take advantage of the special nature of the locale to offer a different kind of experience to those attending the conference.

During the SAGEEP 2017, I learned that Steve Cosway, Mark Dunscomb, and Chuck Young were guitar players. This led to a discussion of a possible jam session while in Nashville which subsequently led to genesis of a concept for a Guitarist's & Musician's Workshop and Jam Session to be taught by a professional musician \ teacher \ entertainer on the Saturday or Sunday prior to official kickoff of SAGEEP, the Icebreaker Reception. Perhaps, the objective might be for the workshop participants to perform during the Icebreaker Reception.

Another concept under development is a Nashville Music Industry Tour of a guitar manufacturing facility, a recording studio, and a store that sells vintage guitars topped off with a concert performance at musical venue such as the Ryman Auditorium or the Cumberland Caverns. The EEGS Foundation would receive portion of the fees charged for the workshop and the tour.

A committee is currently forming to flesh out the event concepts and build the implementation plan. We wish to know your thoughts and suggestions about these events and, perhaps, other event ideas for the SAGEEP 2018 program.

Please email your comments and suggestions by July 15, 2017 to one or more of the following committee members.

Ron Bell	rbell@igdenver.com
Doug Laymon	doug@collierconsulting.com
Steve Cosway	swc@sensoft.ca

We are striving to create something that is a uniquely musical and fun networking\social\learning event for SAGEEP 2018 providing tangible benefit to EEGS in support of its mission. If you wish to assist with creating these events, consider joining committee.

Geophysical Instruments for Humanitarian Projects

The EEGS Foundation Board of Directors met during the SAGEEP 2017 conference. Among the primary topics of discussion was the initiative to develop a repository of geophysical instrumentation designated to support humanitarian projects. The instrumentation and related gear for geoscientists to use on qualified projects at little or no cost. The details of the program are in the development stage. However, Dennis Mills reported that he recently engaged in a conversation with an organization well suited to provide the storage and maintenance for the equipment. Thus, we are pleased to report that this program concept is beginning to gain some traction.

The EEGS Foundation is seeking your input. Please let us know your thoughts, ideas, and suggestions, or if you wish, help us with the formation of the equipment repository by emailing Dennis Mills or Bill Doll.

Dennis Mills	dmills@expins.com
Bill Doll	William.Doll@tetratech.com

Support the EEGS Foundation through a Cash Donation

If you are an EEGS member or even if you are not an EEGS member, please support the EEGS Foundation through a tax deductible (for US taxpayers) cash donation. A typical amount for an individual is $50. EEGS Corporate members typically provide an annual gift of $2500.00. Of course, giving a larger amount is quite acceptable and very much appreciated. Please keep in mind that you are able to designate your donation to go towards the EEGS Foundation Student Event Fund, the Richard J. Wold Memorial Scholarship Fund, or the EEGS Foundation General Fund.

FOUNDATION UPDATE

If you wish to make a donation via check, please mail it to the following address:

EEGS Foundation
1720 South Bellaire, Suite 110
Denver, CO 80222-4303

If you wish to make a donation via a credit card, please call the EEGS business office at **303.531.7517.** For more information, visit http://www.eegsfoundation.org/.

A donation to the EEGS Foundation will help G***uide Technologies Today*** as well as ***Prepare for A World of Needs Tomorrow.*** Thank you for your support.

EEGS Foundation Board of Directors (December, 2016)

Dennis Mills	Exploration Instruments	dmills@expins.com	President
Doug Laymon	Collier Consulting	doug@collierconsulting.com	Treasurer
John Clark	Corona Resources, Inc.	jclark@coronares.com	Secretary
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William Doll	Tetra Tech	William.Doll@tetratech.com	Director at Large
Rhonda Jacobs	Consultant	rhonda.lindsey.jacobs@gmail.com	Director at Large
Ronald Bell	IGS, LLC	rbell@igsdenver.com	Director at Large
Mel Best	Bemex Consulting	mbest@islandnet.com	Advisor

NOTES FROM EEGS

Renew your EEGS Membership for 2017

Be sure to renew your EEGS membership for 2017! In addition to the more tangible member benefits (including the option of receiving a print or electronic subscription to JEEG, *Fast*TIMES delivered to your email box quarterly, discounts on EEGS publications and SAGEEP registration, and benefits from associated societies), your dues help support EEGS's major initiatives such as producing our annual meeting (SAGEEP), publishing JEEG, making our publications available electronically, expanding the awareness of near-surface geophysics outside our discipline, and enhancing our web site to enable desired capabilities such as membership services, publication ordering, and search and delivery of SAGEEP papers. You will also have the opportunity to donate to the EEGS Foundation during the renewal process. Members can renew by mail, fax, or online at www.eegs.org.

Lifetime Membership

In a move to enable those who wish to join EEGS once and support the organization and receive benefits without renewal, the EEGS Board of Directors approved the formation of a membership category "Lifetime Member." Longtime EEGS member Professor Oliver Kaufmann became the first Lifetime Member in January 2016. Past EEGS President, Lee Slater, welcomed Prof. Kaufmann and said "learning about our first Lifetime Member was one of the high points of my one-year tenure as president of EEGS." President Slater also commended Prof. Kaufmann for his commitment to EEGS and his role in assuring the long-term health and value of EEGS.

Sponsorship Opportunities

There are always sponsorship opportunities available for government agencies, corporations, and individuals who wish to help support EEGS's activities. Specific opportunities include development and maintenance of an online system for accessing SAGEEP papers from the EEGS web site and support for our next SAGEEP. Make this the year your company gets involved! Contact Bethany Burton (blburton@usgs.gov) for more information.

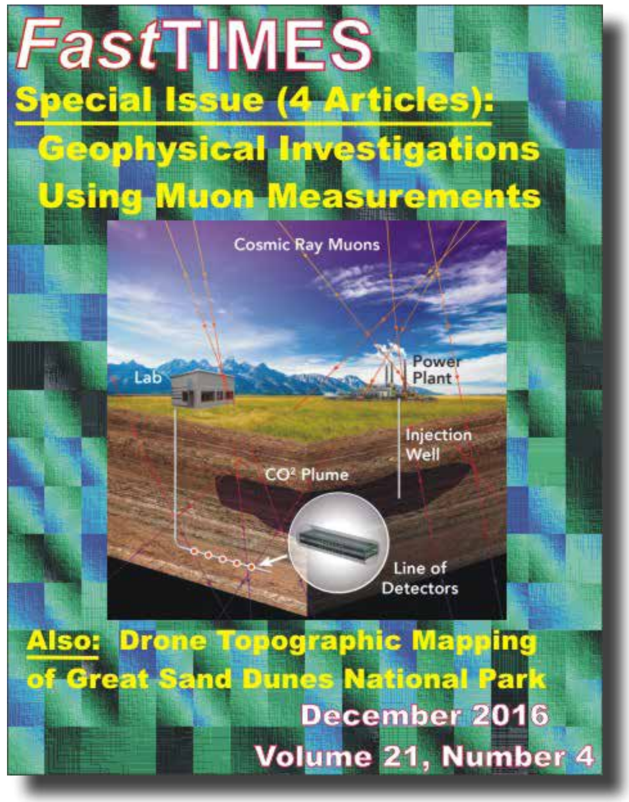
From the *Fast*TIMES Editorial Team

*Fast*TIMES is distributed as an electronic document (pdf) to all EEGS members, sent by web link to several related professional societies, and is available to all for downloading from the EEGS *Fast*TIMES web site (http://www.eegs.org/fasttimes). Past issues of *Fast*TIMES continually rank among the top downloads from the EEGS web site. Your articles, advertisements, and announcements receive a wide audience, both within and outside the geophysics community.

To keep the content of *Fast*TIMES fresh, the editorial team strongly encourages submissions from researchers, instrument makers, software designers, practitioners, researchers, and consumers of geophysics—in short, everyone with an interest in near-surface geophysics, whether you are an EEGS member or not. We welcome short research articles or descriptions of geophysical successes and challenges, summaries of recent conferences, notices of upcoming events, descriptions of new hardware or software developments, professional opportunities, problems needing solutions, and advertisements for hardware, software, or staff positions.

The *Fast*TIMES presence on the EEGS web site has been redesigned. At http://www.eegs.org/fasttimes you'll now find calls for articles, author guidelines, current and past issues, and advertising information.

Special thanks are extended to Katherine Grote for her leadership in developing this special issue of *Fast*TIMES with its focus on environmental geophysics.



Submissions

The *Fast*TIMES editorial team welcomes contributions of any subject touching upon geophysics. *Fast*TIMES also accepts photographs and brief non-commercial descriptions of new instruments with possible environmental or engineering applications, news from geophysical or earth-science societies, conference notices, and brief reports from recent conferences. Please submit your items to a member of the *Fast*TIMES editorial team by July 15, 2017 to ensure inclusion in the next issue. We look forward to seeing your work in our pages. Note: *Fast*TIMES continues to look for Guest Editors who are interested in organizing a *Fast*TIMES issue around a special topic within the Guest Editor's area of expertise. For more information, please contact Barry Allred (Barry.Allred@ars.usda.gov), if you would like to serve as a *Fast*TIMES Guest Editor.

Message from the Organizing Editor of This *Fast*TIMES Issue

Geophysics have been used for environmental applications for many years, but advances in instrumentation and processing make geophysics an ever more useful tool in managing water resources and in monitoring groundwater contamination. The presence and chemistry of water changes the electrical and electromagnetic properties of the subsurface, and both airborne and ground-based geophysics can be used to detect these changes. Large-scale geophysical surveys have been used to detect potential aquifers and to determine likely groundwater quality. Smaller-scale investigations are used to locate preferential flow paths in fractured rocks, find dissolution channels in karst aquifers, and monitor the extent of groundwater contamination or the success of groundwater remediation.

In this special issues of FastTimes, geophysicists in industry and academia use electrical and electromagnetic techniques to solve environmental problems. **Hutchinson and Tsai** explain how the tilt angle and current density measurements of very low-frequency (VLF) electromagnetic techniques can be used to locate water-bearing fractures. Using VLF techniques, they were able to distinguish less-connected fracture zones from deeper, more-connected fractures and to significantly increase the success rate of drilling water wells in fractured rock with a yield adequate for commercial purposes. **Stringfellow, Grossey, and Tuckwell** use electrical resistivity tomography (ERT), ground penetrating radar (GPR), and electromagnetic techniques to delineate the extent of a closed landfill and to estimate leaching in different portions of the landfill. The results of each of the geophysical techniques were in good agreement with each other and were useful for delineating extents and depths of the landfill that were previously undocumented. **Saribudak** describes a study in which resistivity, natural potential (NP), GPR, electromagnetic, and magnetic data are collected over a series of caves in the karstic Edwards Aquifer. The efficacy of these techniques for identifying dissolution zones, and thereby recharges areas, are discussed. In the new "Student Update" section, **Downs, Nowicki, and Jazayeri** show how GPR can be used to characterize the stratigraphy of a wetland and thus to help establish a hydrogeologic framework, which is necessary to guide activities in the recharge zone and assist with wetland preservation.

I hope you enjoy this issue and continue to follow advances in environmental geophysics.

Katherine Grote, FastTimes Associate Editor (grotekr@mst.edu)

The Journal of Environmental & Engineering Geophysics (JEEG), published four times each year, is the EEGS peer-reviewed and Science Citation Index (SCI®)-listed journal dedicated to near-surface geophysics. It is available in print by subscription, and is one of a select group of journals available through GeoScienceWorld (www.geoscienceworld.org). JEEG is one of the major benefits of an EEGS membership. Information regarding preparing and submitting JEEG articles is available at http://jeeg.allentrack.net.

Journal of Environmental & Engineering Geophysics

March 2017 Volume 22 Issue 1
SPECIAL ISSUE
Airborne Geophysics

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The Environmental and Engineering Geophysical Society

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Editor's Note

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The Journal of Environmental and Engineering Geophysics (JEEG) is the flagship publication of the Environmental and Engineering Geophysical Society (EEGS). All topics related to geophysics are viable candidates for publication in JEEG, although its primary emphasis is on the theory and application of geophysical techniques for environmental, engineering, and mining applications. There is no page limit, and no page charges for the first ten journal pages of an article. The review process is relatively quick; articles are often published within a year of submission. Articles published in JEEG are available electronically through GeoScienceWorld and the SEG's Digital Library in the EEGS Research Collection. Manuscripts can be submitted online at http://www.eegs.org/jeeg.

SUCCESS WITH GEOPHYSICS

*Fast*TIMES welcomes short articles on applications of geophysics to the near surface in many disciplines, including engineering and environmental problems, geology, hydrology, agriculture, archaeology, and astronomy. The current issue of *Fast*TIMES is focused on environmental geophysics. As always, readers are very much encouraged to submit letters to the editor for comments on articles published in this and previous *Fast*TIMES.

MAXIMIZING GROUNDWATER PRODUCTION THROUGH VLF MAPPING METHODS

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Abstract

Random drilling for commercially productive groundwater wells is commonly a haphazard approach within the Pennsylvanian-aged rocks of the Appalachian Plateau Region of southwestern Pennsylvania. These rocks have low permeability and porosity, and the average production well produces only enough yield for homeowner use. Often these wells are installed as an open hole to 90 meters to insure an adequate water supply for the homeowner since the well bore acts as a storage reservoir during recovery and drawdown.

Three sites mapped with Very Low Frequency (VLF) methods delineated fractures with the potential to maximize bedrock production through increased fracture-induced permeability. A boring was advanced from a location at each of the three sites selected through VLF mapping. The borings penetrated fractures at the anticipated depths of between 15 and 25 meters below grade. Pump tests indicate that each of the three wells was a commercial success.

Introduction

Commercial quantities of groundwater are rarely discovered in southwestern Pennsylvania. Most wells average 75 liters per minute (l/m) or less (Piper, 1933). Often, deep open-hole borings (>100 m) substitute as groundwater storage within these tight rocks. Random drilling, often for homeowners, invariably exacerbates the notion of low production potential within these Pennsylvanian-aged rocks. Curiously, fracture-induced permeability is available but rarely exploited.

Keywords: Very Low Frequency (VLF) Geophysical Surveys, Groundwater Investigation, Rock Fractures, Southwestern Pennsylvania.

Within southwestern Pennsylvania, the Pennsylvanian-aged rocks are classic examples of cyclothemic sediments. These deposits consist of shale, claystone, siltstone, sandstone, coal and minor amounts of limestone. Due to the high concentration of very fine-grained sediments, these rocks have very low permeabilities and low porosities. Consequently, secondary porosity and permeability are necessary to achieve groundwater yields of greater than 400 l/m. Areas of localized fracturing are ideal for the production of commercial quantities of groundwater.

Most streams within southwestern Pennsylvania were created by fracture-mediated weathering and erosion following Pleistocene glacial retreat and eustatic uplift. Unfortunately, fracture-controlled streams do not have high specific yields unless a fracture cuts the stream channel (Olson and others, 1992). The intersection of 2 fractures maximizes the potential for elevated production (ABEM, 2001).

Very Low Frequency (VLF) surveying is an effective method for detecting long, straight, electrical conductors and has been used to locate fractures, to image subsurface voids, to map landfill margins, and to delineate buried conductive utilities (Hutchinson and Barta, 2002). The hand held VLF meter records the transmitted signal derived from any one of 42 global ground military communication transmitters that operate in the very low frequency radio range (15 to 30 kHz) (ABEM, 2001). The transmitters propagate far field planar electromagnetic waves that can induce secondary eddy currents in electrically conductive linear and planar targets. VLF meters record responses to the induced current and through filtering can accurately locate linear and steeply-dipping planar subsurface anomalies.

VLF surveying has many advantages, including ease of use, rapid deployment, simple processing, and low cost. Limitations of this method include lack of control of the transmitter operation, sensitivity to ferrous and non ferrous cultural noise, single-point data collection, and relatively shallow depth of investigation. Transmitter operation is dependent on the military; therefore, the transmitter may be turned off during a data collection event. Dependence upon a military transmitter can be obviated by the use of a commercial transmitter that decreases the rapid deployment of the tool. Further, the tool's depth of the investigation (probably no more than 100 meters) is shallow but still within the depth window of groundwater supply contractors. Nevertheless, the tool can provide an inexpensive alternative to random drilling or other intrusive investigations.

Many of the commercially available instruments measure changes in the different parameters of the total field. For example, some instruments measure the dip of the major axis and the ellipticity of the polarization ellipse; whereas other instruments measure the vertical and horizontal field components. These components of the anomalous field can be converted into ratios of the vertical anomalous field to the horizontal primary field for tilt angle analysis. Further, a current density can be calculated with respect to depth from the measured magnetic field.

For example, a buried sheet conductor in a resistive medium in a horizontal primary magnetic field will induce changes in the amplitude and direction of the primary field in proximity to the target. Consequently, on one side of the target, the angle between the vectors of the primary and secondary components of the radio wave field will reach a maximum near an object and change to a minimum upon passing a buried target. The point at which the tilt angle passes through zero, the "crossover" point, lies immediately above the target (Ramesh Babu and others, 2007). If the target dips, then the tilt-angle measurements on one side of the anomaly are accentuated at the expense of the tilt-angle measurements on the other side of the target. The tilt angle and current density derived from the anomalous magnetic field can be used in subsequent statistical analyses to locate and to image the subsurface target.

Linear Filtering

Linear filtering of the tilt-angle measurements can aid in locating the position of a buried target. Fraser (1969) proposed a simple linear statistical filter of tilt-angle data that converts tilt-angle crossovers into peaks for ease of analysis. Fraser-filtering consists of averaging the tilt-angle measurement produced by a subsurface conductor. In a linear sequence of tilt angle data M_1, M_2, M_3,..., M_n measured at a regular interval, the Fraser filter F_i is:

$$F_1 = (M_3 + M_4) + (M_1 + M_2) \tag{1}$$

The first value F_1 is plotted half way between positions M_2 and M_3; the second value is plotted halfway between M_3 and M_4.

Current Density Filtering

Many instruments can calculate a current density from the magnitude of the measured magnetic field (Reynolds 1997). Karous and Hjelt (1983) developed a statistical linear filter, based upon Fraser (1969) and linear field theory of Bendat and Piersol (1968). This filter provides an apparent depth profile from the current density (H_0), which is derived from the magnitude of the vertical component of the magnetic field at a specific location (as shown later in Figure 3). The depth profile can be calculated from:

$$I_a(0) = \frac{2\pi(-0.102H_{-3} + 0.059H_{-2} - 0.561H_{-1} + 0.561H_1 - 0.059H_2 + 0.102H_3)}{z} \tag{2}$$

Where, the equivalent current density I_a at a specified horizontal position and depth z is based upon a symmetrical filter of the measured current (from the measured magnetic component of the anomalous field).

Case Studies

Several VLF surveys were performed to determine drilling locations for the placement of water wells that would be able to produce commercial amounts of groundwater. The water is needed to replenish nearby streams that have lost significant amounts of water as result of long wall mining (Figure 1). The Clean Water Act (CWA) protects streams from pollution and loss of flow. During long-wall operations fractures are vertically-induced into the coal overburden as the panels are developed (Figure 1). Consequently, the subsidence induces vertical fractures that reach the stream bed and drain it into the long-wall mine. The loss of stream water violates the CWA and the incoming water is a financial burden as the water must be pumped out. Further, incoming water can be a health hazard as it may destabilize the deep-mine.

The surveys were performed using the ABEM Wadi and a 23.9 kHz signal from the transmitter located in Cutler, Maine. A sub-meter-accurate Global Positioning System (GPS) was used for exact spatial positioning of collected data. The tilt-angle data was collected every 10 meters parallel to a portion of the stream bed. Fraser (1969) filtering of the tilt-angle data was performed to locate any targets.

Three types of anomalies were located and represent small-, medium- and large-sized fractures or fractured zones. Discrete, low tilt-angle readings are interpreted to represent shallow fractures or poorly developed fractures. Many small-sized fractures were identified throughout the survey areas. Medium-sized anomalies are interpreted to be well-developed deep-seated (greater than 20 meters deep) fractures with a regional extent. These fractures are normally sealed and thus provide limited opportunity for commercial production of groundwater. Large-sized fractures represent regional deformation and integrate a large area and many fractures, thus have a much greater potential for production than smaller shallow fractures. The working hypothesis for these investigations consisted of mapping fractures that may cross creek beds and increase the potential for fracture production of groundwater.

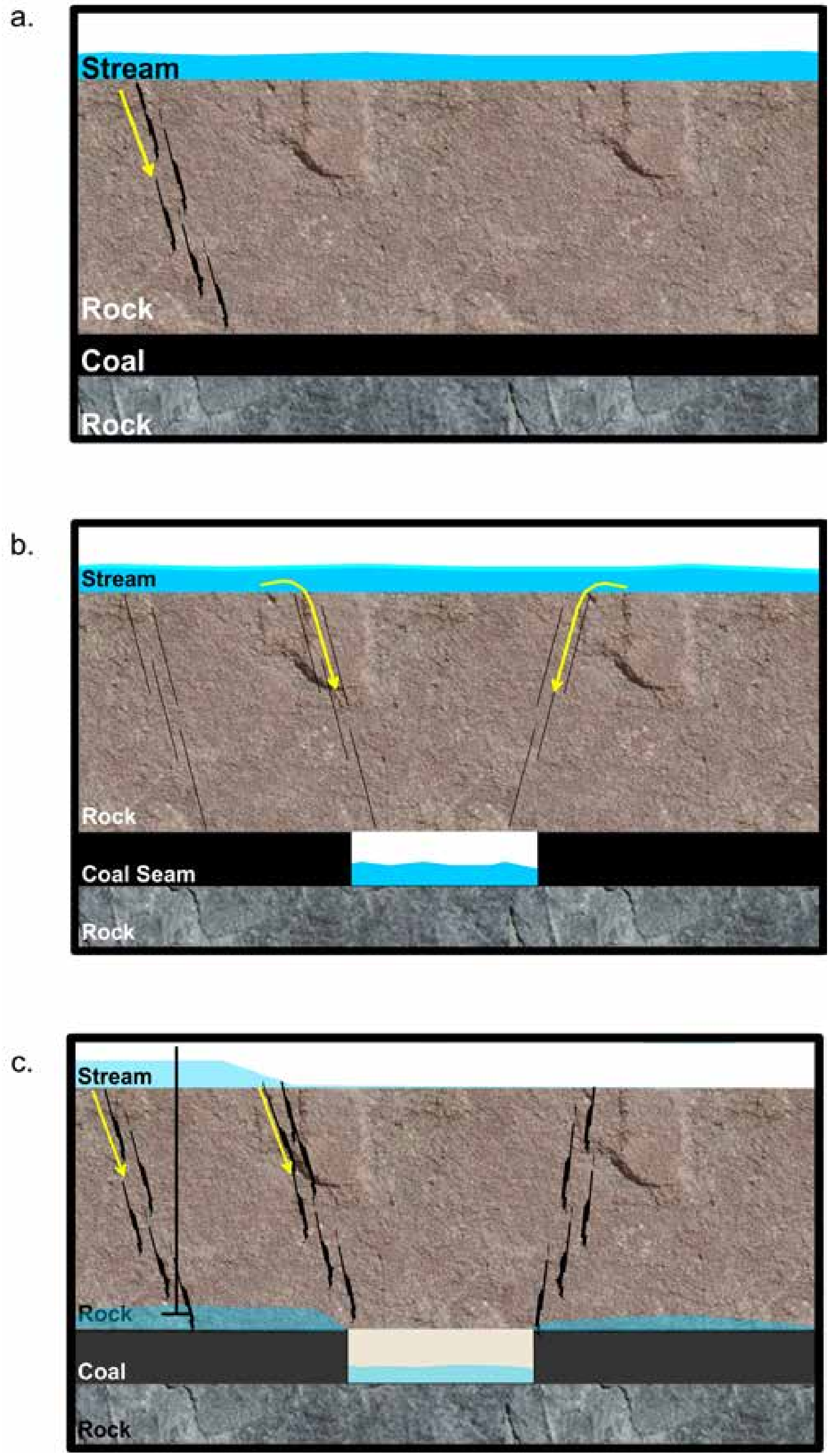

Figure 1: A stylized profile of a coal seam, prior to long-wall mining, showing existing fractures that may or may not transport water vertically downwards (**a**). Post long-wall mining shows that fractures developed during subsidence transmit water vertically downwards (**b**). The net effect is capturing the stream flow and flooding the deep-mine (**c**).

Case Study 1

A commercial venture required a continuous source of water of at least 1,000 l/min in the southwestern portion of Pennsylvania (Figure 2). Two VLF profiles were collected adjacent to an unnamed creek, presumed to be fracture induced. The boring TW-1 was advanced to 32.8 meters below grade and encountered well-developed water-bearing fractures at 9.31 m and 17.0 m below grade. Water level stabilized at 8.29 m below grade. The boring was cased to 6.1 m below grade and completed as an open hole. A pump test conducted for 19 hours indicated a production rate of 1150 l/min. After 19 hours, drawdown was only 2.9 m indicating that commercial quantities of groundwater were available.

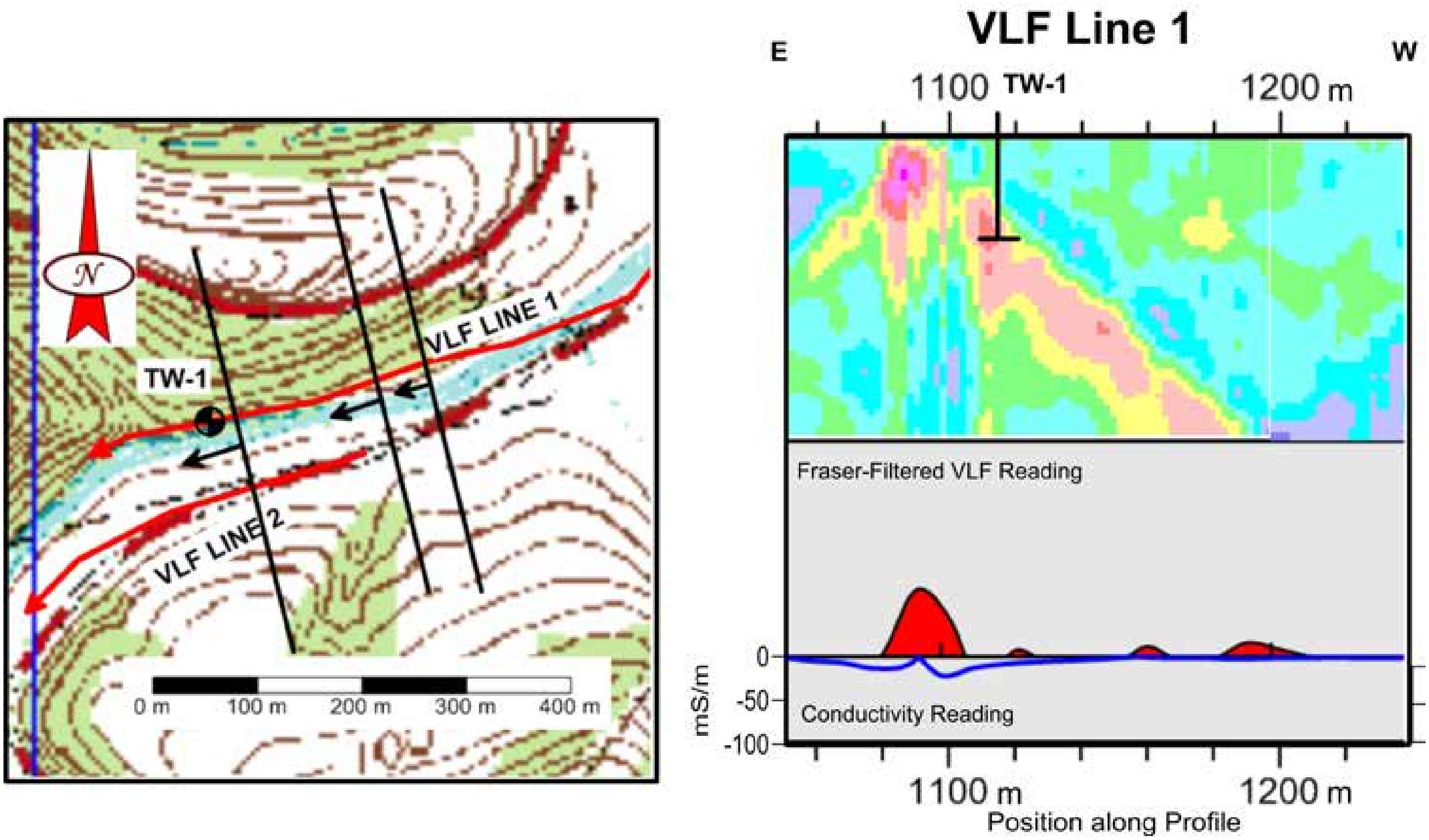

Figure 2: The left image is a plan map of the Case 1 study area. The right image shows the processed data in the form of 3 graphs: the upper graph is a representation for the fracture profile derived from the inphase component of the signal (RAMAG program; Walden, 2004) where reds represent a fracture and blues non-fractured rock, the middle graph is the presentation of the Fraser-filtered inphase signal (arbitrary scale), and the bottom graph is the quadrature phase converted linearly to terrain conductivity.

Case Study 2

Another commercial venture required a continuous source of water of at least 500 l/min in the southwestern portion of Pennsylvania (Figure 3). One VLF profile was collected adjacent to Crafts Creek. Again the creek is assumed to be created by fracturing parallel to the creek bed. Boring TW-9 was advanced to 54.9 meters below grade and encountered well-developed water-bearing fractures at 8.5 m and 15.2 m below grade. The boring was cased to 5.8 m below grade and completed as an open hole. Water level stabilized at 0.9 m below grade after completion of the well. A pump test was conducted for 13.6 hours at a production rate of 1325 l/min. After 13.6 hours of production, drawdown was only 5.4 m below grade indicating that this well met the design basis for the commercial user.

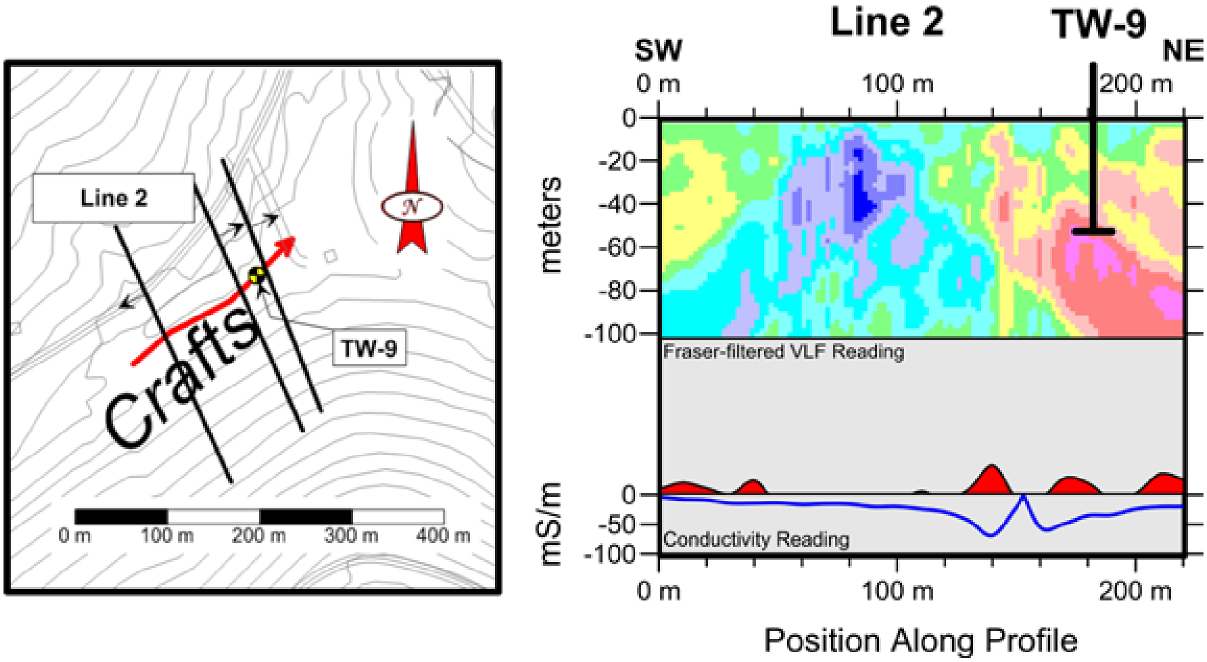

Figure 3: The left image is a plan map of the Case 2 study area. The right image shows the processed data in the form of 3 graphs (see Figure 2 caption for description of this image).

Case Study 3

The third commercial venture required a continuous source of water of at least 400 l/min in the southwestern portion of Pennsylvania (Figure 4). Several VLF profiles were collected adjacent to Templeton Creek, a creek assumed to be created by fracturing parallel to the creek bed. Boring TW-303 was advanced to 18.3 meters below grade and encountered well-developed water-bearing fractures at 8.5 m below grade. Water level stabilized at 4.9 m below grade. The boring was cased to 6.1 m below grade and completed as an open hole. A pump test was conducted for 24 hours at a production rate of 475 l/min. After 24 hours, drawdown was only 2.2 m indicating that this well met the client's needs.

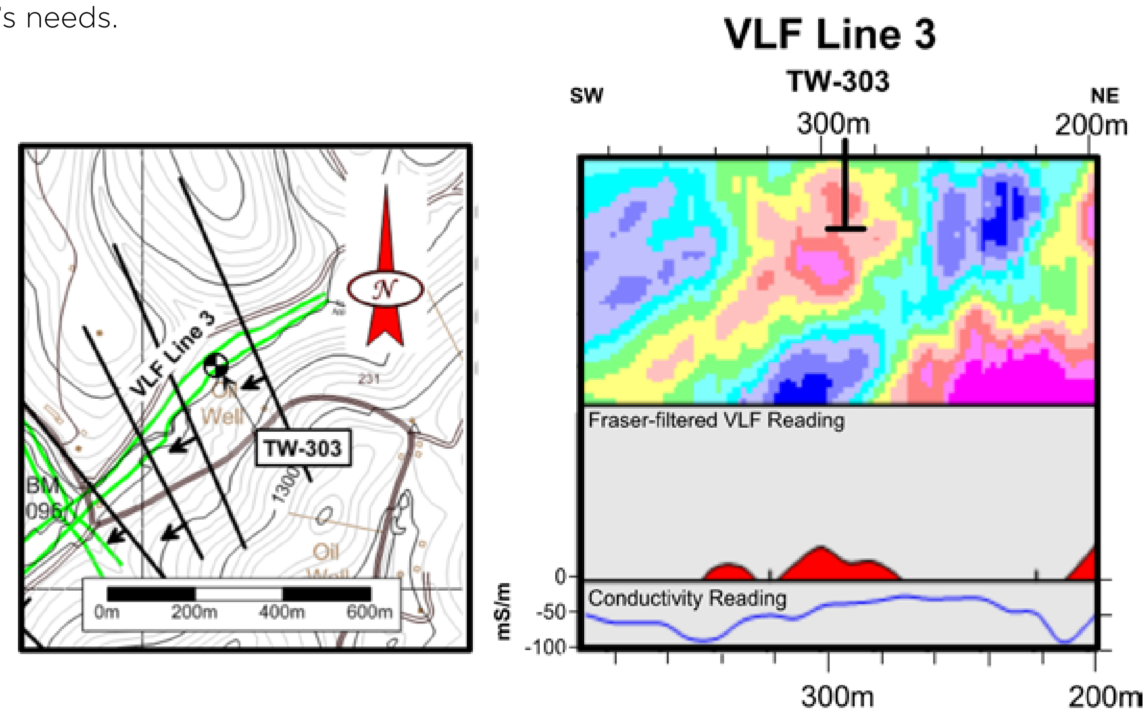

Figure 4: The left image is a plan map of the Case 3 study area. The right image shows the processed data in the form of 3 graphs (see Figure 2 caption for description of this figure).

Conclusion

VLF mapping has been deployed for decades as a useful tool in detecting steeply dipping water-filled fractures and is a useful tool to delimit fractures for commercial water production. Applying structural geology and VLF mapping to a groundwater production investigation increases the prospect for finding wells that have significant yields. The method works particularly well in a low permeability/porosity rock setting where random drilling is unreliable at locating large water-bearing fractures. Three prospective areas in Southwestern Pennsylvania delineated by VLF mapping were drilled. All three wells intercepted productive fractures and their sustainable yields are well above the required design basis.

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MAPPING BRITAIN'S HIDDEN LANDFILLS USING INTEGRATED GEOPHYSICAL METHODS: A CASE STUDY

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Introduction

The UK has around 20,000 operational and closed landfill sites, many of which are not engineered and are unprotected to the environment. Up until the 1980s, many site were operated on the principal of "dilute and disperse" (Brownfield Briefing, 2016). Britain has since adopted appropriate European legislation with new landfill sites based on the principal of full containment. However, even these modern facilities are at risk of leachate leaking through the landfill base and sides to cause contamination of surrounding land and groundwater pollution.

Many "dilute and pollute" sites remain across the UK. Often these are located in close proximity to residential properties as a result of Britain's industrial legacy, which located homes where resources such as quarries and factories were constructed. In the surface voids that were left by old workings, urban waste materials were often dumped to backfill the voids. Containing household waste, ash, industrial chemicals, and sludge waste, these sites pose a contamination legacy for future generations. As rainwater entering the top of such sites percolated through the waste mass, fluids incorporating decomposing organic material, dissolved salts, and other contaminants have the potential to enter the underlying groundwater system with potentially serious consequences to drinking water resources (Soupios et al, 2007).

Geophysical surveys are often the only practical method of investigation on landfills as they do not involve penetration of the cap or liner and exposure of any wastes (RSK, 2014). Geophysics can be used in a wide range of landfill applications, from determining the location and geometry of old landfills where boundaries may be unknown (historic records can be notoriously inaccurate, incomplete, or even missing entirely), through to aiding the investigation of groundwater pollution plumes and pathways in the subsurface, which are essential for demonstrating compliance with Integrated Pollution Prevention and Control requirements.

Among the toolbox of available geophysical techniques available, electrical and electromagnetic methods have been found remarkably suitable for such studies, due to the conductive nature of most contaminants (Sauck, 2000). In addition, ground penetrating radar (GPR) can be used to supplement the locating of features such as buried infrastructure (pipes and tanks), shallow pollution plumes, and landfill boundaries across which the electrical properties of the soil can vary (Ting-Nien, 2006).

Keywords: Historic Landfill, Contamination, Geophysical Surveys, Resistivity, Electromagnetic Induction, Ground Penetrating Radar.

Project Background

This article presents a near-surface geophysical survey from a closed landfill in Denton, near Manchester, UK. The site which covers an area approximately 300 m by 500 m was previously a brickworks with a large open clay pit. A mixture of industrial, commercial and household waste, and sludge was deposited in the pit in the 1970s, after which housing was built adjacent to the site. By the late 1980s, issues with landfill gas migration and leachate were being reported. A gas extraction system was installed but was largely ineffective due to fluid ingress. The site continues to suffer from gas migration to nearby residential properties. Waste has also been reported in a number of residential gardens being uncovered in the ground during building works to extend or refurbish the properties. The problems have arisen because the landfill boundary was not fully defined before the properties were developed.

The local authority commissioned RSK Environment to provide information on the physical extent of a closed landfill and the depth and distribution of the waste to characterize the site and inform the design of subsequent remedial work. Previous limited intrusive investigation had indicated waste in the gardens of properties abutting the site. Given the sensitive nature of the residential environment, the use of rapid, non-intrusive surveying techniques was preferable. The information presented here shows how an integrated geophysical ground investigation can be successfully deployed to map the extents of the waste (depth and laterally) in order to constrain the conceptual site model and inform the design of remediation works.

Survey Details and Data Acquisition

The site is currently a "green-field" area open to the public and incorporates wooded areas with rough grassland. Based on previous site investigation data, the landfill site comprises a mix of domestic and industrial waste to a thickness of 6-8 m. The landfill overlies Glacial Till and the Middle Coal Measures, and is capped with ~1 m thickness of clay. The principal geophysical technique used for surveying the site was electrical resistivity tomography (ERT) imaging. Six resistivity profile lines were acquired east-west across the eastern landfill boundary where the residential properties were located, together with a single north–south line to tie all the other lines. Ground penetrating radar and electromagnetic (EM) conductivity measurements were also taken in as many residents' gardens as possible to supplement the resistivity data. The geophysical data were calibrated and compared to borehole data from previous intrusive investigations to constrain and validate the interpretations. A plan of the resistivity lines and boreholes used is shown in Figure 1. The ERT profiles were located to tie in to as many boreholes as possible.

Resistivity Imaging

The resistivity imaging method employs a number of electrodes that are deployed along a survey line, and between which ground resistivity measurements are taken. By making direct current resistivity measurements between different combinations of electrodes the resistivity at different locations and depths is recorded to build up a cross-sectional image of the resistivity of the subsurface. An electrode spacing of 2 m for the E-W profile and 5 m for the N-S profile was used to allow imaging of the sub-surface up to 15 m depth. The electrodes were connected to an Iris Syscal 72 switching box where measurements are computer controlled. Where electrodes were located on hardstanding through residential gardens, holes were drilled to allow the electrode to be placed into the underlying soil (see Figure 2). In addition, topographic changes along each profile were recorded using a high precision GPS. The elevation data were determined at each electrode point and these data were used in the modeling of the ERT data.

Figure 1: Resistivity lines in yellow with expected landfill boundary in red.

Figure 2: ERT profiles crossed residential gardens before entering the landfill site (beyond the hedgerow at back of image).

Electromagnetic Mapping

EM measurements were collected using a Geonics EM31-MK2 ground conductivity meter. This instrument uses two electrical coils to send, induce and detect a current that is modified according to the electrical properties of the subsurface. Average bulk soil conductivity data is returned for a depth up to 6 m, depending on the properties of the ground. Data were acquired along survey lines at 5 m on the landfill and, where access allowed, in residential gardens. The quadrature (related to conductivity) and in-phase (metallic) components were recorded in continuous mode and positioned using GPS.

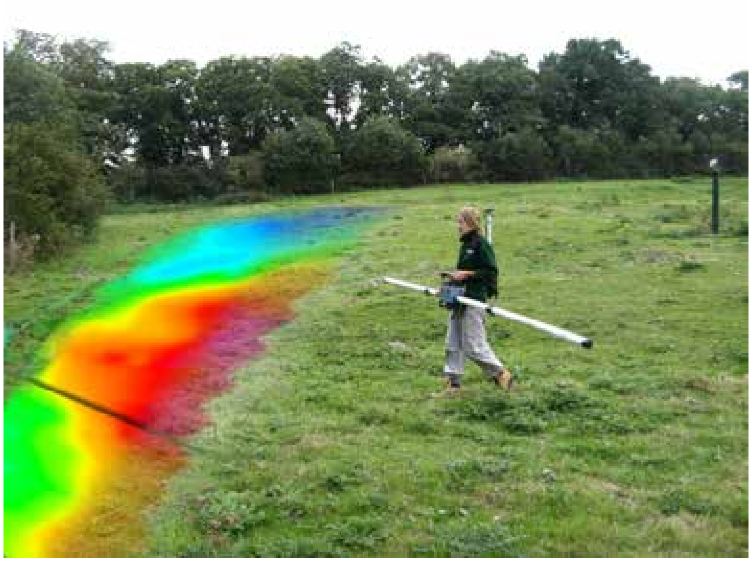

Figure 3: EM surveying with Geonics EM31 on a landfill. Schematic showing warm colors to denote presence of conductive waste mass.

Ground Penetrating Radar

The GPR technique operates by directing a pulse of electromagnetic radiation into the subsurface which is reflected back to the instrument at boundaries between materials with contrasting electrical properties. GPR measurements were acquired using a SIR-3000 system from Geophysical Survey Systems with a central antenna frequency of between 400MHz and 120MHz to scan the ground up to 5 m depth. The GPR data were acquired in systematic surveyed grids covering the entire plot of front and rear gardens of the residential properties in order to determine the edge of the landfill with half-meter transverse lines and using an odometer to measure distance.

Figure 4: GPR survey with the 120MHz antenna.

Data Interpretation and Results

The resistivity data were interpreted using the RES2DINV software. Forward modeling is used to calculate the apparent resisitivity values. The results of the resistivity survey indicated three layers within the landfill (Figure 5). The thin top layer is interpreted to be covering material. The second layer is a low-resistivity material likely to have high leaching activity. The bottom layer is moderately resistive and likely represents the glacial clay underlying the site. The depth of waste was shown to be about 7–10 m. The eastern landfill boundary nearest the houses is shown to lie predominately below the rear gardens of the properties (Figure 6).

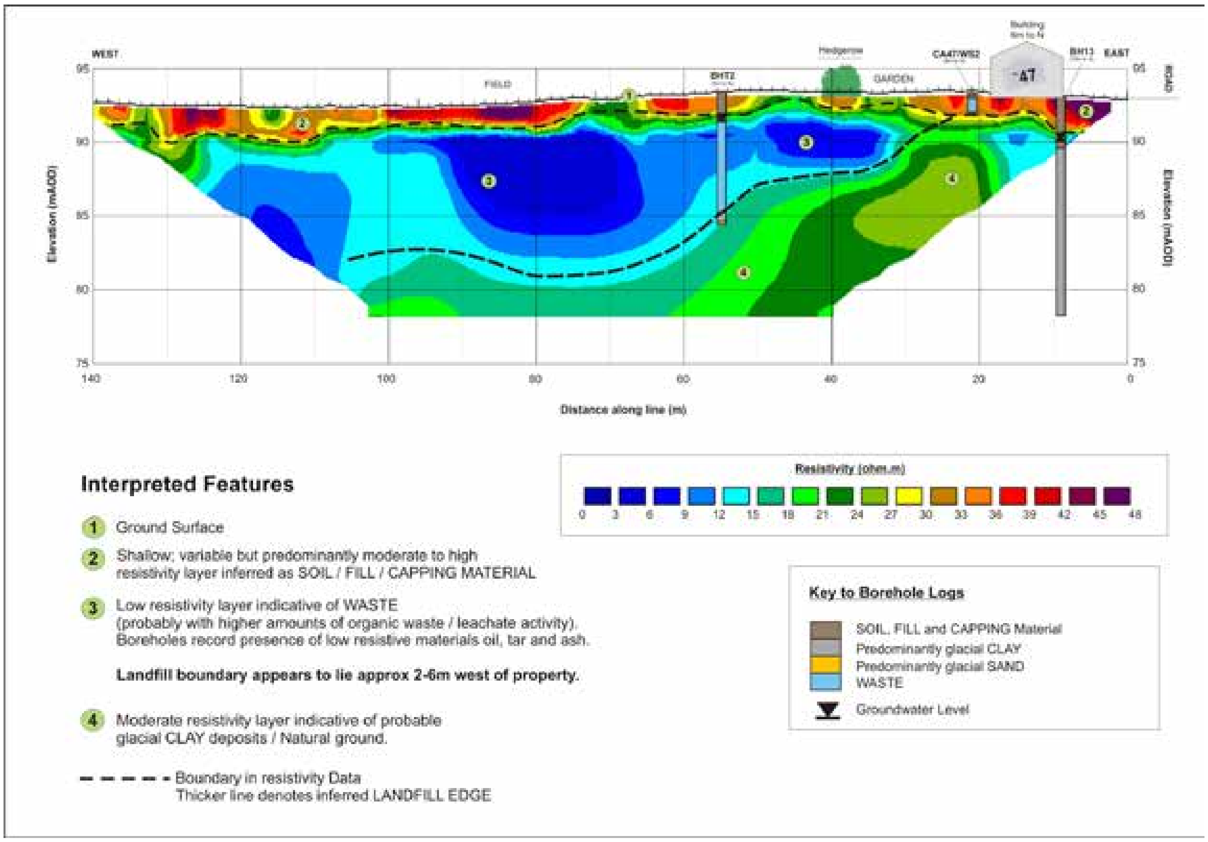

Figure 5: An east-west resistivity survey line.

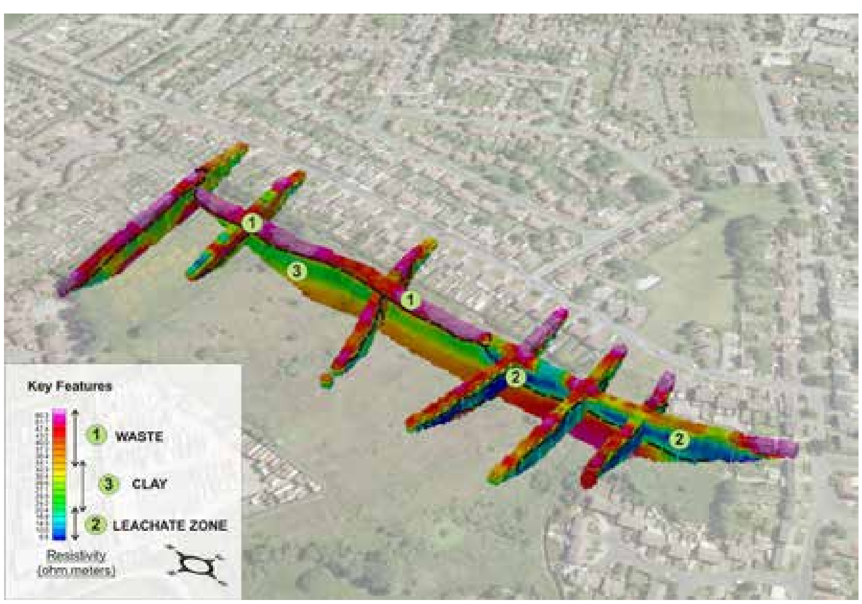

Figure 6: 3D view of the resistivity lines.

The electromagnetic data were transferred into Oasis Montaq and positioned spatially. Landfill waste in the near surface will manifest itself as a conductivity anomaly in comparison to the surrounding natural ground which is likely to manifest itself as more homogenous and lower values of conductivity. The EM conductivity measurements across the site (Figure 7) showed a wide distribution of conductive materials, particularly in the southern end of the site where a zone of active leaching seems to be concentrated. The relatively low conductivities recorded in the north of the site suggest the materials in the sub-surface here has minimal metal content or waste with little leachates in this area. Based on a broad zone of high conductivity material in the south, the waste appears to potentially underlie a number of properties on the southern edge of the site where it was previously thought the landfill wasn't under the properties. This correlates with evidence of subsidence of the ground surface in the vicinity, together with historical mapping features and also issues with gas ingress into these properties in the past.

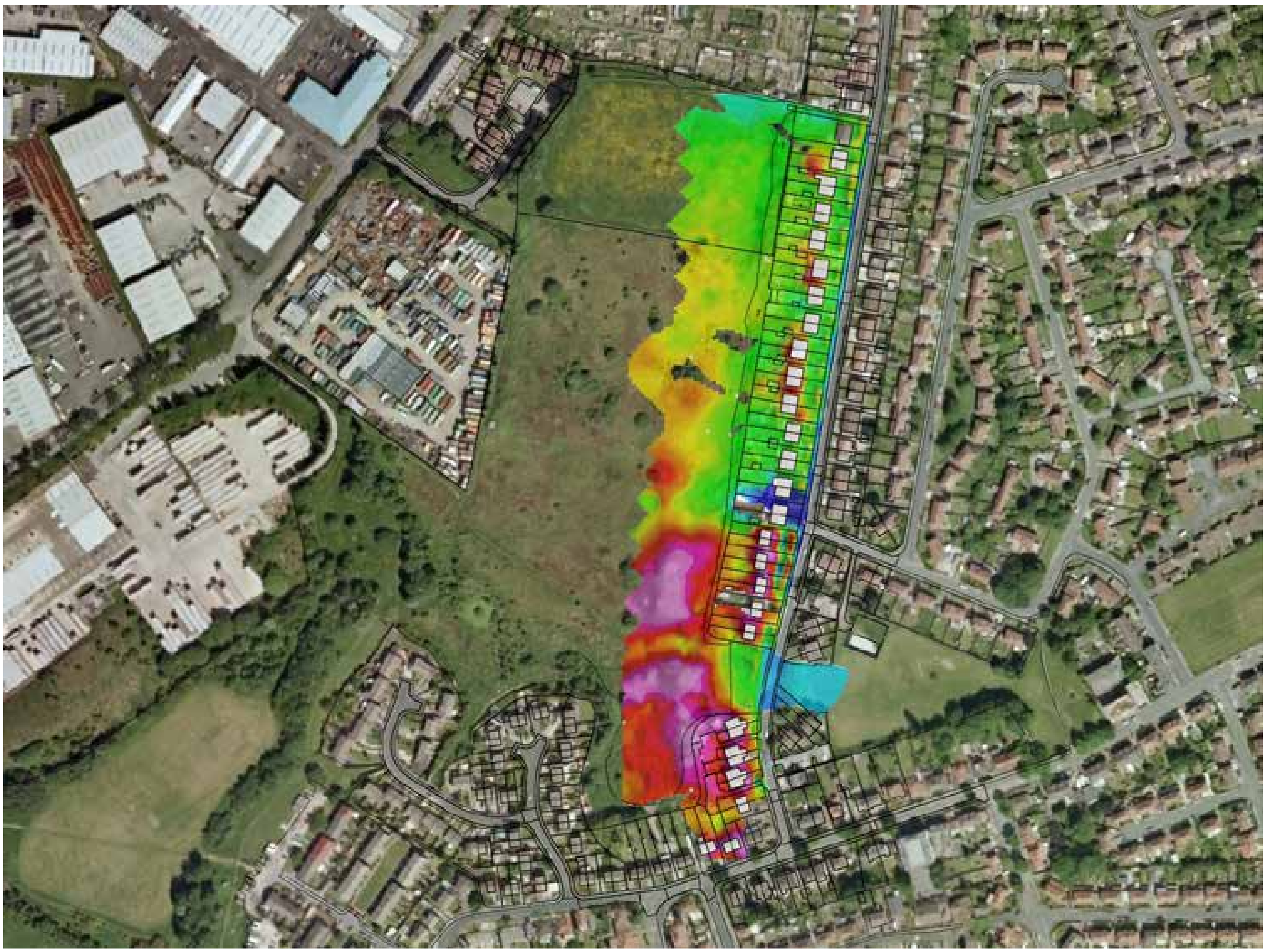

Figure 7: Conductivity data; red and pinks are high conductivity values (>50 mS/m), with green colours representing lower background conductivity.

The GPR data were processed using RADAN which allows typical GPR processing algorithms to be applied to the data, including zero offset, background removal and gain adjustment. The results of the ground penetrating radar survey (Figure 8) indicated that the edge of the landfill generates clear dipping reflection anomalies (likely the former side of the clay pit) and high-amplitude discontinuous reflections indicative of a heterogeneous mix of rubbly, conductive waste. On the 'landward' side, the GPR data shows a highly attenuated homogenous response with a lack of reflections, which is indicative of undisturbed clay rich ground.

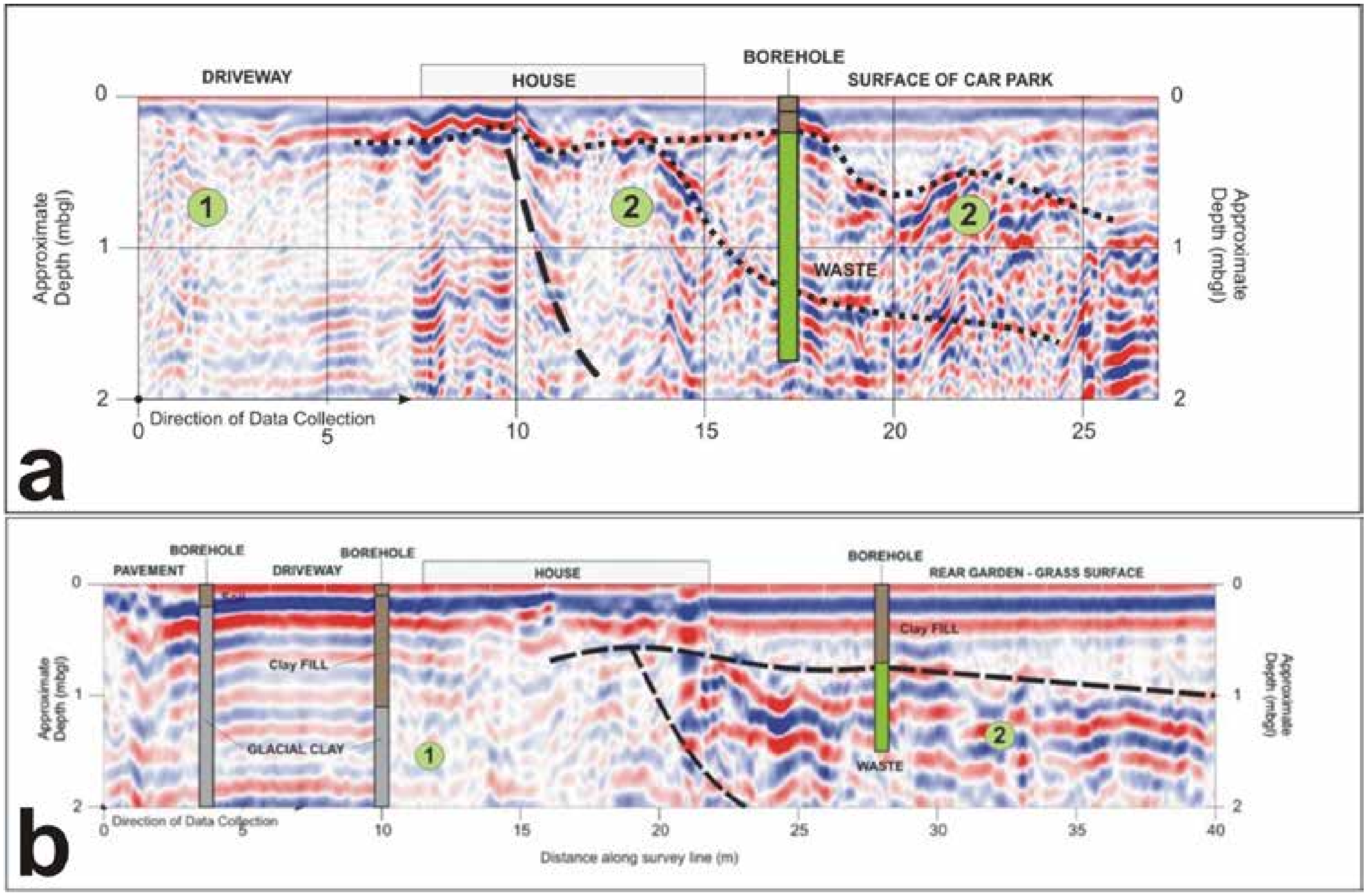

Figure 8: Example GPR radargrams (**a**,**b**)across the front and rear gardens of the nearby properties. Blue/red shows negative and positive amplitude reflections. Where the signal is strongest, it likely shows areas of changing ground conditions.

Conclusion

The inferred landfill boundary from all geophysical datasets combined is in good overall agreement. In combination with borehole data, the geophysical data has greatly improved the conceptual site model of the landfill. Its geometry and the areas of leachate are better defined, which has been vital in determining the proximity of the landfill to properties and for future targeted site investigation and remediation works.

Closed landfill sites in particular pose a potential risk to groundwater resources. Although there is no single instrument or technique that is right for every situation, in the case of landfill sites where significant electrically conductive material is present, these can provide a suitable environment for the deployment of electrical resistivity, EM, and GPR to successfully delineate the structure of the landfill and clearly map out areas of anomalous conductivities in a safe, rapid, and cost-effective manner.

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THE MILLION DOLLAR QUESTION: WHICH GEOPHYSICAL METHODS LOCATE CAVES BEST OVER THE EDWARDS AQUIFER? A POTPOURRI OF CASE STUDIES FROM SAN ANTONIO AND AUSTIN, TEXAS, USA

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Abstract

This article describes resistivity imaging and natural potential data (NP) collected over six caves between the years of 2000 and 2014, which are air filled and are located in the northern part of Bexar County, San Antonio, and in the south and north of Travis County, Austin, Texas. All caves were encountered through drilling and/or excavation for construction and utility lines or power pole reconstructions. The study area falls into the part of the Recharge Zone of the Edwards Aquifer region and it represents a well-developed karstified and faulted limestone (Stein and Ozuna, 1996).

The resistivity and NP data over these 6 caves suggest that the resistivity data does not specifically determine where karstic features are located in the subsurface. However, it provides significant information on the near-surface geology and geological structure. The NP data, on the other hand, notably defines the location of cave features. Thus the merits of integrating the NP method along with the resistivity imaging over the Edwards Aquifer, in order to reduce the ambiguity in the interpretation, are evident.

Keywords: Edwards Aquifer, Karst, Caves, Resistivity, Natural Potential.

Introduction

Currently, several geophysical methods exist to locate subsurface voids. These geophysical methods are resistivity (2D and 3D), natural potential (NP), ground penetrating radar (GPR), gravimetry, magnetics, electromagnetics, and seismic (refraction, reflection and shear waves). Natural potential method is also called self-potential.

Detecting incipient sinkholes, bedrock cavities, rock pinnacles, and other karst-related features using these geophysical methods has been proven over the years (Ahmed and Carpenter, 2003, Dobecki and Church, 2006). But each method has limitations in depth and resolution accuracy based on geological factors and void size, shape, and orientation. In addition, some methods, such as gravity, and seismic, take longer and they may be cost-inhibitive.

We have collected geophysical data over the Edwards Aquifer in the San Antonio and Austin areas for the last 15 years. We have used almost all methods mentioned above. Based on these results, we conclude that the best methods have been the combination of NP and resistivity techniques (Saribudak, M., 2010, Saribudak, 2011, Saribudak et. al., 2012a; Saribudak et. al, 2012b, Saribudak et al, 2013).

The 2D resistivity method images the subsurface by applying a constant current in the ground through two current electrodes and measuring the resulting voltage differences at two potential electrodes some distance away. An apparent resistivity value is the product of the measured resistance and a geometric correction for a given electrode array. The geometric factor incorporates the geometric arrangement of the electrodes and contributes a unit length, giving apparent resistivity values in units of ohm-meters (Ω-m). Resistivity values are highly affected by several variables, including the presence of water or moisture, and the amount and distribution of pore space in the material, and temperature.

Based on our experience on the Edwards Aquifer, the expected resistivity for weathered limestone varies between 50 to 300 Ω-m, while fresh limestone is expected to produce a range of values between 350-10,000 Ω-m and more. The presence of moisture or groundwater reduces resistivity values. The presence of air-filled caves causes the highest resistivity values. But, it is rare that caves are purely filled with air. A variety of sediments accumulates in caves and can be preserved more or less intact for long periods of time (Palmer, 2007). The presence of sand and gravel and clay deposits, mineralization, faults and fractures, perched water in caves are the rules rather than the exception. Clay-filled caves cause low resistivity values.

We acquired the resistivity data using an Advance Geosciences, Inc. (AGI) SuperStingR1 and R8 resistivity systems. We processed the data using AGI's 2D EarthImager software.

Natural electrical currents occur everywhere in the subsurface. In seepage or cave investigations, we are concerned with the unchanging or slowly varying direct currents (DC) that give rise to a surface distribution of natural potentials due to the flow of groundwater within permeable materials. Differences of potential are most common in the millivolts range and can be detected using a pair of non-polarizing copper sulfate electrodes and a sensitive measuring device (i.e. a voltmeter or potentiometer). It should be noted that water movement should be present within or surrounding a cave in order to determine a void or cave location. Positive and negative natural potential values are attributed to changes in the flow conditions and the resistivity distribution of the subsurface. The source of NP anomalies can be also due to changes in topography, soils and rock conditions. It should be noted that NP measurements made on the surface are the product of electrical current due to groundwater flow and the subsurface resistivity structure. NP anomalies do not provide information on the depth of their sources.

There is no commercially available NP geophysical instrument in the geophysical market. For this reason, we developed a NP system to locate karstic features.
We processed the NP data using Geosoft Oasis Montaj Mapping software.

Two Case Studies from San Antonio Area

The location of two caves from the San Antonio area is shown with a red square in Figure 1.

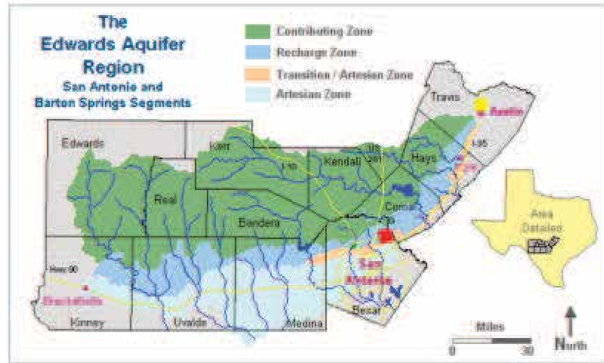

***Figure 1**: Locations of study area. The red and yellow squares indicate the approximate location of caves in the San Antonio and Austin areas, respectively (The figure is taken from the Edwards Aquifer Authority website, www.edwardsaquifer.net).*

Cave 1

A series of voids (cave 1) were encountered during the installations of piers into the Person Formation of Edwards Aquifer limestone (Stein and Ozuna, 1996) for a construction project. These voids had a depth of about 4 meter (15 feet) and appear to be connected. Combination of lowering a tape and a video camera indicated that the cave extended as deep as 50 feet. The cave was wet and air-filled.

Following the discovery of the voids, geophysical surveys were conducted to evaluate the extent of the cave and the voids. Geophysical surveys included, resistivity, natural potential and ground penetrating radar methods.

Four resistivity profiles, with a profile spacing of 6 m (20 feet) were acquired across the pier locations and adjacent areas. Figure 2 displays one of the resistivity imaging profiles along with 4 borehole locations, three of which encountered the cave. The resistivity data show that the cave encompasses high resistivity (10000 Ohm-m), medium (750 Ohm-m) and as well as low resistivity values (200 Ohm-m).

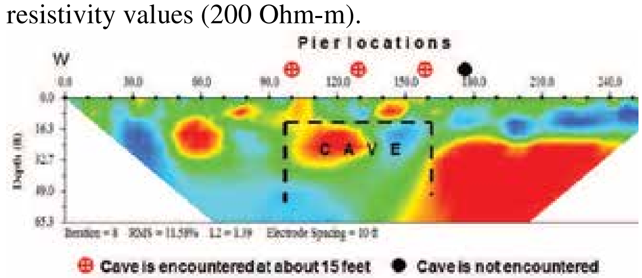

***Figure 2**: Resistivity data across cave 1 along with pier locations drilled into the limestone. Black lines indicate the geometry of the cave.*

Four resistivity profiles were combined to create a 3-D block diagram and is shown in Figure 3.

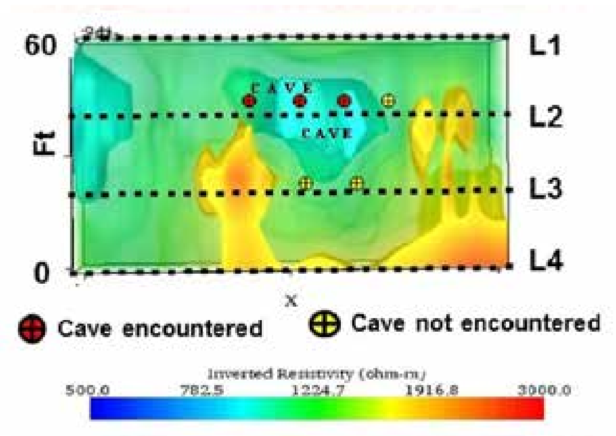

Figure 3: *A map view of 3D resistivity block diagram showing the cave geometry. Note that cave location corresponds to low resistivity values (light blue color).*

A 3-D top-view of the cave area is shown in Figure 3. The known void locations encountered by borehole drilling are shown with red circles. Three borehole locations that did not encounter the cave are shown with yellow circles. Note that the boundaries of the cave defined by the borehole data include the low and medium resistivity values as in the 2-D resistivity profile. The 3-D image of the resistivity data appear to define the geometry of the cave much better than the 2-D resistivity data.

Figure 4 shows a NP profile along the same resistivity profile shown in Figure 2.

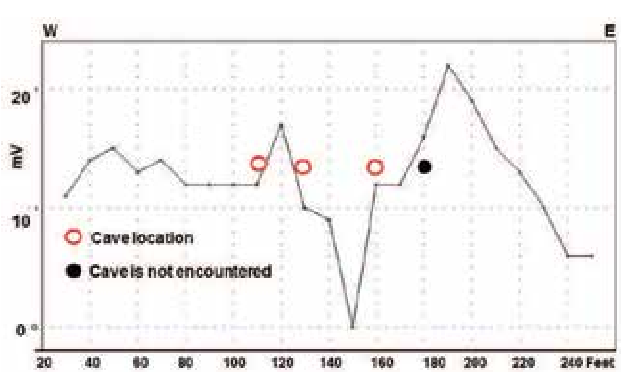

Figure 4. NP data across cave 1 along with pier locations drilled into the limestone.

The NP data indicates a significantly low anomaly where the cave is located. Correlation of both data sets suggest that it would have been difficult to determine the precise location of the cave with only the resistivity data without either having boreholes or the NP data.

Cave 2

Cave 2 was observed along a utility trench in the north San Antonio (Figures 1 and 5). The trench was about 4 meter (15 feet) deep and 35 meter (112 feet) long. The cave was air-filled and its width along the trench was about 4 meter (15 feet). A measuring tape was lowered into the cave and its apparent depth was determined to be 9 meter (30 feet).

Figure 5: *A picture showing the cave location along the trench. The cave is located 3.5 meter below the ground.*

Figure 6 displays the resistivity data along the utility trench. The cave's dimensions are also superimposed on the resistivity data. The resistivity profile indicates medium range resistivity values (300 to 800 Ohm-m), not high resistivity values, across the air-filled cave. The cave's geometry defined by the resistivity data is quite correlative with the observed dimensions of the cave.

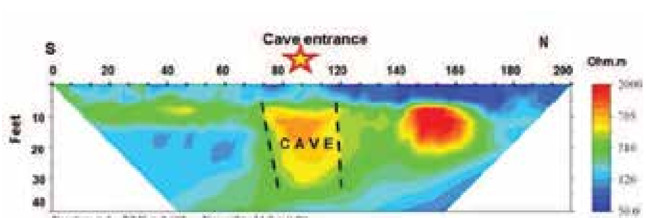

Figure 6: *The resistivity profile along the trench cave.*

The resistivity data also indicate a well-defined high resistivity anomaly between stations 49 and 55 meter

(160 and 180 feet), which could be interpreted as an air-filled cave by a novice interpreter based on the resistivity data only.

The NP data provided in Figure 7 shows a significant low NP anomaly across the cave. However, the NP data does not indicate any anomaly over the high resistivity anomaly that was located to the north of the cave.

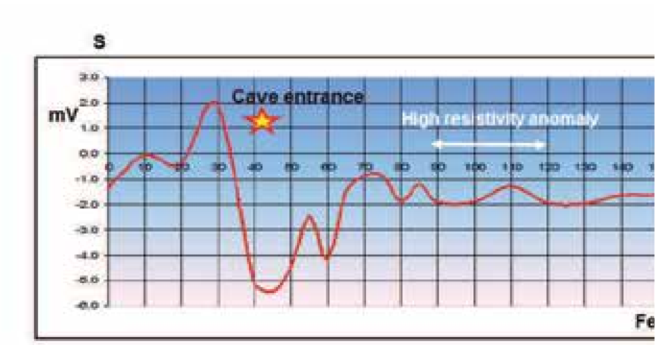

Figure 7: The NP data across the Trench cave.

Three Case Studies from the Austin Area

Three case studies were performed over the Edwards Aquifer in the Austin area (see Figure 1 for general location). A cave location was determined during the geophysical field work and borehole drilling in the year of 2008. The purpose of the study was to locate potential karstic features along a transmission line, which consisted of 25 transmission poles with 300 meter (1000 feet) spacing.

Cave 3

A resistivity survey was conducted across the location of transmission number 15, and is shown in Figure 8.

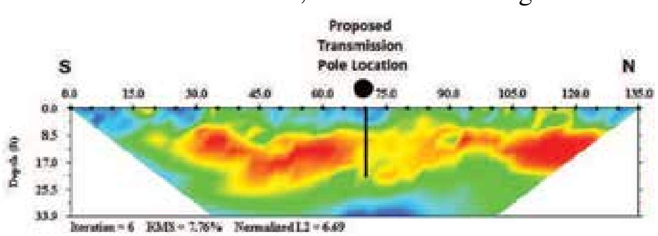

Figure 8: *The resistivity data across a proposed transmission pole location. The black line indicates a borehole drilling location.*

The resistivity values across the profile range between 10 and 10,000 Ohm-m. The resistivity data did not indicate any significant karstic features beneath the proposed transmission pole location.

However, the NP data collected along the same profile shows a high NP anomaly where the proposed pole is located Figure 9). This is a typical NP anomaly indicating presence of a cave.

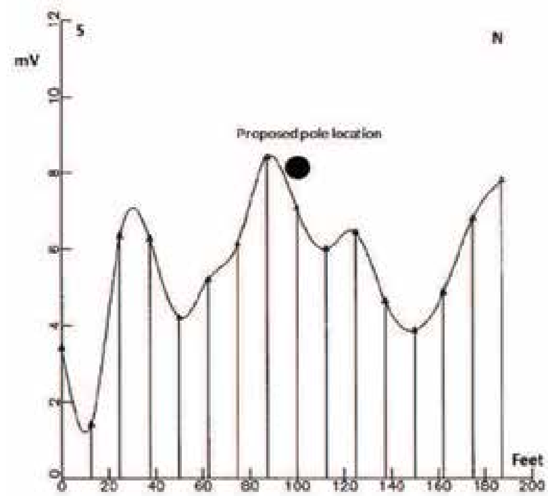

Figure 9: *NP data across the proposed transmission pole.*

A borehole was drilled at the proposed location, down to 25 feet depth and a 2.5-inch downhole camera was lowered into it. A cave passage at 5.2 meter (17 feet) depth was encountered and it blew moist air. Another karstic feature (a minor void and a fracture) was observed at 7.2 meter (24 feet) (Pete Sprouse of Zara Environmental, LLC, Pers. Comm., 2010).

In the light of the borehole data, the resistivity data did not show any specific anomaly indicating the potential presence of the cave; however, the NP data did display a unique M-shaped anomaly where the cave is located. The pole location was relocated to 20 feet to the north of the proposed location and did not have voids or caves.

Caves 4 and 5

The City of Austin (City) Watershed Protection performed a hydrogeologic investigation related to the design and construction of the Martin Hill Transmission Main (TM) on the Northern Edwards Aquifer Recharge Zone. Several karst features have been identified by the City of Austin in the vicinity of the Recharge Zone. These features include a sinkhole/cave opening located behind McNeil High School; the McNeil Bat Cave, located on the east side of the high school; and 3 caves (Weldon Cave, No Rent Cave) located west of the high school and McNeil Bat Cave. To acquire such information and address these concerns multiple geophysical surveys (resistivity, NP, GPR, magnetic and conductivity) were performed across the site (Figure 10). The GPR, magnetic and conductivity data did not provide useful subsurface information due to the presence of cultural features and the conductive soil along the geophysical profile. In this paper only the resistivity and NP results along the McNeil Road profile will be discussed.

Figure 10: *Location of a geophysical profile - a mile long-along the McNeill Road and McNeil High School in north Austin, Texas. Two stars shown with red and white colors (A and B) are locations where significant NP anomalies are observed.*

A combination of resistivity and NP data from the west side of the study area is provided in Figure 11.

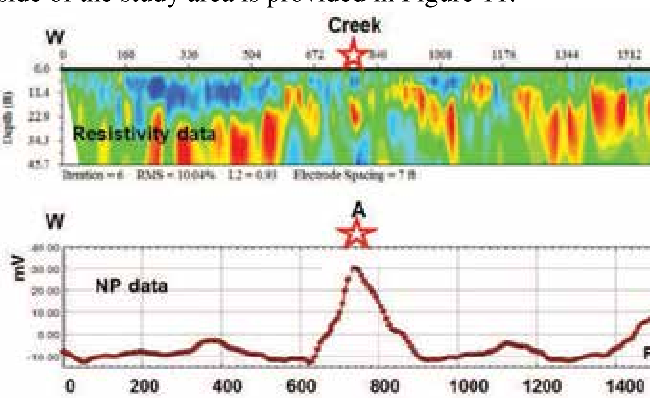

Figure 11: *Resistivity and NP data from the west side of the study area. Note that a significant NP anomaly is detected across the creek and is shown with the letter A.*

The resistivity data shows a high resistivity layer undulating under a low resistivity layer along the profile. There is no striking resistivity anomaly due to a karstic feature across the Creek. However, the NP data displays a significant anomaly, in terms of horizontal coverage of 60 meter (~200 feet) and a magnitude of 50 mV.

Another combination of resistivity and NP data from the east side of the study area, where the McNeil High School is located, is shown in Figure 12.

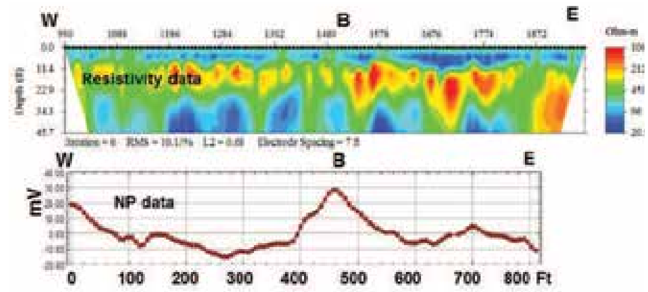

Figure 12: *Resistivity and NP data from the east side of the study area. The letter B indicates a significant NP anomaly.*

The resistivity data shows a highly resistive unit (red and yellow in color) in the middle of the profile and it is enclosed by two low resistivity layers below and above. The high resistivity unit appears to thicken to the east of the letter B. This observation would signal to an experienced interpreter that there could be a karstic feature in this area.

The NP data, however, clearly displays a major anomaly between the stations 121 meter (400 feet) and 168 meter (400 and 550 feet), and is annotated with the letter B. The maximum magnitude of this anomaly is about 40 mV.

During the months of summer and fall of 2014, a major construction activity started along the geophysical profile. Bulldozers excavated the water transmission line down to a depth of 6 meter (20 feet) on the McNeill Road. Two caves (Cave 4 and Cave 5)) were encountered at a depth of 5 meter (17 feet) where the NP anomalies A and B are located. Picture of Cave 4 and Cave 5 are provided in Figures 13 and 14.

Figure 13: *Cave 4 was observed where the NP anomaly A is observed (see Figure 10).*

Figure 14: *A void was encountered where the NP anomaly B is observed (see Figure 11). This void is enlarged to the north towards the McNeill High School and became a cave (Cave 5).*

Cave 6

A cave feature (Cave 6) was confirmed in the sidewalls and floor of a wastewater line (WWL) trench and manhole excavation located on the Northern Edwards Aquifer Recharge Zone, a few miles to the north of McNeil Road (Figure 15).

Figure 15: *Site map showing the location of the geophysical profile, and the geometry of the cave, which was defined by trenching. The length of the geophysical profile is about 122 meter (400 feet).*

The cave 6 represents a bedding plane cave that has developed into a groundwater flow channel. The feature lies at approximately 6 meter (20 feet) below ground surface, and has exposed openings along approximately 22 meter (71 feet) of the trench and manhole excavation sidewalls. The visible length of the cave is about 35 meter (115.0 feet) in length, 3.5 meter (12.0 feet) average width, and about1.5 meter (5 feet) in average height (see Figure 16).

Figure 16: *A picture showing the part of the cave which was encountered during the excavation.*

After the discovery of the cave, geophysical surveys (resistivity and NP) were performed to map the karstic features. The purpose of the work was to define the geology along the Wastewater line and map potential karstic features. The length of the profile was extended. 200 feet further north from the northern end of the trench.

The resistivity data are given in Figure 17. The cave locations on the western sidewall of the trench are exposed on the southern and northern ends and are superimposed on the resistivity profile. A groundwater flow channel is observed from the northern cave to the southern cave. Resistivity values in the vicinity of the caves vary between 50 to 5000 Ohm-m. It is difficult to determine the cave locations based on the resistivity data.

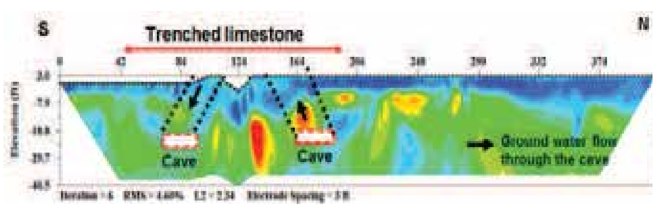

Figure 17: *Resistivity data along the trenched wastewater line. Locations of caves encountered on the western sidewall of the caves are indicated as dashed red lines filled with white color. There is a groundwater flow from the northern cave to the southern cave.*

Note that the high resistive pinnacle shown with a red color between the two caves on the resistivity section, based on the trenching, is not defined as a karstic feature.

The NP data is provided in Figure 18, which indicates a strong but linear NP gradient towards to the north. It is not possible to detect small NP anomalies along the profile with the superimposition of such a high gradient. The source of the high NP gradient could be due to the significant ground water flow from the north to the south.

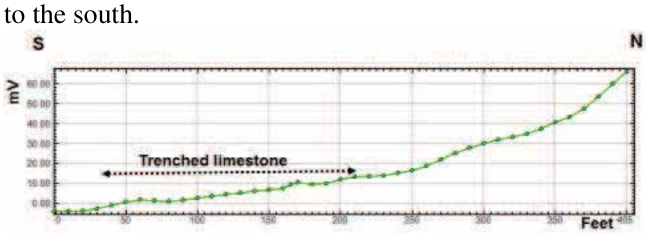

Figure 18: *NP data along the trenched wastewater line. Note that there is a strong NP gradient towards to the north.*

The majority of the high gradient NP data was clipped out (a sort of regional removal) between stations 76 meter (250 feet) to (121) 400 feet, and the rest of the profile is provided in Figure 19.

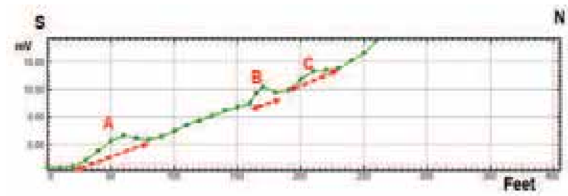

Figure 19: *Residual NP data collected along the wastewater line. Note that there are three NP anomalies (A, B and C) are defined now after taking out the majority of the strong gradient.*

The NP data indicates three NP anomalies as shown with letters A, B and C. The locations of these anomalies are correlative with the two cave locations exposed on the side wall of the trench.

The resistivity data did not show the presence of the air-filled caves along the trench; however, the NP data did locate them with a good accuracy.

The trench was completed up to the northern end of the geophysical profile without encountering any void as the NP data predicted.

Conclusion

It is clear from the ongoing discussion above that the 2-D resistivity data does not specifically determine where karst features are located in the subsurface. However, it provides significant information on the near-surface geology and geological structure. The combination of 2D and 3D resistivity measurements illustrates the subsurface conditions in a sufficiently accurate manner as shown in the Cave 1 case study.

The NP data, on the other hand, notably defines the location of karst features. Thus the merits of integrating NP method along with the resistivity imaging, in order to reduce the ambiguity in the interpretation, are evident. Thus the best methods are chosen to be the natural potential and resistivity techniques over the Edwards Aquifer.

Acknowledgments

A research paper like this is a journey from the past, and I am grateful to the many people who helped me along the way. Thanks to Art Lange, my mentor on natural potential method, who has been instrumental for me to understand the NP technique and apply it correctly in the field. I dedicate this paper to him.

Special thanks to Alfred Hawkins, who has been my associate since late 1990s, for his help all those years and sharing the load of the fieldwork with me, and having a good time most of the time.

I would like to thank Nico Hauwert, Sylvia Pope of City of Austin, for providing information on some of the data that is presented in this paper.

I thank to Janet Atkinson City of Austin Water Utility for giving permission to publish the geophysical data on McNeil Road.

Finally, but not the least, I thank Aaron Googins for allowing me to present some of the geophysical data on Cave 6.

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STUDENT'S CORNER

Student's Corner is a new *Fast*TIMES section specifically devoted to be a forum for college students to provide information on their geophysics related activities. Submissions are always welcome and can include research updates, EEGS student chapter news, reports from recently attended conferences or field trips, etc. This first Student's Corner section contains an interesting article from three University of South Florida Ph.D. students that corresponds very well with the environmental geophysics theme of this *Fast*TIMES issue.

ASSESSMENT OF HYDROGEOLOGICAL CONTROLS ON SANDHILL WETLANDS IN COVERED KARST USING GROUND PENETRATING RADAR

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Abstract

Sandhill wetlands are one of many types of karst-controlled wetlands and are defined by their isolated position in sandy upland environments. Ground penetrating radar (GPR) data were collected at a sandhill wetland in west-central Florida to resolve the stratigraphy both surrounding the wetland pool and beneath it - defining the stratigraphy allows a better understanding of recharge to the wetland and can aid in guiding wetland preservation. Survey transects were designed to cross through or radiate out from the wetland. The GPR data showed that sands thin or completely pinch out when approaching the wetland pool. Beneath the sand is relatively low permeability silty sand and sandy clay. Slope seepage occurs where these localized aquitards intersect with the ground. Strata gently dip away from the wetland pool. Although bedrock is not recorded in the borehole log, limestone is presumed to exist beneath clay. The bedrock surface is highly irregular and only slightly controls topography. Within the wetland pool, strata are truncated by the dissolution event that created the pool. These findings differ from other wetlands in the area (i.e. marsh wetlands and cypress swamps). The results of this survey, along with water level records, can assist in constructing a hydrogeological framework for the wetland at this site.

Keywords: Sandhill Wetland, Karst, West-Central Florida, Ground Penetrating Radar, Borehole Log, Stratigraphic Investigation.

Introduction

In west-central Florida, wetland and lake distribution is strongly controlled by karst formation. This study considers sandhill wetlands and lakes, which are sand-filled depressions in upland basins. Groundwater recharge dominates these features, so the wetlands may or may not contain surface water. These sandhill wetlands are geographically isolated wetlands (GIWs), meaning they are completely surrounded by upland environments (Tiner, 2003). The Florida Natural Areas Inventory, 2010, describes sandhill communities as "[dry] uplands with deep sand substrate". Current research indicates a strong connection between surface water levels within the wetlands and the Upper Floridan Aquifer levels (Nowicki, 2016, USF, 2016). These sites differ from the marsh and cypress wetlands that are more common in the region both in their topographic position and vegetation type. What is not well understood is how the subsurface geologic features controlling groundwater flow differ from marsh and cypress wetlands. A hydrogeological framework for sandhill wetlands does not currently exist.

The current wetland assessment procedure designed by the Southwest Florida Water Management District (SWFWMD), in which these sandhill wetlands are located, is a rating index used in assessing district wetlands. The procedure involves classifying a wetland (i.e. marsh or cypress wetland) and rating its health according to its attributes and characteristics. A conceptual model for sandhill wetlands does not exist and thus is not included in this rating index. As a result, most sandhill wetlands are not properly identified, and the impact of groundwater pumping, urban development, and climate change cannot be assessed. A better understanding of the hydrolithostratigraphy of sandhill wetlands and their adjacent landscape is necessary for the development of a conceptual model of their ecohydrology. This study reports characterization results for one of these sandhill wetland pools. Further findings on this and five other sandhill wetlands, driven by the need to construct a hydrogeological framework of sandhill wetlands, are summarized in a public technical report (USF, 2016).

Physical Site

Referred to as "Boy Scout" by SWFWMD, Sandhill Scout Reserve is a 3.3-acre ear-shaped wetland-pond system (referred to here as a "wetland" for simplicity) with a gently sloping northern side and steeply sloping southern sides, which descend into a relatively deep pool (Figure 1). Regional hydrostratigraphy consists of a surficial aquifer comprised of undifferentiated sands, silts, and clay separated from the carbonate Upper Floridan Aquifer by a clay-rich confining unit that can pinch out in areas. Lithological and stratigraphic data were not available for this area beyond a single borehole log, but the site occurs in the Gulf Coastal Lowlands, where confinement by Hawthorn Group clays is thin or absent (Arthur and others, 2008). Hydrographic and regression analyses of the wetland pool levels and the Upper Floridan levels show the water levels to be very highly correlated (R^2=0.99, Nowicki, 2016)

Methods

GPR data were collected along the six transects shown in Figure 1. Three transects were aligned radially outward from the water's edge, two were acquired via floating GPR equipment across the water (Figure 2), and one traced the perimeter of the wetland. Radial transects are positioned in areas of anomalous vegetation and to intersect with the single borehole log. Anomalous vegetation was either indicative of species obliged to wetland habitat, yet growing high up the wetland slope where inundation is rare [i.e., every 7-10 years, Nowicki, 2016].

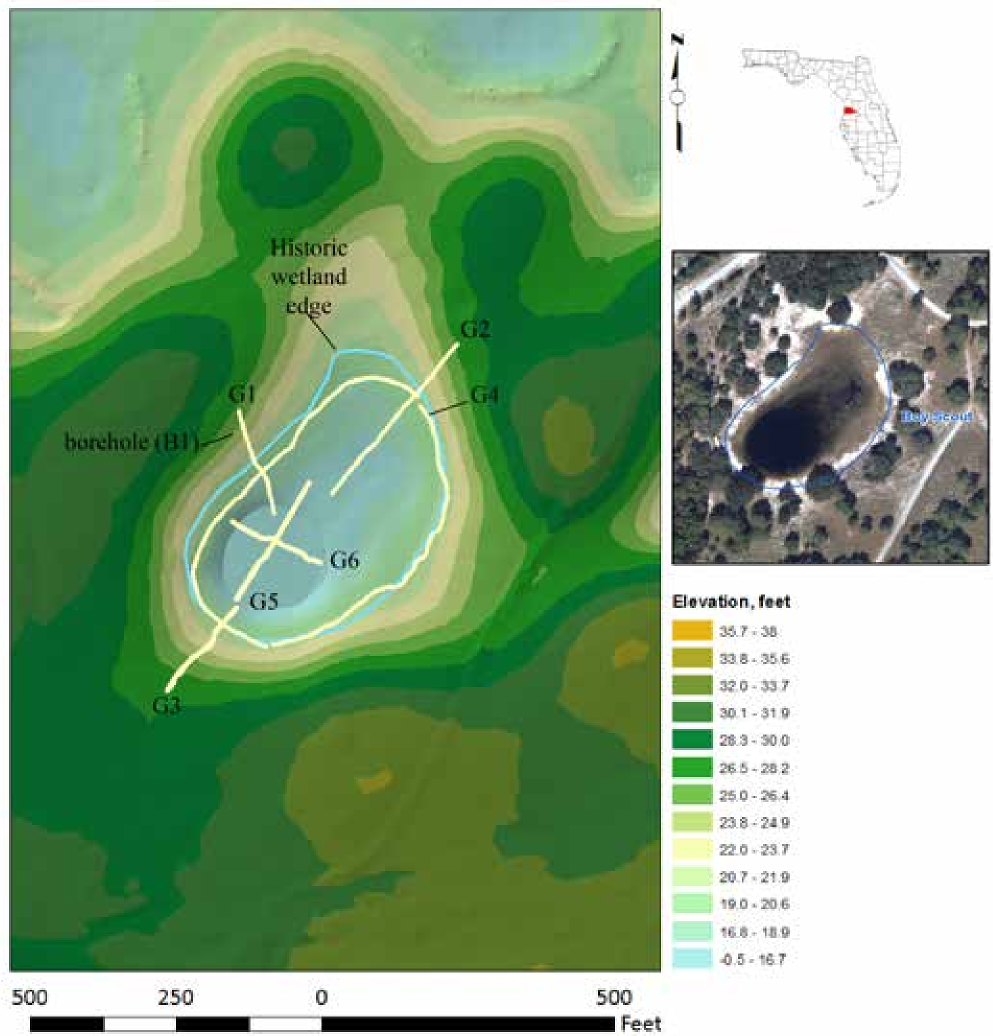

Figure 1: Location of Hernando County on Florida map (right); GPR surveys lines overlying bare earth LiDAR in Boy Scout wetland (left).

Figure 2: Floated GPR system; GPS antenna is installed at top of the GPR antenna.

Data were collected with MALÅ 250 MHz antennae and Groundvision v.1 acquisition software. Ground GPR data were acquired at a 0.02 m trace interval with a time window of 253 ns. Floating data were acquired at a 0.1 ns time interval with a 782 ns time window. Data were processed using Sandmeier Reflex-Win v.7.5. The low-frequency transmitter energy was removed ("dewow"), and a time-zero correction was performed by shifting the arrival time of the direct wave. Floating GPR data required a bandpass frequency filter to remove high frequency noise. GPS positioning was collected concurrently with GPR using a Trimble R10 rover and base station. Both horizontal and vertical positioning was collected, but unfortunately the vertical positions could not be adequately resolved and thus were not used. Elevations of ground profiles were instead obtained by importing horizontal positions as polylines into ArcGIS over a regional LiDAR dataset. The Stack Profile tool was used to extrapolate a topographic profile with distance derived from the polylines and elevation derived from the LiDAR. A MATLAB script calculated the elevation for each GPR trace, and we finished processing the ground profiles with a topographic migration. A single velocity for each profile was estimated via hyperbolas.

Reflection horizons of one profile (G1) are correlated with the lithology record from a borehole log provided by the SWFWMD and is especially helpful in distinguishing different sediment types versus changing sediment properties (i.e. reflections in GPR data that do not correspond to a change in lithology). Wetland water level was measured by a staff gage at the time of the geophysical survey.

Results

Transects G1, G2, and G3 begin in the uplands, intersect the historic wetland edge, and continue to the shoreline. G1 is just west of the borehole log. G2 begins in the uplands beyond the wetlands northeastern edge and spans an area of relatively low relief. G3 begins in the uplands beyond the southwestern edge and spans a relatively steep terrain.

Transect G1 serves as a reference point for correlating GPR reflectors and stratigraphic changes in the subsurface. The borehole log stops at the clay to avoid puncturing the confining unit between the surficial aquifer and the Upper Floridan. Water level data collected from the wetland staff gage show the water elevation at 17.1 feet above sea level during the ground survey and 16.1 feet during the water survey. G1 shows two prominent reflectors between -5 feet and 20 feet elevation, except where the lower reflector appears discontinuous (start of the profile to 25 feet) and hummocky (120 feet to the end of the profile) (Figure 3). The top reflector approximately corresponds to the bottom of a sand layer. It is possible that a sharp change in the physical properties (i.e. porosity, compaction, grain size) of the sand towards the bottom produces a stronger reflection than an actual change in lithology. This would explain why the top reflector does not exactly line up with the interfaces between sand and silty sand recorded in the bore log. A relatively weaker reflector corresponds to the interface between silty sand and sandy clay. The borehole does not reach far enough to correlate a stratigraphic interface with the bottom reflector, however the presence of dense plastic clay suggests it is the weathered top of limestone.

G1 illustrates an uneven bedrock surface with flat or close to flat sediments deposited on top of it. The bedrock surface is, at least partially, comprised of weathering clay products, but likely not in abundance. Pure clay does not allow the GPR signal to penetrate through, thus creating a shadow zone (no return signal) beneath it. There do appear to be small sections of the profile where little or no energy is reflected back from below -20 feet (Figure 3, top). Small patches of clay (dense, plastic or otherwise) likely sit atop bedrock.

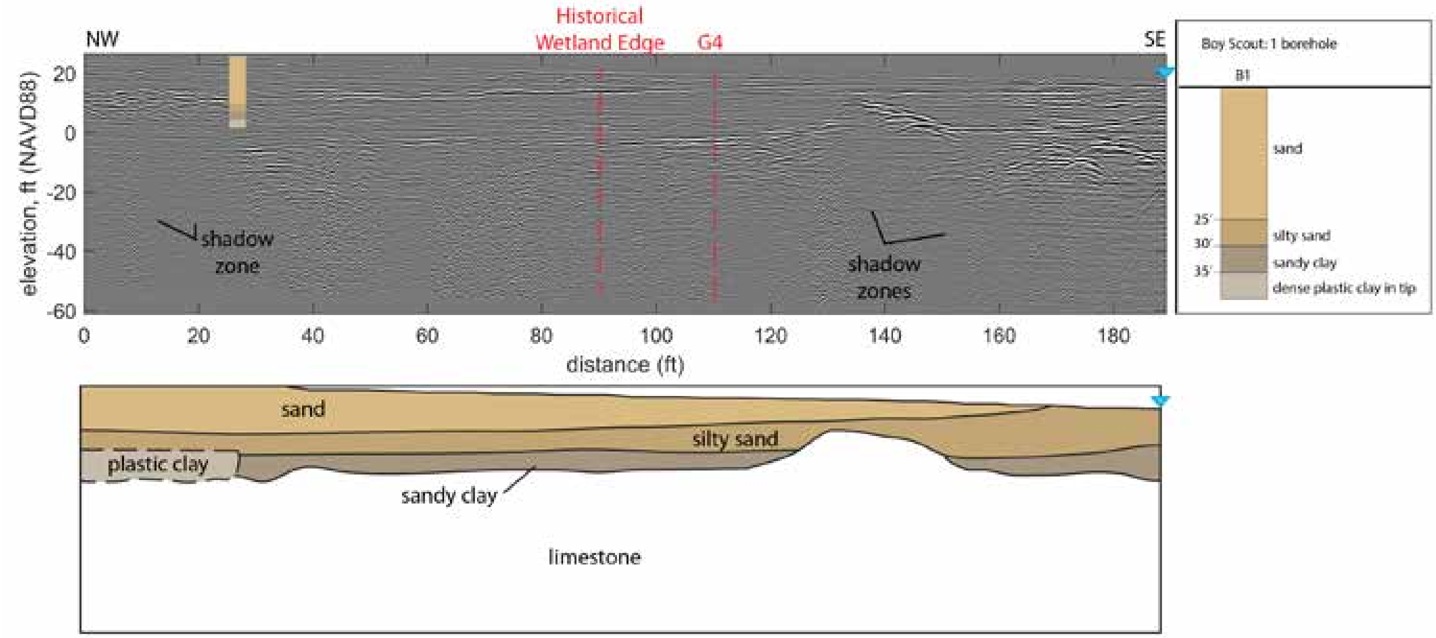

Figure 3: Profile G1 and borehole log. Note water table height measured at the edge of the pool.

Lithological interpretations for G2, G3, and G4 rely heavily on the correlations made between G1 and the borehole log. At the start of G2, sand and silty sand overlie limestone and thin out in the direction of the wetland pool (SW). The top of bedrock is irregular upslope and flat downslope. Strata appear to gently dip to the NE.

The land surface slope flattens around 175 feet. From here to the end of G2, there is an increase in soil moisture observed at the surface as well as accrual of denser, organic sediments (Figure 4). The slope change and surface soil change coincide with the sand pinching out and suggests surficial groundwater seepage at this location.

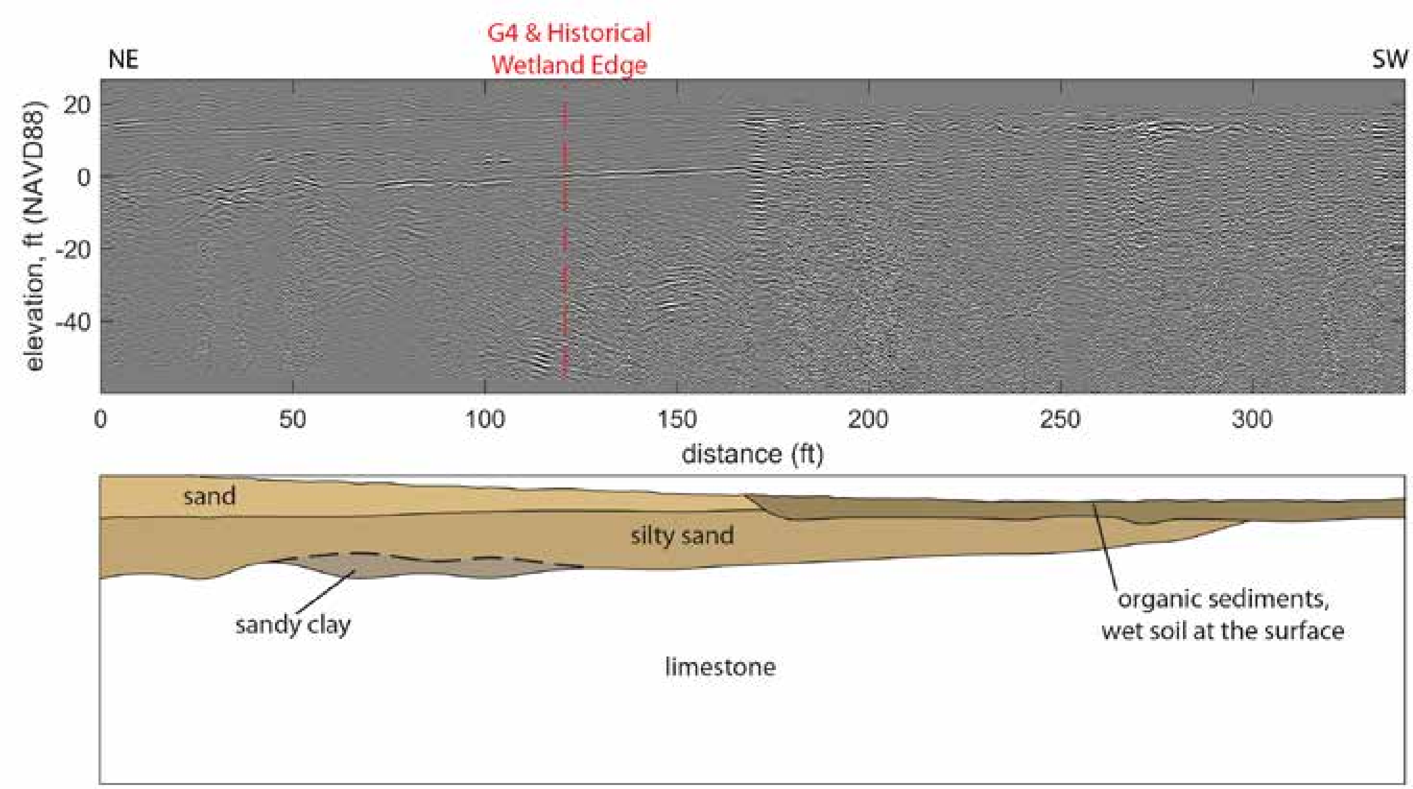

Figure 4: Profile G2 along gradually sloping northern portion of wetland (long-axis).

The geometry of strata overlying bedrock in G3 is different from G2 (Figure 5). Here sand and silty sand thin out in the direction of the wetland pool (NE) and have a gentle apparent dip to the SW suggesting all strata thin or pinch out towards the pool and are either flat lying or gently dipping away from the pool. However, bedrock is much closer to the surface along G3 (within as little as 10 feet as opposed to 20-25 feet in G2) and appears to have an irregular surface throughout. Bedrock surface is also steeper along G3 and seems to, at least slightly, control ground slope (recall that G3 is a relatively steeper slope and G2).

An increase in soil moisture and organic sediment is also observed at the surface along G3, the length of which spans a shorter portion of the slope (10 feet at the end of the transect versus 180 feet at the end of G2). Interestingly, anomalous wetland vegetation is growing just upslope of this (Figure 5, bottom). Similar to G2, the start of moist organic sediment coincides with the sand pinching out. This, again, suggests seepage and supports the existence of wetland plants in the upland environment surrounding the wetland.

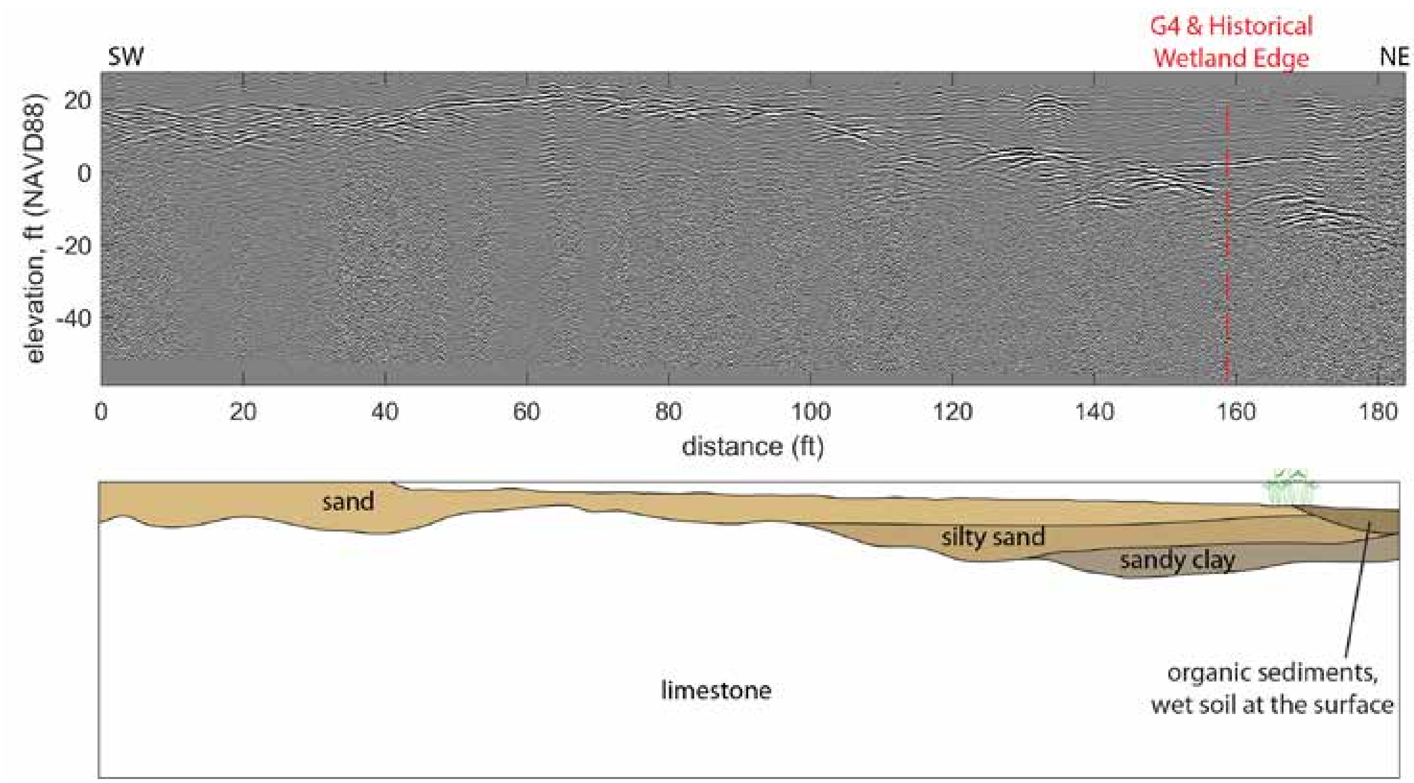

Figure 5: Profile G3 along steep southern portion of wetland (long axis).

Transect G4 was acquired around the perimeter of the pond, starting just east of transect G1 and continues clockwise around the wetland (Figure 6). Along the way, G4 intersects with G3, G1, and G2, as shown in the profile. The clearest feature imaged in undulating top of bedrock ranging from approximately 10 feet above to 20 feet below sea level. Referencing reflectors in radial transects, strata overlying bedrock are at relatively constant elevations surrounding the wetland pool. Breaks or hummocky reflections from the top of bedrock are interpreted as pits or peaks in the limestone and illustrate the highly irregular bedrock surface. The second half the G4's profile is brighter (stronger reflections) reflecting an increase in soil moisture.

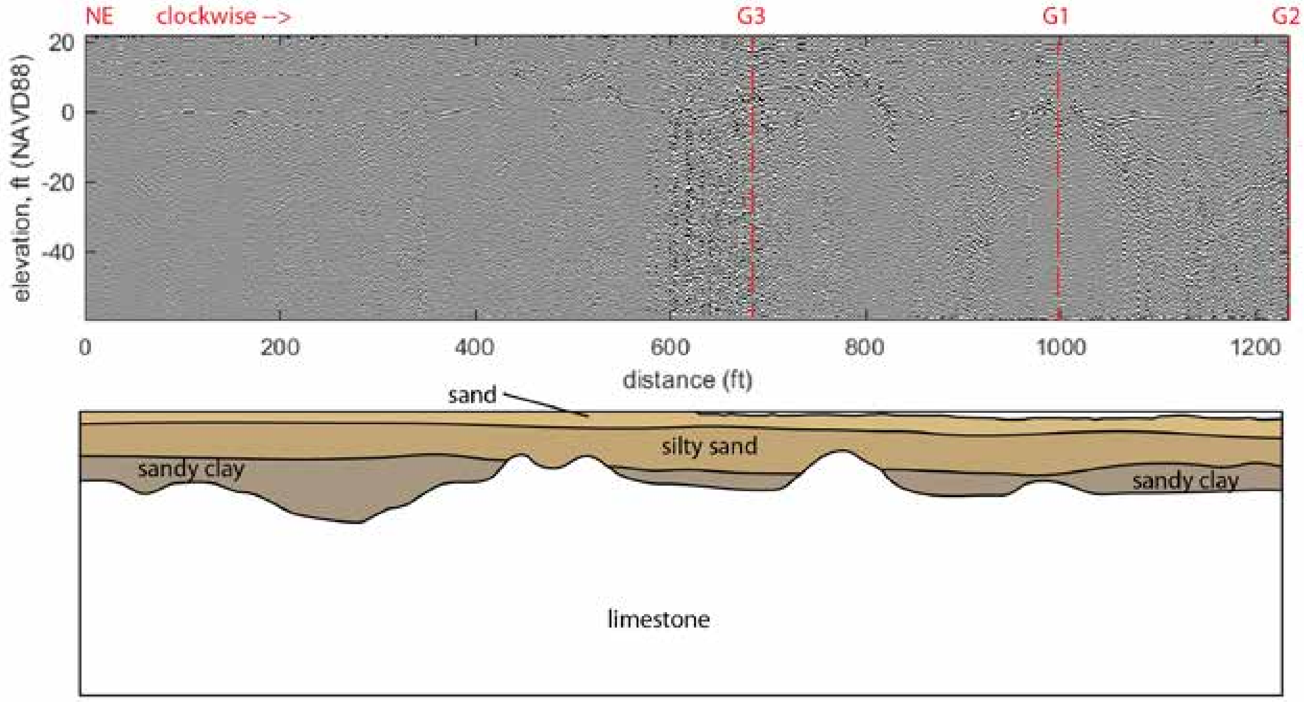

Figure 6: Profile G4 starting just east of G2 and traversing clockwise along wetland edge

Transect G5 and G6 extend perpendicularly to each other across the long and short axes, respectively, of the wetland pool (Figure 7 and Figure 8, respectively). Both profiles show a steeply sloping pool with strata truncated at, rather than dipping parallel to, its banks. Assuming the pool was created by a dissolution event, this suggests strata were truncated during dissolution. The surface of the pool's slopes and the extremely faint reflector at the bottom of the pool are dense, organic sediments. Deep reflectors beneath the pool slopes (18-30 feet from the start of G6) are identical to reflectors directly above them and deemed signal artifacts (i.e. ringing) rather than true stratigraphic features.

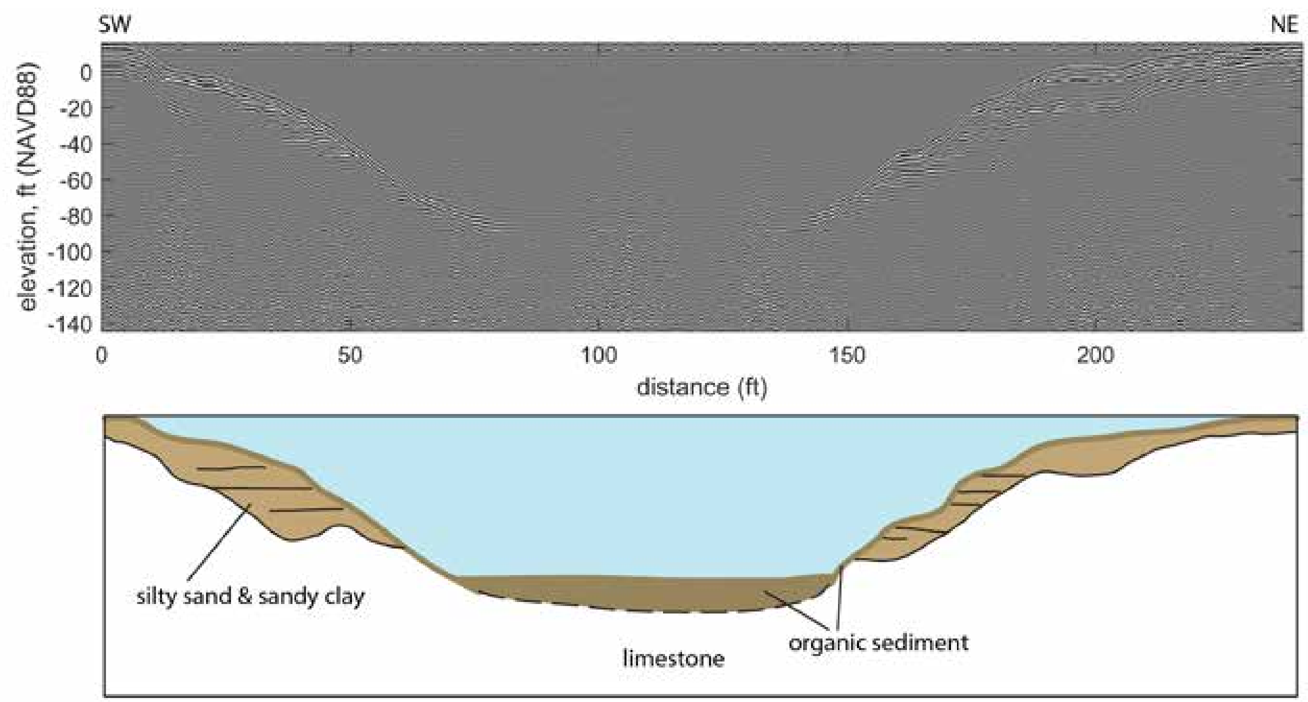

Figure 7: Profile G5 across long axis of wetland pool. Water level elevation is 16.1 feet NAVD88.

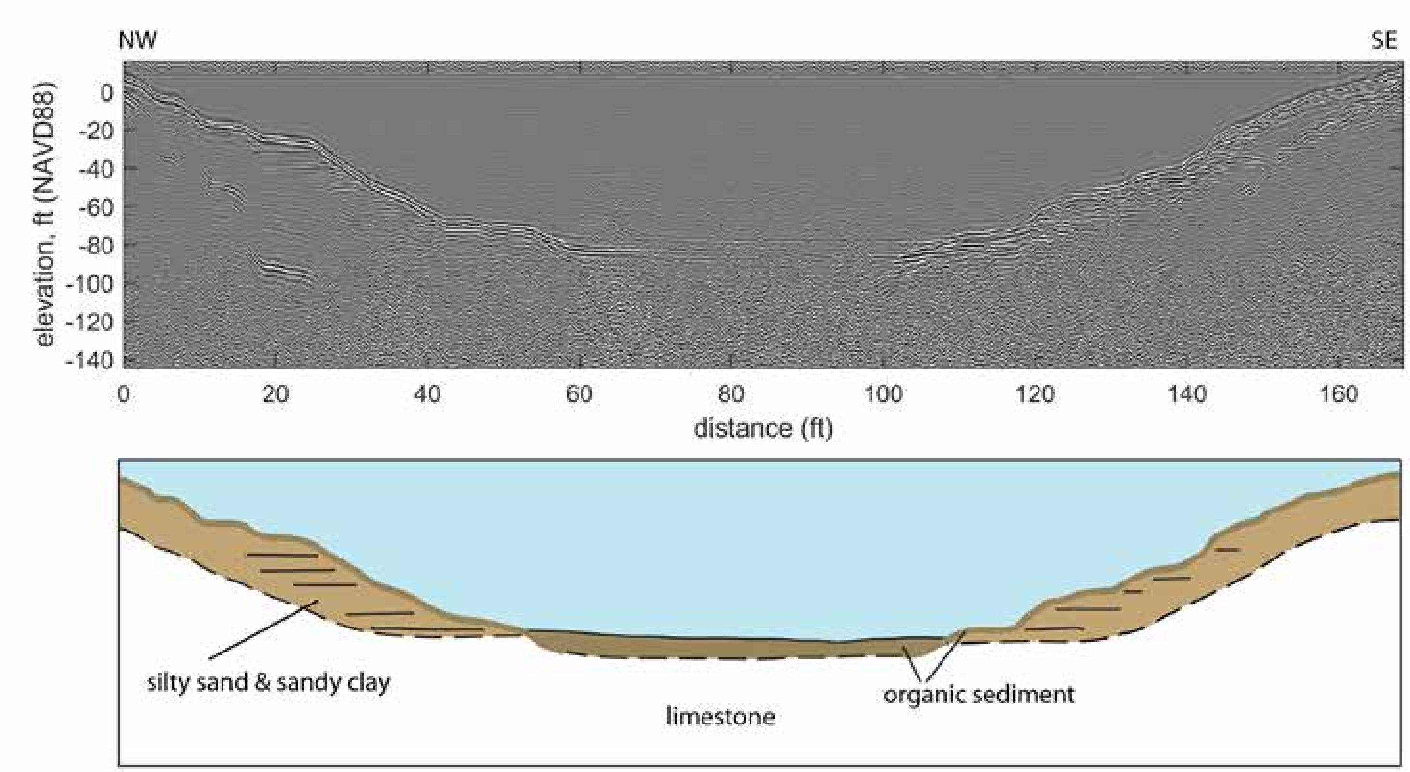

Figure 8: Profile G6 across the short axis of the pool. Water level elevation is 16.1 feet NAVD88.

Discussion

Sandhill wetlands are highly variable and data from other sites are necessary to present larger scale interpretations. Nevertheless, the GPR survey conducted at Sandhill Scout Reserve ("Boy Scout") shows not only the dissolution of limestone bedrock expressed at the surface at a depression, but with undulating limestone surrounding it which is not always expressed in topography. Depth to bedrock varies from 10 feet to 25 feet. Furthermore, the pinching out of overlying strata control slope seepage, which supports wetland vegetation in the uplands. Both the surficial aquifer and partially confined aquifer supply water to vegetation and the pool.

These findings differ from other wetlands in the area where sediments overlying bedrock slump down into secondary openings of dissolving limestone as seen in Lee and others (2009). Instead lenses, albeit thin lenses, of sediment define the uplands and the lack of sediment along with the dissolution of limestone define the depression. It is possible to construct a hydrogeological framework for Boy Scout, but this is not enough information to construct one generalized framework for all sandhill wetlands. Similar work has been done at other sandhill wetlands in west-central Florida and the full results of the can be found in USF (2016). The extent of strata and geometry of the bedrock surface can be used in tandem with historic water level records to illustrate the major factors influencing wetland pool levels and the distributions of wetland vegetation. Both of these are essential to delineating wetlands and assessing them according to their particular attributes and characteristics. Without this, it is impossible to know for show when the wetland is being impacted by anthropogenic activities, which is the ultimate goal of this study.

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geoDRONE Report

by Ron Bell   e-mail: rbell@igsdenver.com   tel: 720-220-3596

March 2017

- **Drones at the PDAC & SAGEEP 2017**
- **UAS Magnetometry**
- **The Starfish**
- **Upcoming Drone Relevant Events**

During the month of March I attended two conferences, the Prospectors and Developers Association Conference (PDAC) held annually in Toronto, Canada and the SAGEEP 2017 Conference in Denver, CO. There were drone relevant presentations at both conferences, although it was only at the PDAC that UAS services and UAS compatible geophysical instrumentation were being shown and offered in the exhibit hall. Though the sampling is small and limited, the mere fact that technical presentations and discussion of the application of UASs were given at both conferences is a clear sign that drones are, indeed, seeping into the workflows of geoscientific investigators and resource explorationists.

At the PDAC, an international conference focused on mineral resource exploration, discovery, and development, I came in on the tail end of a presentation by Peter Dueck and Thomas Stanley-Jones of Aerial Imaging Resources (http://www.airesources.ca). After the talk, I asked Peter if he would be willing to share his slide deck which he did along with permission to present bits of it in this report. What I surmised from his presentation is that the Canadian requirements for civil operation of a sUAS are undergoing revision so that they are similar to the FAA Part 107 Rule. I also noted that he presented on the use of sUAS to obtain the lay of the land and perform UAS photogrammetric surveys in remote difficult to access areas. The objective of the endeavor is to obtain an up-to-date high definition orthophoto mosaic for the project area that can be used as a base map for locating and referencing other types of geoscience data. He also spoke about using drones to map geology and quantitatively monitoring the extraction process at working mines.

What I found most interesting, of course, were the geophysical applications. He shared a bit about the Procyon 800 Potassium Magnetometer, HeliSAM, Gamma Ray Spectrometry, Ground Penetrating Radar (GPR), and VLF-EM. Of course, due to the proprietary nature of these methods and the fact that a number of groups are scrambling to gain a competitive advantage, none of the details of the methods or systems were included in the slide deck. Figure 1 through 4 present versions of some of the slides that Peter used in his presentation.

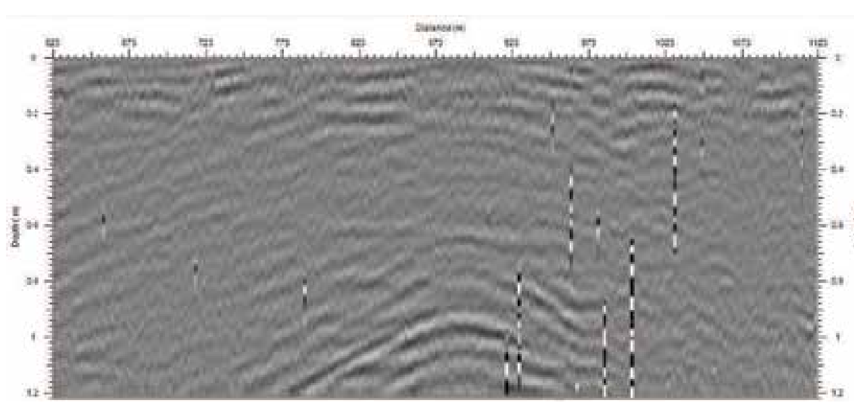
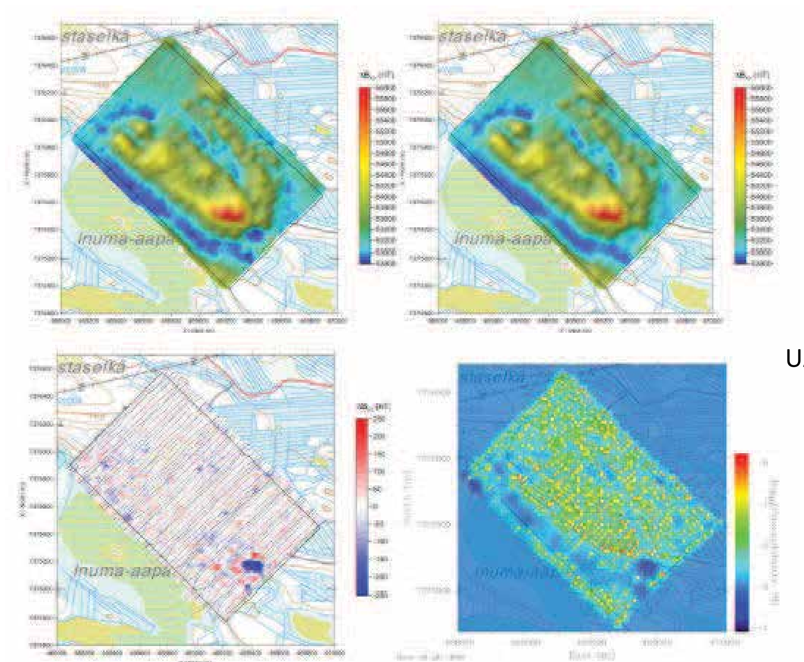
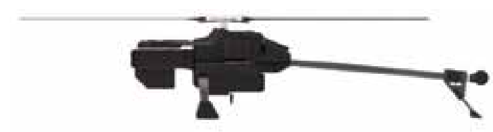


Figure 1: Ground Penetrating Rader by drone (P. Deuck, et. al. – from presentation at PDAC 2017).





Unmanned Aircraft System (UAS)

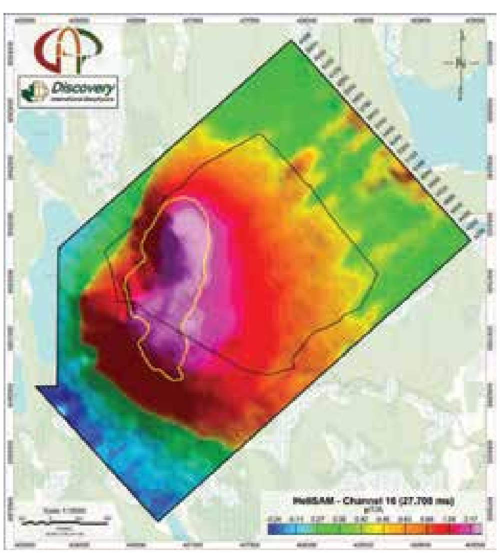
UAS Magnetic Survey Results

Procyon 800 UAS Magnetic Survey System

Magnetometer: potassium

Courtesy of Peter Deuck – Aerial Imaging Resources
For more information, visit: http://www.airesources.ca .

Figure 2: UAS magnetometry example from presentation at the PDAC 2017.



SAM – Sub-Audio Magnetotellurics

The Heli-SAM survey was conducted using a conventional pilot on board helicopter where the receiver was passed over the project area to measure the electromagnetic field generated by a loop source on the surface or a galvanic current flow from a grounded dipole. The image was included in Peter Deuck's slide deck which suggests to me that the Discovery International Group is adapting their HeliSAM technology for use with a drone.

To learn more, contact visit the following website: http://discogeo.com/.

Figure 3: The potential for electromagnetic measurements using a sUAS (Courtesy of Peter Deuck).

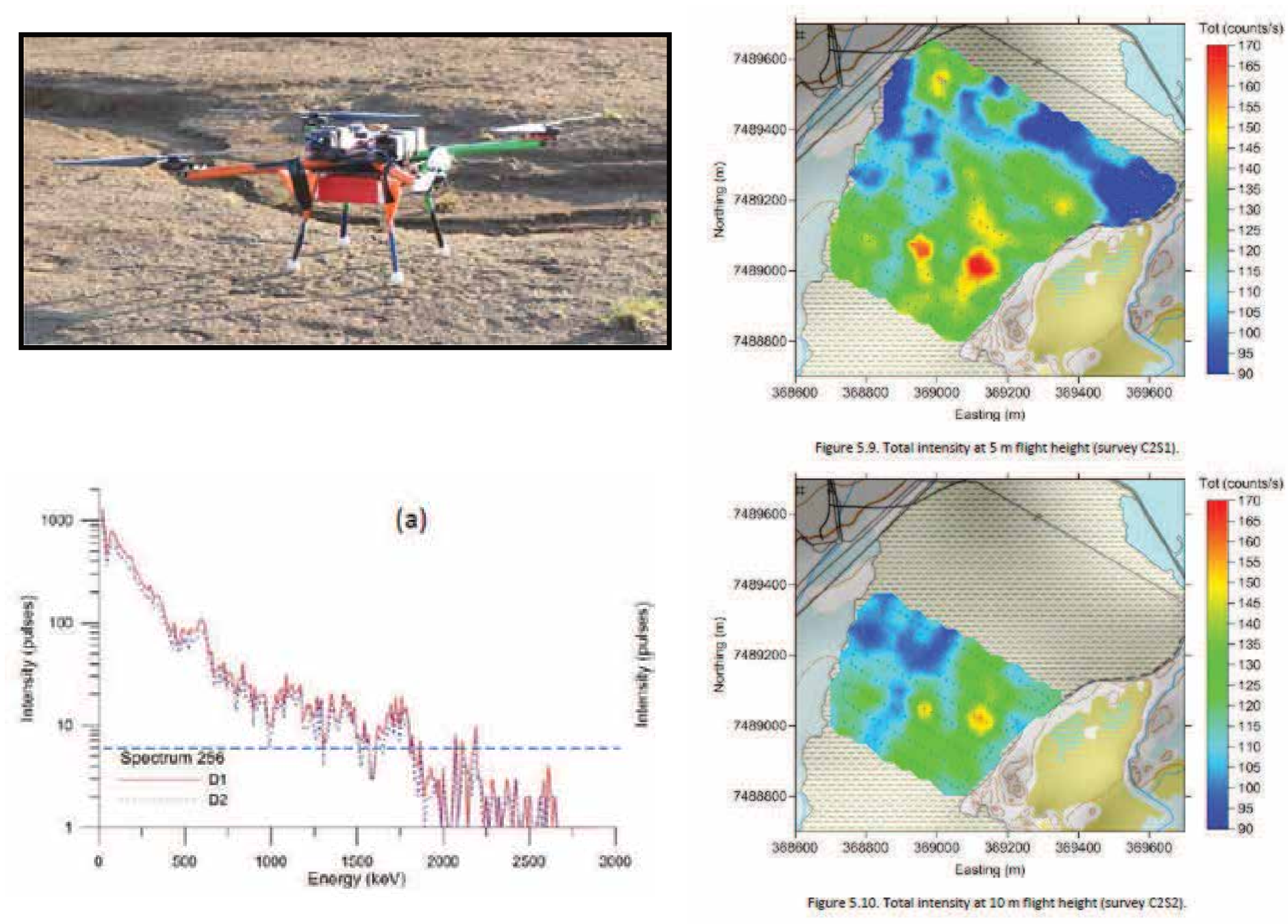


Figure 4: Gamma Ray Spectrometry using a drone (Courtesy of Peter Deuck).

The following two authors presented drone relevant talks at the SAGEEP.

James Oliver of MASER Consulting P.A. presented on the application of gamma ray mapping via a drone at the site of a former uranium mine in Arizona. (http://www.maserconsulting.com/services/).

Isaac Fage of Ground Truth Exploration presented on the use of drone photogrammetry at the beginning, during the data sampling and mapping, and at the end (i.e. reclamation) stages of a mineral exploration project. (http://groundtruthexploration.com/)

UAS Magnetometry

The most desired drone based geophysical measurement for subsurface mapping is low altitude magnetometry. For these surveys, the magnetic field sensor or sensors are passed over the surface of the earth from less than three (3) feet up to 400 feet above the ground surface, the maximum flight height allowed by FAA. There is a growing demand for magnetometers than can be deployed using a small UAS whose maximum take-off weight is 55 lbs (25 kgs) or less and the traditional magnetometer manufacturers are responding.

Gem Systems offers several magnetometers and magnetometer-UAS combinations. The following is the descriptive text and photos provided by Shawn Kovacs (shawn.kovacs@gemsys.ca).

Given the increase in popularity of multi-copters and unmanned rotary-wing platforms because of usability, minimal area for landing and take-off, payload capacity, stability and autonomous capabilities, GEM Systems Inc. (Markham, Ontario, Canada) has added and developed a high-sensitivity potassium magnetometer for UAV applications. The innovative GEM AirBIRD is a turnkey towable UAV solution which carries a high-sensitivity potassium magnetometer, GPS, laser altimeter, IMU and a radio link, where all data is synchronized and transmitted to the ground station in real time using GEMDAS. Total bird length is approximately 2.1m while weighting in at just under 3.6 kg (total weight = all components added, including battery).

For alternative solution to UAV platforms that are lighter and have a restricted payload of less than 3.5 kg, GEM Systems developed the AirMag: a "sling" magnetometer solution under 1.8 kg. The electronics component of the magnetometer has been modified to both store magnetic data and integrate with additional components (GPS,Laser,IMU,radio link) if weights permits.

GEM Systems - http://www.gemsys.ca/uavs-pathway-to-the-future/

While speaking with Bill Male of Scintrex Ltd, (http://www.scintrexltd.com/) at SAGEEP 2017, I learned that his firm has recently experienced a surge in sales of their GS-VL Cesium magnetometer for UAS applications. I also learned that Scintrex is placing their emphasis on the next generation gravity meter, the CG-6 Autograv^{TM}. It is light enough to be hoisted by a small UAV. Perhaps, one day Scintrex will offer a gravity meter on a drone.

Geometrics Inc. (http://geometrics.com/) is adapting the MFAM Cesium magnetometer technology to a drone with a product called the MagArrow. It is my understanding that several groups have been conducting field trials of a pre-production prototype. Recently, I conversed with a geophysicist who has been test flying the system. He shared that he was quite pleased with the data quality.

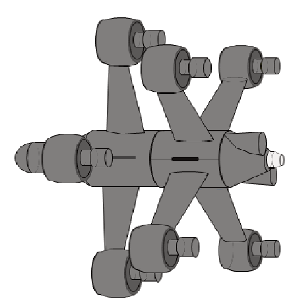
The Starfish

Most of the time, the focus is placed on drones that fly about in the air space. There are also drones that "swim about" under water. I recently learned of such a drone called "Starfish". It is made by Global Design Solutions. The following text and photos were provided by Sean McClung, a principal in the company.

Starfish is an underwater tethered robot connected to its human operator on the surface with a 300-foot umbilical cord. As divers and scientists can attest, a good deal of important data can be collected between the surface and that depth.

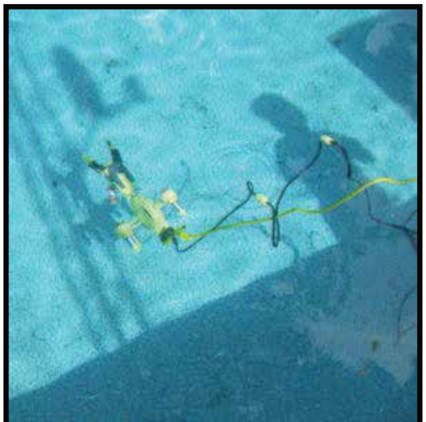
Connected to a hand held control device, Starfish maneuvers, searches and provides video photography of geological features in rivers, lakes, and even the ocean floor. The Starfish has remotely controllable grappling capabilities that can retrieve underwater samples weighing up to 500 pounds. This is not only useful for retrieving samples from below the surface, but is also helpful in retrieving items lost overboard from your boat. The camera maneuvers to explore tight underwater geological features, inspect underwater structures and pipes and move equipment from one area to the next. The Starfish is naturally buoyant, making surface set-up easy. Four 12-volt thruster motors are used to maneuver downward and laterally to surveil features with the onboard video camera. With Starfish at around $3,000 per unit, trolling for geological treasures now becomes easier and less expensive than diving with a camera.

The Starfish body is constructed of Syntactic Foam and provides buoyancy and strength for mounting hardware. The central hull is an aluminum tube structure containing electronics and other systems for operation of the underwater drone. All components are cast in molds providing for low cost and mass production of the body and thruster arms. Standard components can be mixed up to change configuration of the system for different purposes with the baseline four thruster unit being the only common item on each variation. A number of four thruster systems can be mounted back to back giving a single Starfish twice the propulsion thrust of the baseline unit, as required.



The Starfish has been tested for commercial purposes. It is a scalable system that ranges from 18 inches to fourteen feet in diameter for various functions. Shown below is the 18" commercial

Starfish complete with grapple claw attachment. Underwater dynamics and flight characteristics for the system including an umbilical-to-surface connection have been thoroughly tested. Prototype production has begun on a four foot diameter Starfish with



Global Design Solutions
A Concept Research and Development Company

product launch scheduled for spring 2017.

For more information, contact

Charles Rash @ 720-480-6334 or Sean McClung @ 719-208-9244

Upcoming Drone Relevant Events

The following conferences, short courses, and workshops are worth checking out.

XPONENTIAL 2017 Dallas, TX May 8-11, 2017
Sponsored by AUVSI for more info: http://www.xponential.org/xponential2017

geoDRONEology© Short Course Colorado Springs, CO Sept. 16, 2017
Applying Drones to Geoscientific Mapping
at the AEG Annual Meeting https://www.aegannualmeeting.org/short-courses

Drones Applied to Geophysical Mapping Houston, TX Sept. 29, 2017
A post conference workshop
at the SEG Annual Meeting for more information, email rbell@igsdenver.com

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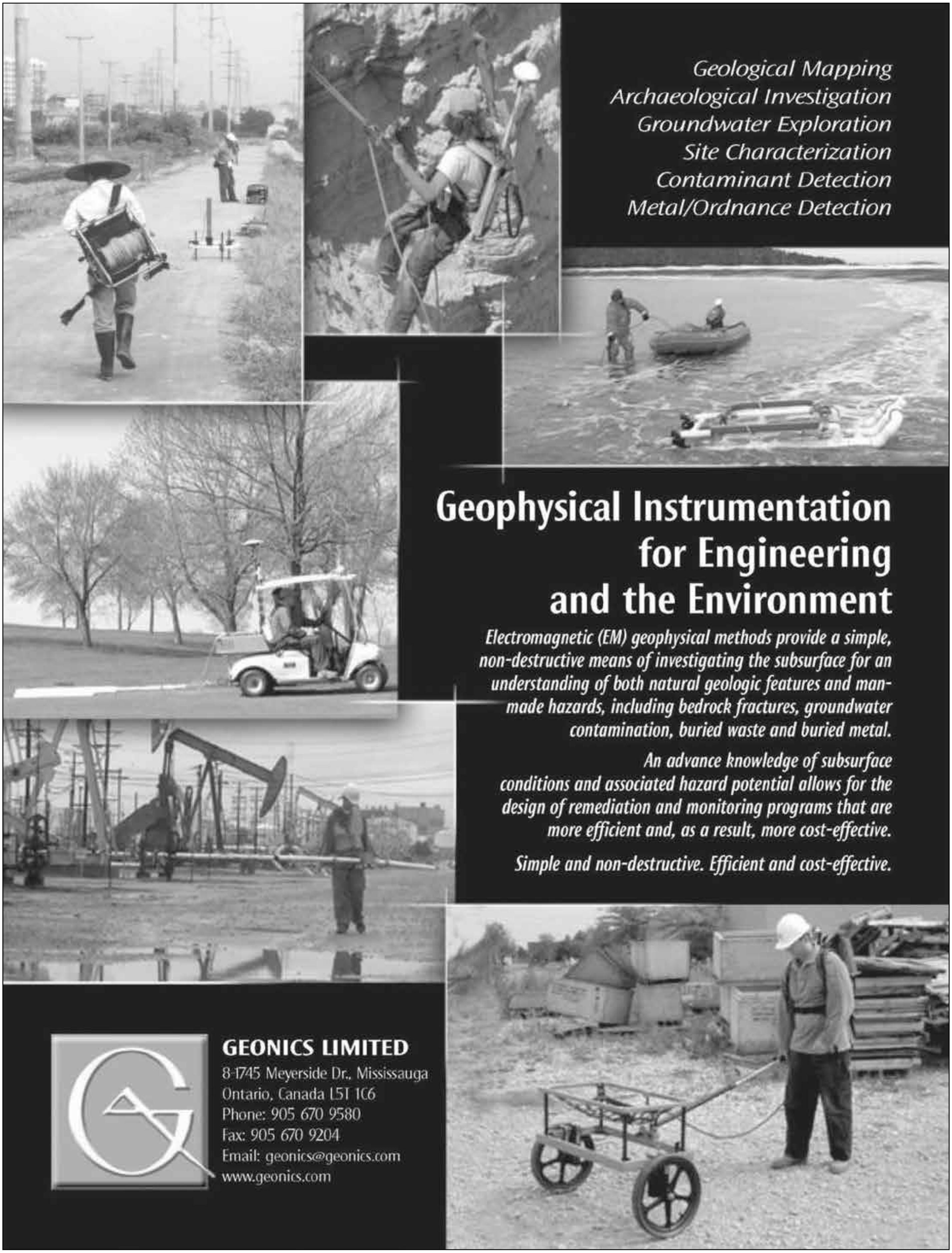
*Dear Readers: While at SAGEEP, Mark Dunscomb shared with me that he likes reading the **geoDRONE Report** which was gratifying to hear. Please take a moment to drop me an email with your thoughts and suggestions about this report. I strive to provide interesting and informative stuff. Thank you for reading. ~Ron (rbell@igsdenver.com)*



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www.geonics.com

Sensors & Software Announces Latest Evolution of pulseEKKO GPR

Press Release
April 21, 2017

Toronto - Sensors & Software, Inc. announces the immediate availability of the new pulseEKKO ground penetrating radar (GPR) system. After more than 30 years of innovation, pulseEKKO systems continue to improve. The latest evolution of pulseEKKO – the addition of the digital video logger (DVL) 500P– makes GPR surveys easier and time in the field more efficient. Plan, execute and document GPR investigations more effectively with the new, high-resolution DVL with a color touchscreen and intuitive interface. The DVL supports GPS, Wi-Fi, Bluetooth triggering, USB data transfer, streamlined survey setup, enhanced data collection options, and advanced in-field analysis.

The DVL is compatible with pulseEKKO PRO components and pulseEKKO 100 transmitters, making it easy to upgrade existing systems to unlock additional functionality.

INDUSTRY NEWS

Discerning professionals around the world know of the superior performance and signal quality of pulseEKKO. With its wide range of antenna frequencies from 12.5 to 1000 MHz, the pulseEKKO covers every conceivable application for GPR: Antarctic ice sheets, glaciers, deep geology/stratigraphy, mining, geotechnical investigations, archaeology, forensics, utility detection, roads, bridges, and concrete.

pulseEKKO GPR offers several deployment configurations – Full Bistatic, One-Man, SmartCart, SmartTow, and SmartChariot to provide efficient data collection in any terrain, temperature, and environment.


pulseEKKO GPR allows you to change any data collection parameter or deployment configuration to try something new – including time window length, temporal sampling interval, step size, stacking and triggering. It's full bistatic antennas enable users to go beyond simple common-offset reflection data collection and change the antenna geometry for the collection of Common-Mid-point, Wide Angle Reflection and Refraction, cross polarization, borehole, transillumination and multi-channel surveys. The flexibility of the pulseEKKO sets it apart from any other GPR system in the world and makes it the system of choice for GPR professionals.

Founded in 1989, Sensors & Software is the worldwide leader of GPR innovations. The company offers a wide range of products and services designed to understand what lies beneath the surface and empower informed decision-making.

For more information please visit www.sensoft.ca.

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Press Release

Contact: Chris Stapleton
Phone: (864) 527-4644

FOR IMMEDIATE RELEASE
4 P.M. EDT, June 9, 2017

PRESS RELEASE

SynTerra Corporation Announces Charlotte Office

Greenville, SC (June 9, 2017) - SynTerra Corporation, a leading regional provider of environmental consulting services to industrial and governmental clients, announced that it opened an office in Charlotte, NC.

The Charlotte location allows office manager Judd Mahan, PG, and his staff to better serve existing North Carolina clients and expand into new markets in the growing Charlotte area. SynTerra serves the power generation, forest products, and chemicals manufacturing markets in North Carolina. Recent staff additions provide the capability to serve the municipal water and wastewater market and industrial site development market in the region.

"Opening the Charlotte office is a major milestone for SynTerra," said Mark Taylor, President and CEO. "We have provided environmental services across the country from our Greenville headquarters for nearly 25 years. The new office will allow us to anchor existing client relationships and enter new markets in a leading Southeastern city."

ABOUT SYNTERRA

SynTerra Corporation is an employee-owned environmental science and engineering consulting firm. Its clients include Fortune 500 businesses, small manufacturers, and local and state governments. SynTerra provides highly collaborative consulting services focused on accomplishing client business objectives. Scientific service offerings include hydrogeology, toxicology, biology, and wetlands. Engineering disciplines include environmental compliance, civil (including geotechnical, hydrology, mining, and solid waste), and mechanical. Typical projects include regulatory compliance, site assessment, hydrogeology, remediation, solid waste design and operations support, wetlands assistance, infrastructure design, and mining. The Charlotte office is located at 10806 Reames Road, Suite A, Charlotte, NC 28269 (980.312.5999). Visit www.synterracorp.com for more information.

-END-

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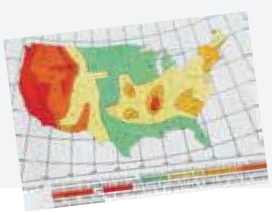
COMING EVENTS AND ANNOUNCEMENTS

WWW.EEGS.ORG/SAGEEP 2018

Nashville, Tennessee USA is the site of numerous attributes of interest to near surface geophysicists and will form the core of a timely and relevant technical program, including:

Karst
Dams and Levees
Earthquake Engineering & Fault Zone Studies
Infrastructure
Geohazards

Coal Mining
Hazardous Waste Remediation & Assessment
Renewable / Unconventional Energy
Groundwater
Unexploded Ordnance



SAGEEP General Chair
William E. Doll, Ph.D.
William.Doll@tetratech.com

SAGEEP Technical Co-Chairs
Andrew Parsekian, Ph.D. aparseki@uwyo.edu
Oliver Kuras, Ph.D. oku@bgs.ac.uk

EEGS

Symposium on the Application of Geophysics to Engineering and Environmental Problems

EAGE
EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

COMING EVENTS AND ANNOUNCEMENTS

12 June 2017

Attention: ***All EEGS Members and SAGEEP attenders***

From: ***The Ad Hoc Committee for Sidebar Events***

Re: ***Uniquely Nashville Musical Events for SAGEEP 2018***

The Ad Hoc Committee for Sidebar Events is working on developing concepts for two (2) musically oriented events at the SAGEEP 2018 conference to be held in Nashville, TN (a.k.a. "Music City").

>> ***<u>Songwriting & Muscian's Workshop plus Jam Session</u>***

to be held on the Saturday before the official start of SAGEEP 2018 is envisioned to teach about musicianship, performance, and song writing – mostly it is a chance to come together under the premise of learning & playing some new tunes all the while having a good ole' time making music.

>> ***<u>Nashville Music City Tour</u>***

to be held on Thursday during the week of SAGEEP, it is currently envisioned to include a visits to a sound recording studio, an acoustic guitar manufacturer, a vintage guitar shop, the Country Music Hall of Fame, the Johnny Cash Museum, and other interesting locales ***<u>PLUS</u>*** a concert in the evening.

<u>We need your help!</u>

Please take a moment to email your reply to the following three questions to rbell@igsdenver.com.

1) ***Do you like the Uniquely Nashville Musical Events concepts?***
2) ***Do you play guitar or another instrument?***
3) ***Would you participate? If so, which event strikes your fancy?***

Please e-mail your reply on or before JULY 15, 2017.

We know you are quite busy and are truly grateful for your willingness respond to this mini-survey.

Yours truly,

The Ad Hoc Committee for Sidebar Events

Ron Bell	rbell@igsdenver.com	Steve Cosway	swc@sensoft.ca
Doug Laymon	doug@collierconsulting.com	Mark Dunscomb	MARKD@schnabel-eng.com

Environmental and Engineering Geophysical Society

2017 Individual Membership Application

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Individual Membership Categories

EEGS is the premier organization for geophysics applied to engineering and environmental problems. Our multi-disciplinary blend of professionals from the private sector, academia, and government offers a unique opportunity to network with researchers, practitioners, and users of near-surface geophysical methods.

Memberships include access to the *Journal of Environmental & Engineering Geophysics (JEEG)*, proceedings archives of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), and our quarterly electronic newsletter, *FastTIMES*. Members also enjoy complimentary access to SEG's technical program expanded abstracts, as well as discounted SAGEEP registration fees, books and other educational publications. EEGS offers a variety of membership categories tailored to fit your needs. Please select (circle) your membership category and indicate your willingness to support student members below:

☐ **Yes, I wish to sponsor _______ student(s) @ $20 each to be included in my membership payment.**

Individual Members

Individual members are invited to sponsor student members. Simply indicate the number of students you'd like to support (at $20 each) to encourage growth in this important segment of EEGS' membership.

Category	Electronic *JEEG* Available Online	Printed *JEEG* Mailed to You
Individual	$105	$150

Retired Members

Your opportunity to stay connected and support the only organization focusing on near surface geophysics. Retired members are invited to sponsor student members. Simply indicate the number of students you'd like to support (at $20 each) to encourage growth in this important segment of EEGS' membership.

Category	Electronic *JEEG* Available Online	Printed *JEEG* Mailed to You
Retired (*Must be Approved by EEGS Board of Directors)*	$50	$150

Introductory Members

If you have not been a member of EEGS before, we offer a reduced rate (electronic JEEG option) for new members to enjoy all the benefits of individual membership (except vote or hold office) for one year.

Category	Electronic *JEEG* Available Online	Printed *JEEG* Mailed to You
Introductory	$50	$150

Lifetime Members

Support EEGS, receive benefits on an ongoing basis and never renew again! Members of this category enjoy all the benefits of Individual membership.

Category	Electronic *JEEG* Available Online	Printed *JEEG* Mailed to You
Lifetime Member	$995	$995

Developing World Members

Those selecting this category of EEGS membership are invited to check the list of countries to determine qualification.

Category	Electronic *JEEG* Available Online	Printed *JEEG* Mailed to You
Developing World *(List of qualifying countries next page)*	$50	$150

Student Members

Students represent EEGS' future and we offer complimentary membership subsidized by Corporate Student Sponsor Members and those who sponsor students. Student members enjoy all the benefits of individual membership (except to vote or hold office). Available to all students in an accredited university up to one year post-graduation. Please submit a copy of your student ID and indicate your projected date of graduation: ___ /____ (Month/Year). Students in year two beyond graduation are offered a special rate for 1 year.

Category	Electronic *JEEG* Available Online	Printed *JEEG* Mailed to You
Student up to 1 Year Post Graduation **(Grad Date: Mo/Yr.: ___/___)**	$ 0	$110
Student - Year Two Post Graduation	$50	$110

Membership Renewal
Developing World Category Qualification

If you reside in one of the countries listed below, you are eligible for EEGS's Developing World membership category rate of $50.00 (or $150.00 if you would like the printed, quarterly *Journal of Environmental & Engineering Geophysics* (*JEEG*) mailed to you). To receive a printed *JEEG* as a benefit of membership, select the Developing World Printed membership category on the membership application form.

Afghanistan
Albania
Algeria
Angola
Armenia
Azerbaijan
Bangladesh
Belize
Benin
Bhutan
Bolivia
Burkina Faso
Burundi
Cambodia
Cameroon
Cape Verde
Central African Republic
Chad
China
Comoros
Congo, Dem. Rep.
Congo, Rep.
Djibouti
Ecuador
Egypt
El Salvador
Eritrea
Ethiopia
Gambia
Georgia
Ghana
Guatemala
Guinea-Bissau
GuyanaHaiti
Honduras
India
Indonesia
Iran
Iraq
Ivory Coast
Jordan
Kenya
Kiribati
Kosovo
Kyrgyz Republic
Lao PDR
Lesotho
Liberia
Madagascar
Malawi
Maldives
Mali
Marshall Islands
Mauritania
Micronesia
Moldova
Mongolia
Morocco
Mozambique
Myanmar
Nepal
Nicaragua
Niger
Nigeria
North Korea
Pakistan
Papua New Guinea
Paraguay
Philippines
Rwanda
Samoa
Sao Tome and Principe
Senegal
Sierra Leone
Solomon Islands
Somalia
Sri Lanka
Sudan
Suriname
Swaziland
Syria
Taiwan
Tajikistan
Tanzania
Thailand
Timor-Leste
Togo
Tonga
Tunisia
Turkmenistan
Uganda
Ukraine
Uzbekistan
Vanuatu
Vietnam
West Bank and Gaza
Yemen
Zambia
Zimbabwe

1720 South Bellaire Street | Suite 110 | Denver, CO 80222-4303
(p) 001.1.303.531.7517 | (f) 001.1.303.820.3844 | staff@eegs.org | www.eegs.org

Environmental and Engineering Geophysical Society

2017 EEGS Membership Application

Renew or Join Online at www.EEGS.org

CONTACT INFORMATION

Salutation	First Name	Middle Initial	Last Name

Company/Organization	Title

Street Address	City	State/Province	Zip Code	Country

Direct Phone	Mobile Phone	Fax

Email	Website

ABOUT ME: INTERESTS & EXPERTISE

In order to identify your areas of specific interests and expertise, please check all that apply:

Role	Interest or Focus	Geophysical Expertise	Professional/ Scientific Societies	Willing to Serve on a Committee?
☐ Consultant	☐ Archaeology	☐ Borehole Geophysical Logging	☐ AAPG	☐ Publications
☐ User of Geophysical Svcs.	☐ Engineering	☐ Electrical Methods	☐ AEG	☐ Web Site
☐ Student	☐ Environmental	☐ Electromagnetics	☐ ASCE	☐ Membership
☐ Geophysical Contractor	☐ Geotechnical	☐ Gravity	☐ AWWA	☐ Student
☐ Equipment Manufacturer	☐ Geo. Infrastructure	☐ Ground Penetrating Radar	☐ AGU	
☐ Software Manufacturer	☐ Groundwater	☐ Magnetics	☐ EAGE	
☐ Research/Academia	☐ Hazardous Waste	☐ Marine Geophysics	☐ EERI	
☐ Government Agency	☐ Humanitarian Geo.	☐ Remote Sensing	☐ GeoInstitute	
☐ Other	☐ Mining	☐ Seismic	☐ GSA	
	☐ Shallow Oil & Gas	☐ Other	☐ NGWA	
	☐ UXO		☐ NSG	
	☐ Aerial Geophysics		☐ SEG	
	☐ Other		☐ SSA	
			☐ SPWLA	

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FOUNDATION CONTRIBUTIONS

FOUNDERS FUND

The Founders Fund has been established to support costs associated with the establishment and maintenance of the EEGS Foundation as we solicit support from larger sponsors. These will support business office expenses, necessary travel, and similar expenses. It is expected that the operating capital for the foundation will eventually be derived from outside sources, but the Founder's Fund will provide an operation budget to "jump start" the work. Donations of $50.00 or more are greatly appreciated. For additional information about the EEGS Foundation (an IRS status 501(c)(3) tax exempt public charity), visit the website at http://www.EEGSFoundation.org.

Foundation Fund Total: $ ____________________

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Student Support Endowment Total: $ ____________________

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Corporate Contribution Total: $ ____________________

Foundation Total: $ ____________________

PAYMENT INFORMATION

- ☐ **Check/Money Order**
- ☐ **VISA**
- ☐ **MasterCard**
- ☐ **AmEx**
- ☐ **Discover**

Subtotals

Membership: $ ____________________

Student Sponsorship: $ ____________________

Foundation Contributions: $ ____________________

Grand Total: $ ____________________

Card Number **Exp. Date** **CVV #:**

Name on Card

Signature

Make your check or money order in US dollars payable to: EEGS. Checks from Canadian bank accounts must be drawn on banks with US affiliations (example: checks from Canadian Credit Suisse banks are payable through Credit Suisse New York, USA). Checks must be drawn on US banks.

Payments are not tax deductible as charitable contributions although they may be deductible as a business expense. Consult your tax advisor.

Return this form with payment to: EEGS, 1720 South Bellaire Street, Suite 110, Denver, CO 80222 USA

Credit card payments can be faxed to EEGS at 001.1.303.820.3844

Corporate dues payments, once paid, are non-refundable. Individual dues are non-refundable except in cases of extreme hardship and will be considered on a case-by-case basis by the EEGS Board of Directors. Requests for refunds must be submitted in writing to the EEGS business office.

QUESTIONS? CALL 001.1.303.531.7517

Environmental and Engineering Geophysical Society	Renew or Join Online at www.EEGS.org
2017 Corporate Membership Application	

EEGS is the premier organization for geophysics applied to engineering and environmental problems. Our multi-disciplinary blend of professionals from the private sector, academia, and government offers a unique opportunity to network with researchers, practitioners, and users of near-surface geophysical methods.

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☐ **Yes, I wish to support ____ student(s) at $20 each to be included in my membership payment.**

Category	2017 Electronic JEEG	2017 Basic Rate (print JEEG)	2017 Basic + Web Ad Package
Corporate Student Sponsor *Includes one (1) individual membership, a company profile and linked logo on the EEGS Corporate Members web page, a company profile in FastTIMES and the SAGEEP program, recognition at SAGEEP, a 10% discount on advertising in JEEG and FastTIMES, a 20% discount on JEEG article color figure charges and Sponsorship of Student Memberships*	$310	$340	$840
Corporate Donor *Includes one (1) individual EEGS membership, one (1) full conference registra-tion to SAGEEP, a company profile and linked logo on the EEGS Corporate Members web page, a company profile in FastTIMES and the SAGEEP program, recognition at SAGEEP, 10% discount on SAGEEP Short Courses/Workshops for members and employees, ability to advertise job openings via an EEGS Alert or eblast, a 20% discount on JEEG article color figure charges and a 10% discount on advertising in JEEG and FastTIMES*	$660	$690	$1190
Corporate Associate *Includes two (2) individual EEGS memberships, an exhibit booth and registra-tion at SAGEEP, the ability to insert marketing materials in the SAGEEP delegate packets, a company profile and linked logo on the EEGS Corporate Members web page, a company profile in FastTIMES and the SAGEEP program, recognition at SAGEEP, a 20% discount on JEEG article color figure charges and a 10% discount on advertising in JEEG and FastTIMES*	$2410	$2440	$2940
Corporate Benefactor *Includes two (2) individual memberships to EEGS, two (2) exhibit booths and registrations at SAGEEP, the ability to insert marketing materials in the SAGEEP delegate packets, a company profile and linked logo on the EEGS Corporate Members web page, a company profile in FastTIMES and the SAGEEP program, recognition at SAGEEP, a 20% discount on JEEG article color figure charges and a 10% discount on advertising in JEEG and FastTIMES*	$4010	$4040	$4540
Website Advertising *One (1) Pop-Under, scrolling marquee style ad with tag line on Home page, logo linked to Company web site, One (1) Button sized ad, linked logo, right rail on each web page*	Purchase Separately (without membership) $600/yr. $250/yr.	$600/yr. $250/yr.	Package Rates include both website ad locations

Environmental and Engineering Geophysical Society	Renew or Join Online at www.EEGS.org
2017 Corporate Membership Application	

CONTACT INFORMATION

Salutation	First Name	Middle Initial	Last Name

Company/Organization	Title

Street Address	City	State/Province	Zip Code	Country

Direct Phone	Mobile Phone	Fax

Email	Website

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☐ User of Geophysical Svcs.	☐ Engineering	☐ Electrical Methods	☐ AEG	☐ Web Site
☐ Student	☐ Environmental	☐ Electromagnetics	☐ ASCE	☐ Membership
☐ Geophysical Contractor	☐ Geotechnical	☐ Gravity	☐ AWWA	☐ Student
☐ Equipment Manufacturer	☐ Geo. Infrastructure	☐ Ground Penetrating Radar	☐ AGU	
☐ Software Manufacturer	☐ Groundwater	☐ Magnetics	☐ EAGE	
☐ Research/Academia	☐ Hazardous Waste	☐ Marine Geophysics	☐ EERI	
☐ Government Agency	☐ Humanitarian Geo.	☐ Remote Sensing	☐ GeoInstitute	
☐ Other	☐ Mining	☐ Seismic	☐ GSA	
	☐ Shallow Oil & Gas	☐ Other	☐ NGWA	
	☐ UXO		☐ NSG	
	☐ Aerial Geophysics		☐ SEG	
	☐ Other		☐ SSA	
			☐ SPWLA	

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Foundation Total: $ ____________

PAYMENT INFORMATION

- ☐ **Check/Money Order**
- ☐ **VISA**
- ☐ **MasterCard**
- ☐ **AmEx**
- ☐ **Discover**

Subtotals

Membership: $ ____________

Student Sponsorship: $ ____________

Foundation Contributions: $ ____________

Grand Total: $ ____________

Card Number ____________ **Exp. Date** ____________

Name on Card ____________ **CVV#** ____________

Signature ____________

Make your check or money order in US dollars payable to: EEGS. Checks from Canadian bank accounts must be drawn on banks with US affiliations (example: checks from Canadian Credit Suisse banks are payable through Credit Suisse New York, USA). Checks must be drawn on US banks.

Payments are not tax deductible as charitable contributions although they may be deductible as a business expense. Consult your tax advisor.

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QUESTIONS? CALL 001.1.303.531.7517

EEGS CORPORATE MEMBERS

Corporate Benefactor

Your Company Here!

Corporate Associate

Advanced Geosciences, Inc.
www.agiusa.com

Allied Associates Geophysical Ltd.
www.allied-associates.co.uk

CGG Canada Services Ltd.
www.cgg.com

Exploration Instruments LLC
www.expins.com

Geogiga Technology Corporation
www.geogiga.com

Geometrics, Inc.
www.geometrics.com

Geonics Ltd.
www.geonics.com

Geophysical Survey Systems, Inc.
www.geophysical.com

Geosoft Inc.
www.geosoft.com

Geostuff
www.geostuff.com

GeoVista Ltd.
www.geovista.co.uk

Interpex Ltd.
www.interpex.com

Mount Sopris Instruments
www.mountsopris.com

Northwest Geophysics
www.northwestgeophysics.com

Ontash & Ermac, Inc.
www.ontash.com

R. T. Clark Co. Inc.
www.rtclark.com

Sensors & Software Inc.
www.sensoft.ca

Scintrex Limited
www.scintrexltd.com

Vista Clara Inc.
www.vista-clara.com

Zonge international, Inc
www.zonge.com

Corporate Donor

Fugro Consultants, Inc.
www.fugroconsultants.com

Geomar Software Inc.
www.geomar.com

Geomatrix Earth Science Ltd.
www.geomatrix.co.uk

Quality Geosciences Company, LLC
www.quality-geophysics.com

Spotlight Geophysical Services
www.spotlightgeo.com

EEGS STORE

Environmental and Engineering Geophysical Society

2017 Publications and Merchandise Order Form

1720 S. Bellaire Street, Suite 110
Denver, CO 80222-4303
Phone: 303.531.7517; Fax: 303.820.3844
E-mail: staff@eegs.org; Web Site: www.eegs.org

Sold To:
Name: ______________________________
Company: ______________________________
Address: ______________________________
City/State/Zip: ______________________________
Country: ________________ Phone: __________
E-mail: ________________ Fax: __________

Ship To (If different from "Sold To":
Name: ______________________________
Company: ______________________________
Address: ______________________________
City/State/Zip: ______________________________
Country: ________________ Phone: __________
E-mail: ________________ Fax: __________

Instructions: Please complete both pages of this order form and fax or mail the form to the EEGS office listed above. Payment must accompany the form or materials will not be shipped. Faxing a copy of a check does not constitute payment and the order will be held until payment is received. Purchase orders will be held until payment is received. If you have questions regarding any of the items, please contact the EEGS Office. Thank you for your order!

SAGEEP PROCEEDINGS

			Member	Non-Member
	0041	2016 (USB Thumb Drive)	$75	$100
	0040	2015 (CD-ROM)	$75	$100
	0036	2014 (CD-ROM)	$75	$100
	0034	2013 (CD-ROM)	$75	$100
	0025	2008 (CD-ROM)	$75	$100
	0023	2007 (CD-ROM)	$75	$100

			Member	Non-Member
	0013, 0014, 0015, 0016, 0018, and 0020	CD-ROMs for 2001, 2002, 2003, 2004, 2005 and 2006 are available upon request (call or email EEGS to check availability and place order)	$75 each	$100 each
	0012	1988-2000 (CD-ROM	$150	$225
SUBTOTAL—PROEEDINGS ORDERED				

SAGEEP Short Course Handbooks

	0039	2013 Agricultural Geophysics: Methods Employed and Recent Applications - Barry Allred, Bruce Smith, et al.	$35	$45
	0038	2010 Processing Seismic Refraction Tomography Data (including CD-ROM) - William Doll	$35	$45
	0037	2011 Application of Time Domain Electromagnetics to Ground-water Studies – David V. Fitterman	$20	$30
	0032	2010 Application of Time Domain Electromagnetics to Ground-water Studies – David V. Fitterman	$20	$30
	0027	2010 Principles and Applications of Seismic Refraction Tomography (Printed Course Notes & CD-ROM) - William Doll	$70	$90
	0028	2009 Principles and Applications of Seismic Refraction Tomography (CD-ROM w/ PDF format Course Notes) - William Doll	$70	$90
	0007	2002 - UXO 101 - An Introduction to Unexploded Ordnance - (Dwain Butler, Roger Young, William Veith)	$15	$25
	0009	2001 - Applications of Geophysics in Geotechnical and Environmental Engineering (HANDBOOK ONLY) - John Greenhouse	$25	$35
	0004	1998 - Global Positioning System (GPS): Theory and Practice - John D. Bossler & Dorota A. Brzezinska	$10	$15
	0003	1998 - Introduction to Environmental & Engineering Geophysics - Roelof Versteeg	$10	$15
	0002	1998 - Near Surface Seismology - Don Steeples	$10	$15
	0001	1998 - Nondestructive Testing (NDT) - Larry Olson	$10	$15
	0005	1997 - An Introduction to Near-Surface and Environmental Geophysical Methods and Applications - Roelof Versteeg	$10	$15
	0006	1996 - Introduction to Geophysical Techniques and their Applications for Engineers and Project Managers - Richard Benson & Lynn Yuhr	$10	$15

Books and Miscellaneous Items

	0031	***New Pricing!!*** Advances in Near-surface Seismology and Ground Penetrating Radar—R. Miller, J.Bradford, K.Holliger Special Pricing Available for Limited Time—through March 23, 2017—end of SAGEEP 2017!	$79	$99
	0022	Application of Geophysical Methods to Engineering and Environmental Problems - Produced by SEGJ	$35	$45
	0019	Near Surface Geophysics - 2005 Dwain K. Butler, Ed.; Hardcover—Special student rate - $71.20	$89	$139
	0035	Einstein Redux: A Humorous & Refreshing New Chapter in the Einstein Saga—D.Butler	$20	$25
		EEGS Lapel Pin	$ 3	$3
		SUBTOTAL—SHORT COURSE/MISC. ORDERED ITEMS:		

EEGS STORE

Publications Order Form (Page Two)

***Journal of Environmental and Engineering Geophysics* (JEEG) Back Issue Order Information:** **Member Rate: $15 | Non-Member Rate: $25**

Qt.	Year	Issue		Qt.	Year	Issue		Qt.	Year	Issue
	1995	To order volumes from			**2006**	JEEG 11/1 - March			**2011**	JEEG 16/4 - December
	to	1995 through 1999				JEEG 11/2 - June			**2012**	JEEG 17/1 - March
	1999	Contact EEGS (call or				JEEG 11/3 - September				JEEG 17/2 - June
		email) for availability				JEEG 11/4 - December				JEEG 17/3 - September
		and to order			**2007**	JEEG 12/1 - March				JEEG 17/4 - December
	2000	JEEG 5/3 - September				JEEG 12/2 - June			**2013**	JEEG 18/1 - March
		JEEG 5/4 - December				JEEG 12/3 - September				JEEG 18/2 - June
	2001	JEEG 6/1 - March				JEEG 12/4 - December				JEEG 18/3 - September
		JEEG 6/3 - September			**2008**	JEEG 13/1 - March				JEEG 18/4 - December
		JEEG 6/4 - December				JEEG 13/2 - June			**2014**	JEEG 19/1 - March
	2003	JEEG 8/1- March				JEEG 13/3 - September				JEEG 19/2 - June
		JEEG 8/2 - June				JEEG 13/4 - December				JEEG 19/3 - September
		JEEG 8/3 - September			**2009**	JEEG 14/1 - March				JEEG 19/4 - December
		JEEG 8/4 - December				JEEG 14/2 - June			**2015**	JEEG 20/1 - March
	2004	JEEG 9/1- March				JEEG 14/3 - September				JEEG 20/2 - June
		JEEG 9/2 - June				JEEG 14/4 - December				JEEG 20/3 - September
		JEEG 9/3 - September			**2010**	JEEG 15/1 - March				JEEG 20/4 - December
		JEEG 9/4 - December				JEEG 15/2 - June			**2016**	JEEG 21/1 - March
	2005	JEEG 10/1 - March				JEEG 15/3 - September				JEEG 21/2 - June
		JEEG 10/2 - June				JEEG 15/4 - December				JEEG 21/3 - September
		JEEG 10/3 - September			**2011**	JEEG 16/1 - March				JEEG 21/4 - December
		JEEG 10/4 - December				JEEG 16/2 - June				
						JEEG 16/3 - September				
SUBTOTAL—JEEG ISSUES ORDERED										

SUBTOTAL - SAGEEP PROCEEDINGS ORDERED	
SUBTOTAL - SHORT COURSE / BOOKS & MISCELLANEOUS ITEMS ORDERED	
SUBTOTAL - JEEG ISSUES ORDERED	
CITY & STATE SALES TAX (If order will be delivered in the Denver, Colorado—add an additional 7.62%)	
SHIPPING & HANDLING (US—$15; Canada/Mexico—$25; All other countries: $50)	
GRAND TOTAL:	

Order Return Policy: Returns for credit must be accompanied by invoice or invoice information (invoice number, date, and purchase price). Materials must be in saleable condition. Out-of-print titles are not accepted 180 days after order. No returns will be accepted for credit that were not purchased directly from EEGS. Return shipment costs will be borne by the shipper. Returned orders carry a 10% restocking fee to cover administrative costs unless waived by EEGS.

Payment Information:

☐ Check #: ________________________________ (Payable to EEGS)

☐ Purchase Order: ________________________________
(Shipment will be made upon receipt of payment.)

☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover

Important Payment Information: Checks from Canadian bank accounts must be drawn on banks with US affiliations (example: checks from Canadian Credit Sulsse banks are payable through Credit Sulsse New York, USA). If you are unsure, please contact your bank. As an alternative to paying by check, we recommend sending money orders or paying by credit card.

Card Number: ______________________________ CVV# _____
Exp. Date: ____

Cardholder Name (Print) ____________________________________
Signature: ____