



FastTIMES

Volume 28, No. 3, September 2026

EEGS Updates

Columns & Resources

Geology-Informed Near-Surface

Geophysics

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Cover Photo: Summer of Applied Geophysical Experience (SAGE) students using near-surface electromagnetic techniques to help resolve the geologic controls on the locations of fens in the Valles Caldera, New Mexico, USA, in June 2026. Credit: Summer of Applied Geophysical Experience (SAGE)

Correction: The June 2026 *FastTIMES* stated there was one MASW course scheduled at SAGEEP 2026, and it was canceled. There were two MASW courses scheduled, and only the first was canceled.



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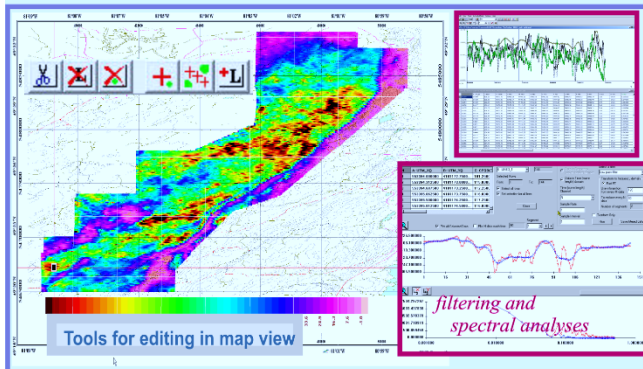
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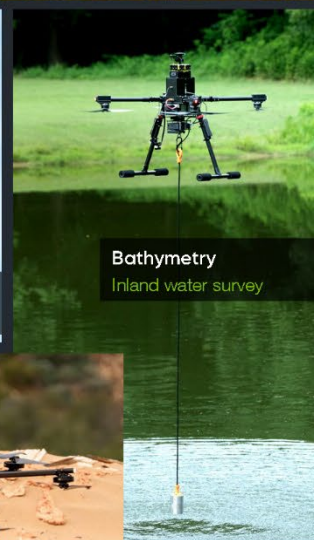
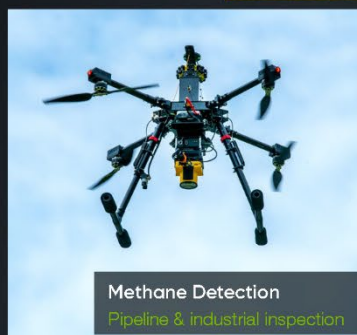
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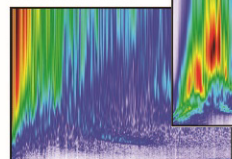
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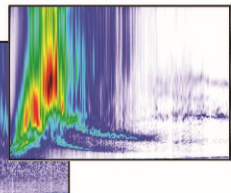
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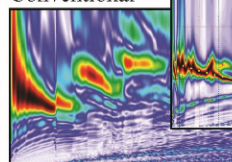


HRLRT

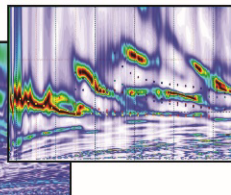


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Conventional



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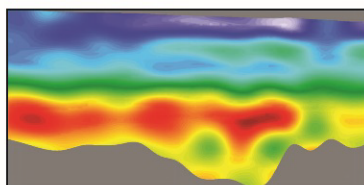


SurfSeis® 6

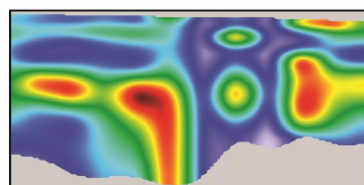
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V_s
with Variable Depth and Topography



Q_s
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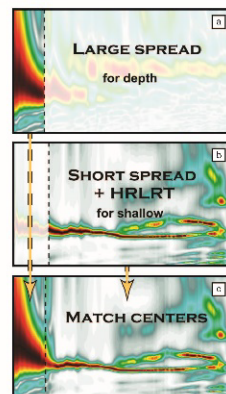
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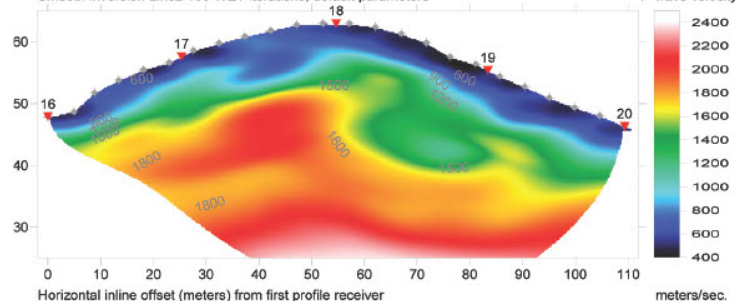


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EEGS Updates

EEGS President



Jacob Sheehan
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It is hard to decide where to start, so I will begin with SAGEEP 2026. In my last letter, I shared my belief that it was a successful conference, and the months since then have confirmed that impression, both technically and financially. While the financial side may be less exciting to discuss than the technical content, this success will help our organization continue to grow and expand what we can offer to the community. Thank you to all the attendees, speakers, organizers, and sponsors who made this success possible.

FastTimes continues to impress as Cian Dawson brings his vision for the newsletter to life. We also have a new edition of *JEEG* thanks to the efforts of our honorary (and unfortunately temporary) Editor in Chief, Dale Rucker. Dale came out of *JEEG* retirement to bring this issue together, and if you have not yet had a chance to read it, I encourage you to do so. It has enough excellent content to feel like two issues in one.

Looking ahead, I am hearing great things about season three of GAINS. Even if you attended during the first two years, I encourage you to join us for this season. The Education Committee has been busy adding new topics and new speakers, and another strong program is taking shape.

I am also hearing rumors of an upcoming photo contest with some great prizes, so now is a good time to start gathering—or taking—those photos. Watch our [LinkedIn](#)



[page](#) and keep an eye on your inbox for more information soon.

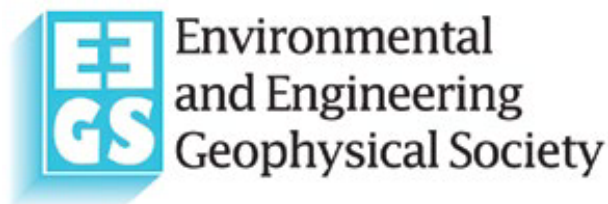
Finally, it is time to start thinking about SAGEEP 2027. You can find a SAGEEP update elsewhere in this issue of *FastTIMES*, so I will not repeat those details here. I will simply say that, based on the updates from the planning committee, I am excited about it.

Sincerely,

Jacob Sheehan
EEGS President



***FastTIMES* Editor-in-Chief**



Welcome!

Welcome to the September 2026 *FastTIMES*, EEGS's near-surface geophysics magazine!

This has been a challenging couple years for many scientists. But the diverse contributions to this issue highlight the resilience, innovation, and vital science happening every day in our near-surface communities.

I hope that this issue helps connect members with EEGS and each other by increasing awareness of opportunities and resources and highlighting recent activities. Don't forget to reach out to authors to follow up!

EEGS Updates

Be sure to browse the EEGS updates, including timely information on JEEG, SAGEEP 2027, GAINS training, and opportunities to volunteer.

Topical Columns

I'm pleased to see that *FastTIMES* recurring topical columns are gaining momentum. This issue's columns include

- *Collaboration Corner* update on the Taking the Pulse of the Planet project.
- *Community Connections* recap of the AGU-SEG Hydrogeophysics Workshop.
- *Signals & Systems* on the importance of open science and actionable evidence.

To propose future column articles, reach out to me. But please act early: many column contributions are being confirmed far in advance – an exciting indication of interest.

Geology-Informed Geophysics

This issue's scientific theme focuses on how geological knowledge improves near-surface geophysics survey planning, data acquisition, interpretation, and decision-making. This is not a new concept – but it is evergreen! Everything from initial methods selection through data

analysis and interpretation need to consider real-world site geologic and hydrologic frameworks.

There was a great response: we have several strong articles highlighting what this looks like in daily practice in a variety of applications.

Submit Community News & Notes!

Share your updates with the community for the December *FastTIMES*:

- Recent photos for the gallery;
- Upcoming conferences for the calendar;
- [Short professional news and notes](#).

Send photos and events to staff@eegs.org. Use [the online form](#) for notes. *Deadline: October 15.*

December Issue Call for Papers

The December 2026 *FastTIMES* will focus on *AI/ML in Near-Surface Geophysics*. [Visit the EEGS website](#) for details about submitting, including important deadlines, page limits, and guidelines. Rebekah Lee will be a guest editor.

Cian Dawson
Editor-in-Chief, *FastTIMES*
cian@cbdawson.com



Photo Credit:

JEEG Update

Dale Rucker, Certerra Subsurface Imaging

Well, here we are. It has been six years since I last sat in the editor's chair for the Journal of Environmental and Engineering Geophysics, and I did not expect to return to it. I served as Editor-in-Chief from 2016 through 2020, and I write now as a past president of the Environmental and Engineering Geophysical Society. When delays and a few communication gaps threatened to hold up this volume, I volunteered to step back in and see it through to publication. I will admit that it has been a real joy to read manuscripts again, and to watch a set of papers come together into a finished issue. That joy is tempered by the knowledge that this is the last issue of *JEEG* for now. The journal is entering a hiatus while EEGS works to identify a new editor and to gain a clearer picture of the Society's finances. Bittersweet is the right word for it.

If this is to be the final issue for a while, it is a strong one to go out on. The eight papers collected here span much of what makes near-surface geophysics such a rewarding field to work in. Readers will find a general inversion code tested against three case studies, a cautionary look at using SPT blow counts to estimate shear wave velocity for ASCE 7-22 site classification, and a comparison of passive MASW and HVSR measurements at a Tennessee dike. Ground penetrating radar features prominently, with contributions on the homogeneity of rock fills, the imaging of fractures and dissolution cavities, and a deep learning method for automatically detecting hidden hazards in levees. Rounding out the issue are preliminary results from a novel frequency domain electromagnetic device for mapping permafrost and a new Gram-Schmidt-based finite difference scheme for acoustic wave modeling. The authors come from across the globe, and their work reflects the methodological range that has long been the journal's strength. It is currently available at <https://pubs.geoscienceworld.org/jeeg/issue/30/1> for you to check out yourself. If you are a member of EEGS, access the issue through <https://www.eegs.org/jeeg-current-issue>.

To everyone who contributed to this issue, the authors, the associate editors, and the reviewers who gave their time without much in the way of public thanks, I am grateful. A pause in *JEEG* does not mean the Society has gone quiet. *FastTIMES* remains active and is publishing articles on a regular basis, and it continues to be one of the best places to share work, ideas, and news with the near-surface community. If you have something you would like to contribute, please reach out to Cian Dawson, who would be glad to hear from you. It has been an honor to help carry *JEEG* across this threshold, and I look forward to the day the journal finds its footing and resumes the run it deserves.

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EEGS Committees Update

Amber Onufer, President, Exploration Instruments EEGS Vice-President Elect – Committees

One of the Board's ongoing priorities has been strengthening the Society's committee structure to ensure every committee has a clear mission, defined responsibilities, and measurable goals. Over the past year, committee chairs and Board members have worked together to develop and update committee charters that better reflect the needs of today's EEGS.

We are pleased to announce that these committee charters are now available on the EEGS website. Each charter outlines the committee's mission, scope, annual goals, responsibilities, membership structure, and expected deliverables. By clearly defining the purpose of each committee, we hope to make it easier for members to understand where they can contribute and how each committee supports the Society's strategic objectives.

Whether your interests lie in membership growth, education, publications, finance, intersociety collaboration, conference planning, awards, or governance, there is a committee where your experience and ideas can make a meaningful impact.

Serving on an EEGS committee is one of the best ways to become involved in the Society, expand your professional network, and help shape the future of environmental and engineering geophysics. Committees provide an opportunity to work alongside colleagues from academia, industry, government, and consulting while contributing to initiatives that directly benefit our members and the profession.

We encourage all members (whether you are an early-career professional, student, or long-time member) to explore the committee charters and consider volunteering. Fresh perspectives and diverse expertise are essential to keeping EEGS a vibrant and forward-looking organization.

You can review all committee charters and learn more about each committee here: <https://www.eegs.org/board-of-directors-committee-chairs>

If you are interested in serving on a committee, please contact the committee chair listed on the webpage or reach out to the EEGS Business Office. We welcome your involvement and look forward to working with you as we continue building a stronger Society together.

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SAGEEP Update

Jeff Gamey, VP SAGEEP 2027

It gives me great pleasure to announce that planning for SAGEEP 2027 has been progressing extremely well due to the efforts of the enthusiastic team of volunteers on the Planning Committee. We will be updating the geoscience community through various media as we move towards our next exciting conference.

You'll be pleased to know that we have already secured the venue and dates for the event. We'll be meeting at the *Sheraton Music City Airport Hotel in Nashville, April 11-15, 2027*. We've also introduced a new partnership with our exhibitors who have signed up in advance to secure a booth at a discount. My perpetual thanks go to Amber Onufer and the exhibitors who pulled this together. Amber and her team are continuing to invite exhibitors, so I expect to see more of you at SAGEEP 2027.

Our theme for the year is *Humanitarian Applications of Geophysics*. This covers a wide range of applications from groundwater and sinkholes to munitions and earthquakes. Correspondingly, we're hosting a parallel stream of Munitions Response technical sessions as part of our biennial partnership with the UXO industry.

We're also planning an exciting field trip through some of the local karst features. The Nashville area boasts more than 10,000 such features to choose from, and we'll only be able to cover a few of them, but it shows just how much there is to learn at this conference.

Our student sections are similarly busy planning a luncheon around another very human topic – the ethics of AI in geophysics. And we're planning an outdoor demo at Andrew Jackson's Hermitage where our many vendors will be collecting data at live archeological sites of interest – telling yet another very human story through geophysics.

As you can see it's a busy time and some plans are obviously still in flux, but abstract submissions will be opening soon. So, brush off your ideas and case studies

and be prepared to get those in. We're hoping to do something special with the best papers but that's a topic for a later update. In the meantime, save the date of April 11-15, 2027, and keep an eye out for more SAGEEP announcements. I look forward to seeing a full house next spring in beautiful Nashville.

EEGS Contacts

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Learning Lab

Learning Lab is a recurring FastTIMES column focused on EEGS professional development resources, as well as providing updates from the EEGS Education Committee

Making GAINS: A Retrospective of the EEGS Education Committee

Sarah L. Morton Ranney, Ph.D., Paul Schwering, and the EEGS Education Committee

It all started, innocuously enough, with a circle back in a meeting. During an EEGS Board of Directors (BOD) meeting in April 2023, Sarah Morton Ranney found her mind starting to wander while the morning meeting minutes were being reviewed. Sarah had been appointed as Student Committee Chair earlier that year and was now thinking about what the committee could do to better serve its members. It was then she reflected on her own career trajectory and why she was originally drawn to near-surface geophysics: real-world problem solving.

For years she had thought about developing a course focused on applied geophysics and even considered a few academic opportunities that came with teaching positions. One hesitation was that pursuing a university opportunity would likely limit the educational reach and she wanted to create something the greater near-surface community would be able to take advantage, no matter their career stage. All of these ideas began to rapidly coalesce and, at the close of the meeting minutes circle back, Sarah abruptly proposed a multi-week training course to the BOD meeting with a tentative launch date targeted for the following two years! She explained to the BOD that education should be available for all members and furthermore proposed the Student Committee should rebrand as the Education Committee (Ed Comm). She advocated to the Board a training course should reflect how practicing geophysicists were presented with projects in the industry, effectively: “I

have this problem I need to solve; can geophysics help?” Her argument proved persuasive, as a motion unanimously passed. When she asked if anyone would like to help, at-large BOD member Paul Schwering raised his hand and suddenly in only minutes-the old Ed Comm doubled in size!

Now a committee of two, and having articulated an ambitious goal, Sarah quickly started scribbling ideas and formed an initial framework for this notional training course (Figure 1). She passed her brainstorming notes to Paul across the room to Paul and the die was cast; they spent the rest of that SAGEEP meeting in New Orleans formulating the course and set to recruiting more committee members to help make this training program a reality. By the end of the week, the Ed. Comm grew to four members with the additions of Miriam Johnston and Nadia Fantello as EEGS member volunteers.

In July 2023, the Ed Comm held its first Education Summit in Colorado (Figure 1). All four members got together for a two-day strategic planning meeting to identify module topics and discuss program logistics such as how it would be executed (virtually), the makeup of technical modules (two-hour sessions) and how long the program would run (14 weeks). It was also decided that the training program would be available as a new member benefit, rather than offering it at an additional

How GAINS was Made

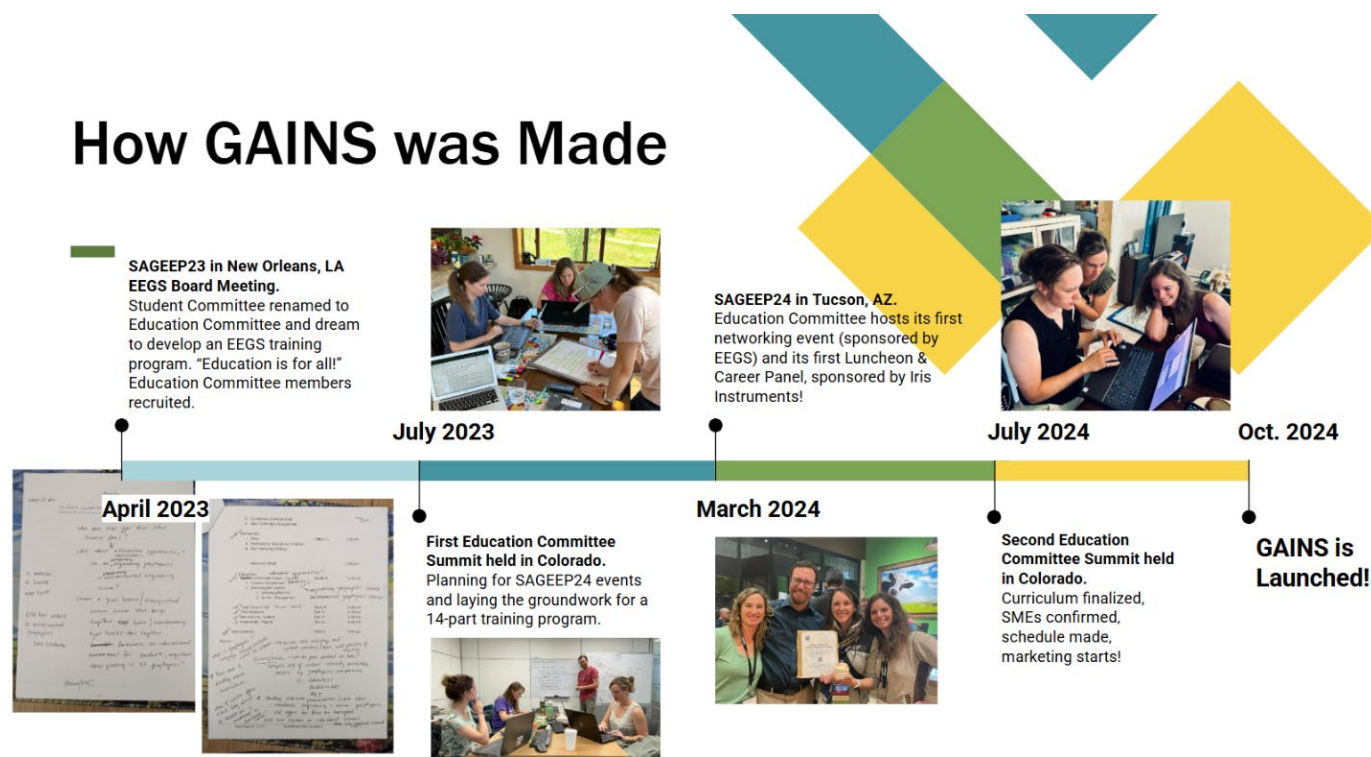


Figure 1. Timeline illustrating the development of the GAINS program that first launched in October 2024. Photos feature Sarah Morton Ranney's graffitied BOD meeting agenda where she developed the GAINS framework (April 2023); Education Committee members Miriam Johnston, Nadia Fantello, Sarah Morton Ranney, and Paul Schwering working at various locations to outline the curriculum and subject matter experts (July 2023); Ed Comm members celebrating at their first Ed Comm sponsored event at SAGEEP (March 2024); and Ed Comm members meeting again to finalize the GAINS program and marketing plan (July 2024) before launching three months later.

cost following the notion that "Education is for everyone." Finally, a name for the program emerged: Geophysical Applications in Near Surface (GAINS).

to week, the consensus was that practitioners are more often presented with a problem to solve: e.g., "I need to map bedrock," rather than "I need seismic refraction tomography." The next step was to recruit various industry professionals, referred to as Subject Matter Experts (SMEs), who would discuss different projects within a specified application space (e.g., dams and levee monitoring), what geophysical methods they would or would not choose to complete the work, survey design considerations, potential pitfalls when investigating that type of problem, and/or review case studies with attendees that illustrate their progress on those types of projects. SMEs were asked to refrain from lecturing on detailed theory and instead highlight their own lessons/experiences and offer a list of resources that have helped shape their own careers.

Course module topics were organized by geophysical application rather than geophysical method (Table 1). Although this would create some redundancy from week

Planning continued through summer 2024 with another Education Summit held in Colorado to finalize details and prepare for its launch (Figure 1). T-shirts, at the suggestion of Dale Rucker, were later designed using the newly minted program logo and soon Ed Comm members and SMEs were wearing GAINS t-shirts at geophysics conferences (Figure 2).

Thanks to the incredible support and will of Jackie Jacoby, Tiffany Clark from the EEGS Membership Committee, the SMEs, and the rest of the BOD, GAINS officially launched in October 2024. Weekly modules were hosted on Zoom, and attendees were encouraged to participate in post-session discussion boards and access links to module recordings. Although continuing education credit or professional development hours

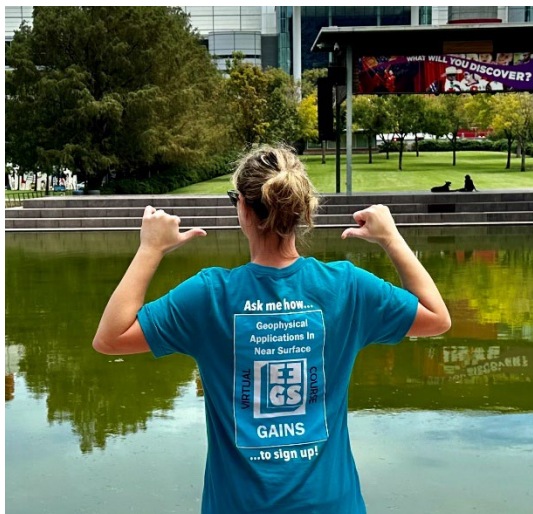


Figure 2. Education Committee member, Nadia Fantello, modeling the GAINS t-shirt with program logo at IMAGE 2023 in Houston, Texas.

(PDHs) are not offered by EEGS, all attendees have received printable Certificates of Attendance that have been successfully used to receive credit hours for different licensing agencies. Another benefit of the program was the GAINS Reference Guide, which compiled information learned from all modules into a summary table. It outlined each application of geophysics discussed, recommended methods for each application, observations or signatures for mapping/imaging the target of interest, and advice from each SME for each topic. This two-page summary table is now available online in the [EEGS Members Only portal](#) with other materials from the GAINS 2024-2025 program.

Table 1. Evolution of GAINS curriculum by Year.

GAINS			
Year 1: October 2024 to March 2025		Year 2: January to March 2026	
Topic:	SME(s):	Topic:	SME(s):
Introduction and Program Overview	Ed Comm Dale Werkema	History and Surveying Essentials	Cathy Skokan Ed Comm
Survey Planning and Site Characterization	Ed Comm	Dams and Levees	Trever Ensele
Utility Locating and Storage Tank Detection	Trever Ensele	Voids and Karst	Jacob Sheehan Mia Painter
Dams and Levees	Phil Sirles	Hydrostratigraphic Mapping and Contaminants	Judy Robinson James St. Clair
Hydrogeology	Scott Ikard	Cold Regions	Esther Babcock
Voids and Karst	Jacob Sheehan Mia Painter	Marine Geophysics	Richard Graham
Pavement and Transportation	Ryan North	Archaeology	Blair Schneider
Geologic Mapping	Sage Wagner	Borehole Applications	Lia Martinez Darin Pendergraft
Critical Minerals and Geothermal	Karen Christopherson	PG Exam and Course Summary	Kate McKinley Ed Comm
Hydrostratigraphic Mapping and Contaminants	Judy Robinson James St. Clair	GAINS Panel at SAGEEP	Rich Krahenbuhl Kennedy Doro Jorden Hayes Sage Wagner
Seismic Hazard	Koya Suto Paul Somerville		
Cold Regions	Esther Babcock		
Course Summary	Ed Comm		
Field Demo at SAGEEP			

After the first year, EEGS registered 300 members for GAINS including 34 student members and 21 corporate members. Modules were attended by 40 to 70 participants each week with recordings having over 770 views by the end of the program in March 2024. Before the end of 2024, EEGS had a record high number of members, exceeding 700 members; this spike in membership is attributed to the GAINS program. Modules topics requested to run again in 2026 were Hydrostratigraphic Mapping and Contaminants and Cold Regions.

GAINS continued into a second year that started in January 2026 with 10 weeks of modules featuring new topics and speakers (Table 1). The new timing of the 2026 program was largely driven by the membership renewal schedule and feedback from previous attendees. The program finished at the 2026 SAGEEP conference in Pittsburgh with a luncheon and panel discussion featuring SMEs and university professions to discuss the Past, Present, and Future of near-surface geophysics education. This luncheon was highlighted in an article in the previous issue of FastTIMES this year. Attendees praised the Dams and Levees, Cold Regions, and Archaeology sessions in 2026. The program also starting archiving recordings and other module documents on the EEGS website within the “Members Only” portal. Members were invited to join the EEGS and GAINS [subreddit](#) to participate in discussion threads between weekly sessions. Meaningful discussions and networking tended to occur during the open Q&A sessions after each SME presentation.

Ed Comm is open for nominations (yourself, or others) to serve 1) as a GAINS SME or 2) as a volunteer member of our committee. Please reach out to sranney@usbr.gov with nominations or questions/comments. The Ed Comm meets on the second Tuesday of each month. [Committees and their current chairs are listed online](#) with each committee’s newly published charter that is also available online. EEGS members are welcome and encouraged to request joining any EEGS committee of interest. Please reach out to staff@eegs.org for more information. Thank you to all who have participated in GAINS and shared information about the program! The program would not exist without the EEGS Community or the SMEs who kindly volunteer their time.

Planning for the next GAINS training is underway with modules starting in January 2027. The curriculum and schedule will be announced in the next issue of *FastTIMES*, so stay tuned and the Ed Comm thanks you for continuing to support GAINS and EEGS!



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Signals & Systems

Signals & Systems is a recurring FastTIMES column for updates on innovation, challenges, and opportunities in near-surface geophysical equipment, software, and systems.

Snake Oil Works Because Pictures Look Like Data

Open data and the discipline of evidence in near-surface geophysics

Alexey Dobrovolskiy, SPH Engineering

The Market Rewards Miracles

A friend once told me: “Those who do not know physics believe in magic.” Another friend, a professional geophysicist and geologist, once said: “I can provide almost any desired interpretation for almost any geophysical data set.”

Both statements are uncomfortable. Both are also true enough to be useful.

Near-surface geophysics has a special weakness: the object of interest is usually invisible. A buyer cannot look underground and directly check whether an instrument sees what it claims to see. Instead, trust is built through signals, maps, processing, interpretation, and expert language. This is powerful when used correctly. It is also dangerous, because a convincing picture can look like evidence even when the evidence behind it is missing.

This is one reason why geophysical snake oil survives. It does not survive only because some buyers are uneducated. That explanation is too simple. In many

cases, buyers are under real pressure: they need cheaper tools, faster answers, easier workflows, and lower project risk. They may not have a geophysicist on staff. They may be comparing professional instruments with marketing materials that promise miracle performance at a fraction of the price.

Physics, unfortunately, does not negotiate with budget.

In a recent discussion, a buyer showed us an advertisement for a long-range detector claiming the ability to find gold nuggets from hundreds or even thousands of meters away (Figure 1). I do not blame the buyer for asking. The offer was exactly what many people want: lower price, simpler operation, and extraordinary performance. The uncomfortable part was not the question. The uncomfortable part was the absence of evidence proportional to the claim.

Examples like this are not difficult to find. The point is not to identify one seller or one product, but to show the pattern: dramatic images, confident language, extraordinary ranges, and very little verifiable data.

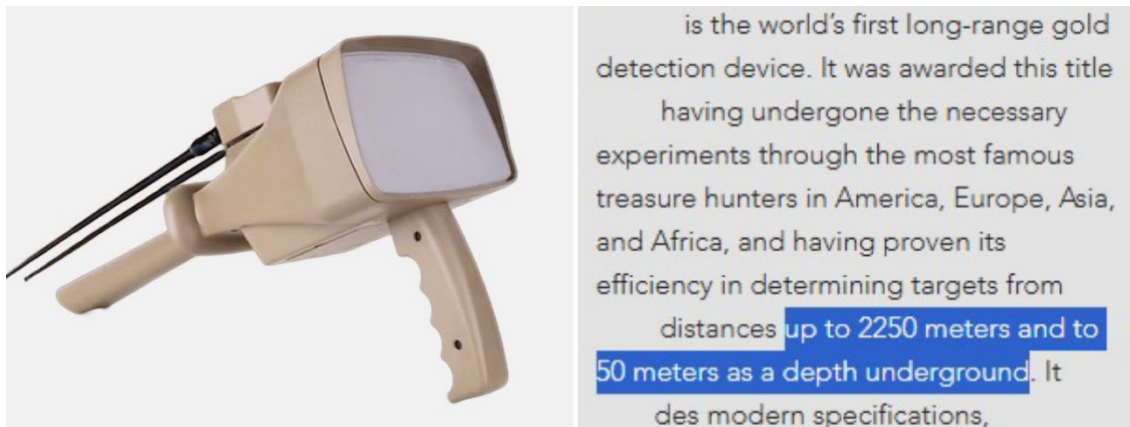


Figure 1. Examples of public long-range detector advertising claims, with identifying details redacted. The issue is not a named product, but the evidence standard required when detection ranges and depths exceed realistic expectations.

When Evidence Disappears

The market contains several recurring categories.

There are “empty” devices: impressive-looking cases, antennas, indicators, batteries, and connectors, but no meaningful measurement principle inside.

There are long-range miracle detectors whose advertised capabilities do not survive basic physics or controlled testing.

There are “almost real” devices: low-grade or hobby-level instruments sold with performance language close to professional systems.

And there are real instruments that are oversold, where laboratory or ideal-condition parameters are presented as if they describe normal field performance.

The last category is important. The problem is not only fraud. The problem is also exaggeration, selective presentation, and the quiet transformation of “possible under ideal conditions” into “expected in the real world.”

This damages everyone. Buyers lose money and time. Projects fail. In UXO and explosive detection, misplaced trust can become a safety issue. Real manufacturers and service companies lose business to unrealistic promises. And when a buyer is disappointed by a fake or oversold device, the disappointment is often transferred to geophysics as a whole.

Four Questions Before Trust

The answer is not to make every buyer a geophysicist. That will not happen. The answer is to make evidence easier to ask for and harder to avoid.

Before trusting an extraordinary claim, a buyer should be able to ask four practical questions.

What physical principle does the instrument use? If the explanation depends on secret military technology, mysterious fields, or words that cannot be tested, that is a warning sign. Working geophysical methods may be technically complex, but their basic principles are not magic.

Has the system been tested over known targets in repeatable conditions? Third-party tests are best.

Double-blind tests are even better for detection claims. But even a systematic report over known anomalies is far better than a brochure.

Can the raw data and metadata be reviewed? Raw sensor files, positioning, survey parameters, target information, and processing steps reveal much more than a final image.

Can the device be tested before purchase, or provided to a trusted party for testing? Serious manufacturers may have practical limitations, but a complete refusal to test extraordinary claims should raise questions.

Pictures Are Not Data

A screenshot, colored map, or exported image may be useful for communication, but it is not evidence by itself. An image is a derivative of data. It depends on filtering, interpolation, gridding, color scale, thresholds, smoothing, and interpretation. These choices can be legitimate. They can also create artifacts, hide limitations, or make weak results look strong.

This is why the second quote at the beginning matters. A geophysical image is not only a measurement; it is also a product of processing and interpretation. Even honest interpretation can be wrong. Dishonest interpretation can be very convincing.

Figure 2 illustrates the problem. A processed map may suggest an anomaly, but the line profile and processing settings are needed to understand whether that feature is supported by measurements or introduced by filtering, gridding, or visualization choices. The screenshot is only an illustration; the evidence is the raw file and processing context behind it.

Open Data as Discipline

This is where open data becomes important.

Open data will not eliminate snake oil, and it should not pretend to. There will always be buyers who prefer miracles, especially when miracles are cheaper than instruments. But open data can change the standard for serious decisions. It moves the discussion from “look at this picture” to “look at this measurement, collected over

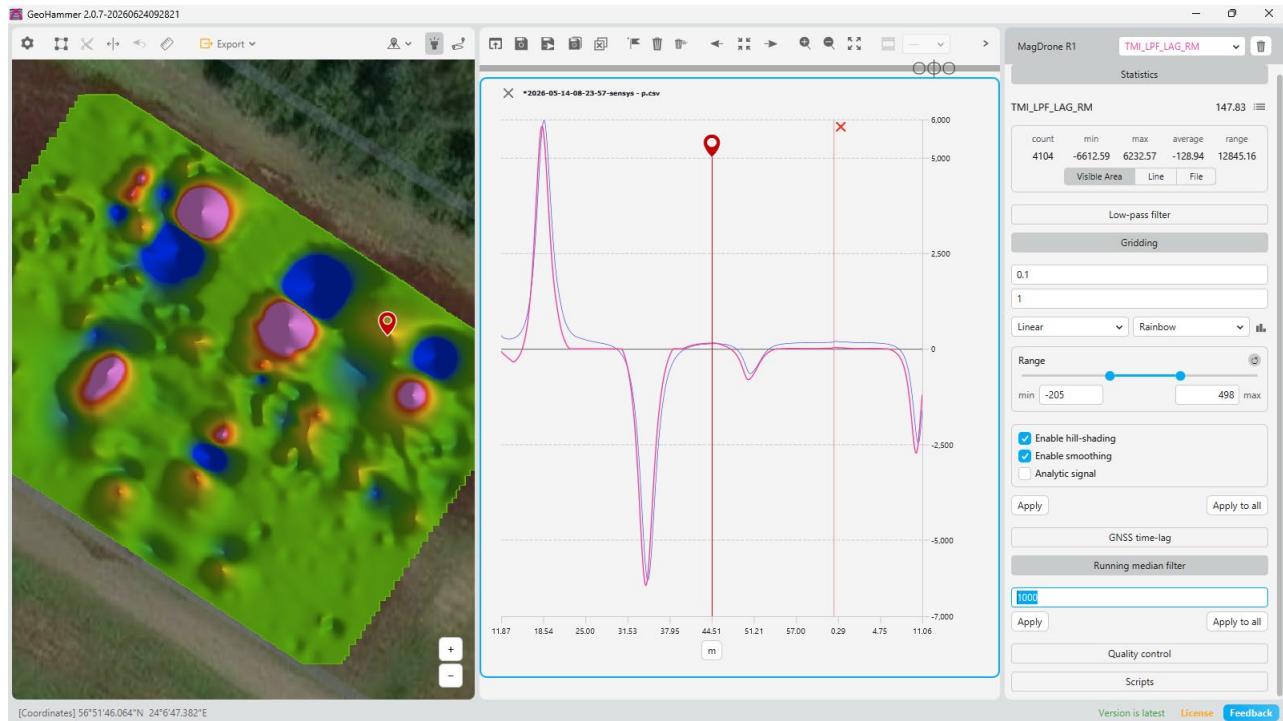


Figure 2. A processed geophysical map can be useful for communication, but the line data, processing settings, and survey context are what allow the result to be checked. A map alone is not the same as evidence.

this target, under these conditions, with these processing steps.”

There are good examples already. The [UAWOS project](#) publishes datasets from unmanned airborne water observing systems, including validation data from more established methods. Test ranges and seeded fields are another strong approach. The [OSU/CENFEX seeded field](#), for example, gives industry and research teams a controlled environment for collecting data over known targets. Related materials include SPH Engineering’s [comparative analysis of UXO detection](#) using atomic total-field and fluxgate magnetometers, and a broader multimodal dataset published on [Zenodo](#).

From Claims to Comparison

At SPH Engineering, our own open data work began with a practical motivation: to prove that systems work and to make technical discussions shorter and more factual. Over time, we found that repeatable datasets collected over the same test areas, with known anomalies, different sensors, different mounting methods, and different survey designs, have value beyond our own sales process.

The [Balozi test range](#) includes permanently installed targets with known coordinates and depths, allowing different sensors and workflows to be compared against the same physical reality.

SPH has also collected additional datasets from locations such as Titurga Lake and Sloka quarry. The table included at the end of this article (Table 1) lists public datasets with direct, currently available links:

We use DroneGIS to publish and organize these datasets. The important point is not only that a map can be viewed, but that raw measurements, processed layers, survey context, and reports can be inspected together (Figure 3).

A Practical Standard

For non-specialists, raw data alone may not answer every question. Interpretation still requires knowledge of physics, site conditions, sensor behavior, and processing. But even a non-specialist can learn to ask whether data exist, whether the target is known, whether the test is repeatable, and whether the result is supported by more than a picture.

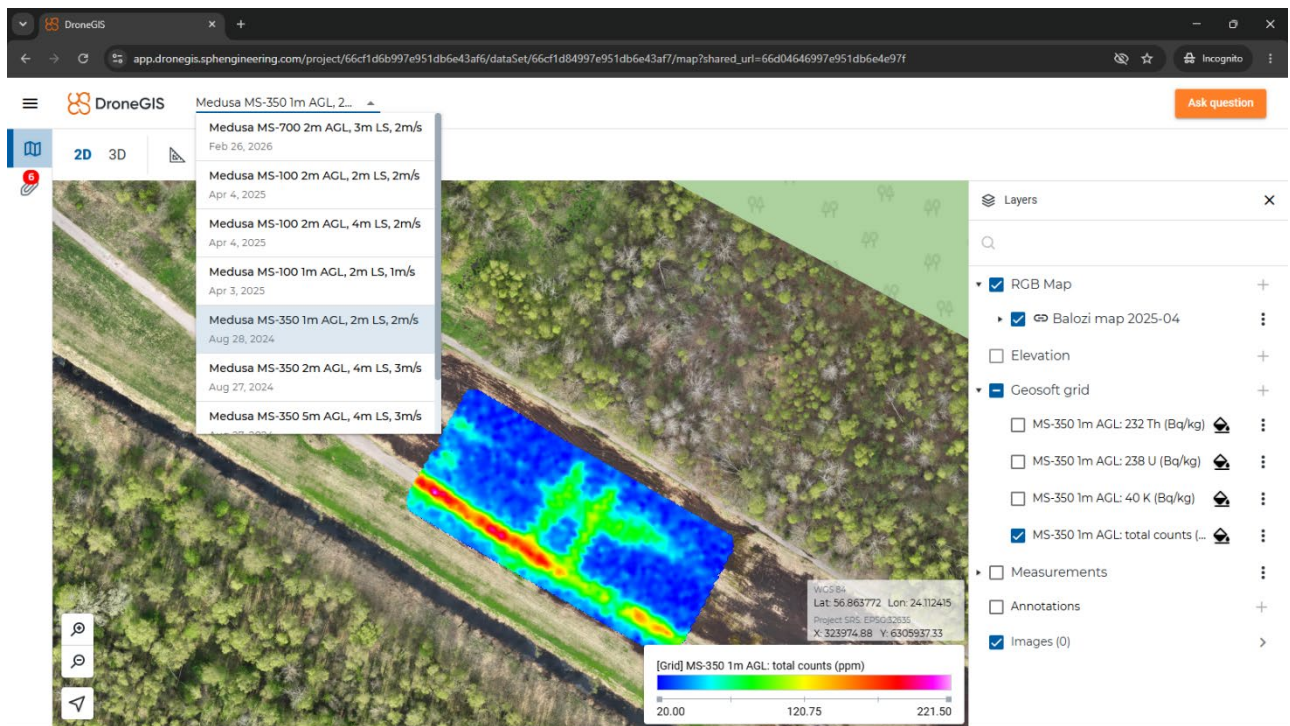


Figure 3. Open datasets are more useful when raw measurements, processed layers, survey context, and reports can be inspected together rather than presented only as final images.

Analytical reports can also help set realistic expectations before a buyer compares them with extraordinary marketing claims. For example, SPH Engineering has published [estimates of UXO maximum detection distances using magnetometers](#).

Open data is not a marketing trick and not a guarantee of truth. It is a discipline. It forces manufacturers, service providers, researchers, and buyers to stay closer to physical reality. It makes exaggeration more difficult. It makes honest comparison easier. It gives serious people something better than trust in words.

If a product works, it should survive raw data, known-target testing, and repeatable comparison. If the answer to every technical question is another screenshot, another secret principle, or another promise, that is also useful information.

The next time a device promises impossible performance at a fraction of the price, the response does not need to be emotional. It can be simple:

Show the physics.

Show the test.

Show the raw data.

Table 1. Currently published public datasets with direct links.

Location / source	Sensor type	Model	Platform / comments	Link
SPH Engineering test range, Balozi	Magnetometer	MagNIMBUS gradiometer	Drone; buried pipes and barrels	Dataset
SPH Engineering test range, Balozi	Magnetometer	MagNIMBUS single-sensor	Drone; buried pipes and barrels	Dataset
SPH Engineering test range, Balozi	Magnetometer	SENSYS MagDrone R1	Drone; buried pipes and barrels	Dataset
SPH Engineering test range, Balozi	Magnetometer	SENSYS MagDrone R3	Drone; buried pipes and barrels	Dataset
SPH Engineering test range, Balozi	Magnetometer	SENSYS MagDrone R4	Drone; buried pipes and barrels	Dataset
SPH Engineering test range, Balozi	Magnetometer	GEM Systems GSM-19W	Terrestrial walking survey	Dataset
SPH Engineering test range, Balozi	Magnetometer	GEM Systems GSMP-35U	Test range survey	Dataset
SPH Engineering test range, Balozi	Magnetometer	Geometrics MagArrow Mk2	Rope-mounted survey	Dataset
SPH Engineering test range, Balozi	Magnetometer	Geometrics MagArrow Mk2	Mounted on DJI M300 RTK legs	Dataset
SPH Engineering test range, Balozi	Gamma-ray spectrometer	Medusa MS-350	Drone	Dataset
SPH Engineering test range, Balozi	Gamma-ray spectrometer	Georadis D230A	Test range survey	Dataset
SPH Engineering test range, Balozi	EMI metal detector	Ebinger VEMOS AIR	Drone / test field	Dataset
SPH Engineering test range, Balozi	EMI metal detector	Geonics EM61Lite	Metallic pipes and barrels	Dataset
OSU/CENFEX seeded field	Magnetometer	MagNIMBUS	DJI M350 RTK; UXO test range	Dataset
OSU/CENFEX seeded field	Magnetometer	SENSYS MagDrone R1	DJI M350 RTK; UXO test range	Dataset
SENSYS GeoMil test range	Magnetometer	MagNIMBUS	Drone	Dataset

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Collaboration Corner

Collaboration Corner is a recurring FastTIMES column highlighting collaborative initiatives and resources.

Taking the Pulse of the Watershed: A Commitment to Open Science

Rosemary Knight, Department of Geophysics, Stanford University; Zach Chandler, Center for Open and Reproducible Science, Stanford Institute for Human-Centered AI; Meredith Goebel-Szenher, Department of Geophysics, Stanford University.

Introduction to the Watershed Project

Taking the Pulse of the Planet is a new research and teaching initiative at Stanford University, with the defined vision being: a global network of sensors - satellite, airborne, land/water-based - to support the adaptive management of planetary health and human activities. A global network of sensors is an ambitious vision which we recognize can only be reached with a global network of people. In order to reach and engage this global network of people, we are committed to ensuring that all activities undertaken as part of Pulse of the Planet align with the principles of Open Science, a movement within the global scientific community that promotes open access publishing, open-source software, FAIR (Wilkinson and others, 2016) data sharing, and transparent, reproducible methods.

In October 2025, we launched the first research project under Pulse of the Planet: [Taking the Pulse of the Watershed](#), with the names of the 12 faculty leads and other project participants given [here](#). Throughout the world, climate change, population growth, and land-use change are negatively impacting both the quantity and quality of available freshwater. We recognized a need to transform the approach to sustainable freshwater management; and believed that the way to do this was through positioning sensors and the acquired data as a central component in all aspects of freshwater management. The specific goal of the Watershed Project

was defined as *the development of a sensor-informed analytical framework that will allow us to accurately quantify connected changes in human-ecological-hydrologic systems across scales and varying climatic, topographic, geologic, and landcover settings*. We are advancing the utilization of existing sources of data through the development of novel workflows, and are developing the capabilities to acquire, process, and interpret new forms of data with new types of sensors. The sensor-informed analytical framework is being structured so that it can be adopted, with minor modification, at the local, regional, and global scales.

Given the challenges being faced in California's Central Valley, with recurring periods of extended drought, we elected to start with a geographic location close to Stanford: the San Joaquin Valley (the southern part of the Central Valley), with the Kaweah Subbasin as the smaller area for targeted development of new sensors and new workflows. Over the past year in this subbasin, researchers in the Watershed Project have deployed 14 broadband seismometers to explore ways of monitoring changes in groundwater storage, and a distributed acoustic sensing (DAS) interrogator to capture data along 130 km of a telecommunications cable. Work has begun on data integration, starting with exploring optimal ways of interpolating between spatially and temporally sparse water level measurements in wells. New approaches are being developed for monitoring the exchange between surface water and groundwater, with satellite InSAR measurements used to monitor river-

sourced groundwater recharge, and distributed temperature sensing (DTS) used to monitor groundwater discharge into the Tuolumne River. New sensors are being developed: To expand the number of stream gauges, by reducing the costs of purchase and maintenance, river-side gauges are being developed; and to provide more timely water quality measurements, in-well sensors are being developed to measure the concentrations of nitrate, arsenic, and uranium. Information about these activities can be found through the [Watershed Project website](#).

From the start, we have committed to this being an Open Science project, welcoming and seeking collaboration with others who share our vision of advancing the adoption of sensors for freshwater management. Our Open Science motivations:

- 1) Accelerating innovation through collaboration.
- 2) Rigor and reproducibility in data and data analysis.
- 3) Expanding access and participation in science.
- 4) Creating opportunities for early career researchers.

As an Open Science project, over the past year we have 1) adopted a platform to facilitate the sharing of data and workflows, 2) hosted weekly seminars to explore a wide range of topics, 3) initiated an online forum where discussion of seminar topics (and other topics) can continue, and 4) encouraged the rapid sharing of results. Each of these is described in more detail below. Important in all aspects of our work is ensuring that we acknowledge all contributions. While the old saying - “imagine what could get done if no-one cared who gets the credit” - had good intentions, we believe a lot more can get done if we all care that others get credit for their contributions.

Redivis: Sharing Data and Workflows

Most Open Science initiatives focus on data sharing as early as the moment of first publication. Taking the Pulse of the Watershed embraces a radically open approach by sharing data prior to publication, allowing others to see the research as it unfolds and have access to the same tools that our researchers have, during the analysis phase of the research. This is done using the cloud-based [Redivis data platform](#). While our goal is to

make our datasets and workflows maximally available, we adhere to the principle of “as open as possible, as closed as necessary” to accommodate cases where restrictions exist on source data, or the data are sensitive in nature. The platform allows for individualized access restrictions on each dataset or workflow.

Data citation and provenance are of utmost importance to us, and we encourage all project participants to [cite data correctly](#), sharing credit with source data providers, and acknowledging the role of data curators in making data more accessible and useful. Through Redivis, both datasets and workflows can obtain digital object identifiers (DOIs) linked to an individual's ORCID to enable proper citation. Our aims include developing metadata standards to ensure flow-through credit to the original creators of any dataset not originating within the Pulse project. We recognize that this may extend the existing practices for persistent identifiers and data citation, so we are interested in adopting a community-centered approach to deriving a best practice. In this way, we are joining the [Make Data Count](#) movement, and welcome community engagement and feedback.

Seminar Series

The Watershed Project hosts seminars, Wednesdays 11-12 pm PT, approximately twice a month throughout the academic year. These are advertised and the zoom link posted at [this website](#). The recordings from many of the seminars are available through the website or on the Stanford Doerr School of Sustainability [YouTube channel](#). With the intent of acknowledging contributions, provided slide decks from presentations can be deposited in [Zenodo](#) and assigned a DOI.

The Watershed Project has been designed to build partnerships with an aim to develop and implement research that will inform decision makers and build toward solutions. In the fall of 2025, we began with presentations by some of our partners: representatives from the California Department of Water Resources, one of the water managers in the Kaweah Subbasin, and the consultants supporting the local agencies. This fall we will have seminars that will provide updates on the four parts of the Watershed Project: water quantity, surface water-groundwater interactions, water quality, and

integrated modeling through the development of a digital twin of the San Joaquin Valley.

Web Forum

Another way that we aim to engage with outside researchers or interested members of the public is via our online [Web Forum](#). After creating a free account, anyone can visit existing discussion topics and post questions or comments on those, or start their own threads on relevant topics of interest. In addition to general interest topics, we have posts that continue conversations started in our seminar series.

Rapid Sharing of Science

We believe that there is an urgency to what we are doing in the Watershed Project. To reflect that urgency, we have a desire to release our findings openly and rapidly, in ways that are responsible and appropriate given the nature of the content. While many of us routinely share our findings by publication in the peer-reviewed literature, preprints can be a viable and valuable option for sharing findings with the broader community. Here we use the word “preprints” to include manuscripts that are on their way (or soon/eventually to be on their way) through the peer-review process and manuscripts that are a final product and not intended for publication in the peer-reviewed literature. In the Watershed Project, we are promoting the use of preprints so that our work can move rapidly to support decision-making and solutions in the sustainable management of our freshwater resources.

In Closing

More details on all of the above topics can be found on the website for the [Watershed Project](#), with a link to [Open Science](#) that expands on our efforts in this area. Most importantly - please join us! We are actively looking for collaborators who are keen to interact with our faculty, students, and postdocs - collect data at our field sites, analyze datasets, suggest new topics that we should be exploring, etc. If you are interested, please fill in [this form](#). We will respond and welcome you to the Watershed Project.

Acknowledgements

The Watershed Project is funded by the Stanford Doerr School of Sustainability’s Solution Areas Program. This project succeeds due to the commitment by all involved researchers to rapidly moving research to solutions, and due to the high level of support received from project partners and collaborators.

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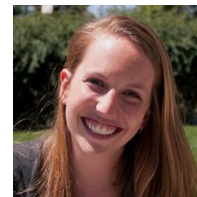
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Community Connections

Community Connections is a recurring FastTIMES column providing highlights from recent scientific meetings and conferences of key interest to the near-surface geophysics community.

4th AGU-SEG Hydrogeophysics Workshop Recap

Sina Saneiyan, Binghamton University

The [4th AGU-SEG Hydrogeophysics Workshop](#) brought more than 40 scientists from around the world together in Boise, Idaho, for a second time since the inception of this cross-society workshop in early 2000s. The goal of the workshop was to bring researchers from both the applied geophysics and hydrology communities together to share the most recent advances in the field of hydrogeophysics.

The workshop started with a two-day short course on Electrical and Hydraulic Properties of Granitic Soils by Dr. Qifei Niu. The first day revolved around fundamentals and laboratory measurements, and the second day was about data processing, modeling, and field hydrogeophysical data interpretation, with the objective of providing graduate students and early career researchers a foundational understanding of the hydraulic and electrical properties of critical zone materials in the context of hydrogeophysical applications.

To cover the newest and most important advancements of the past decade, we designed four themes for the workshop: 1) Hydrogeophysics in Groundwater Science, Application, Society; 2) Hydrogeophysics in Soil and Critical Zone Sciences; 3) Hydrogeophysics in Environmental Science and Remediation; and 4) Computational Techniques in Hydrogeophysics. This allowed us to cover a broad range of topics. Three keynote speakers were invited who provided valuable insights from very different perspectives. On the first day, Professor Andrew Binley from Lancaster University, UK, an AGU Fellow, spoke about recognizing uncertainty in hydrogeophysics and the dangers of misinterpreting geophysical findings in hydrological work. On the second day, Dr. Daniella Rempe from the University of Texas at Austin touched

on field research and applications of hydrogeophysics in understanding hillslope hydrology. She also introduced us to novel advancements in plant hydrogeophysics. Finally, on the third day, Dr. Dale Rucker from Certerra Subsurface Imaging (formerly hydroGEOPHYSICS, Inc.) spoke about how to tackle hydrogeophysical challenges in industry and how to deliver meaningful insights about subsurface hydrological properties to clients.



Professor Binley speaking about recognizing uncertainty in hydrogeophysics.

The first two days included lightning talks followed by poster sessions. On the last day, we had a comprehensive roundtable discussion built around three major topics: 1) advances in hydrogeophysics, 2) integrating hydrology, geophysics, and other disciplines and/or techniques to address science questions, and 3) computational advances, AI/ML, and uncertainty quantification. The discussion aimed to answer two questions: what are the most critical paradigm shifts, structural changes, or technological leaps that have occurred since the

benchmark review by Binley et al. (2015), and what are the urgent scientific, climate, environmental, or societal pressures driving our field? The discussions wrapped up with an hour of open discussion summarizing the entire workshop.



Lightning talks and poster sessions on days 1 and 2 of the workshop.

Following the roundtable discussion, we were joined by Dr. James McNamara, professor of hydrology in the Department of Geosciences at Boise State University, and headed out on a field trip to the Treeline Site of the Dry Creek Experimental Watershed (DCEW). This experimental watershed is designed for research and education in watershed science, and its mission is to provide temporally continuous and spatially distributed hydrometeorological and geographical data from point to watershed scales for researchers and educators. It is also an experimental site where various geophysical

instruments have been applied to hydrologic studies. DCEW covers a diverse landscape, from dry lowland grasslands to snowy upland forests, offering valuable opportunities to investigate interactions among hydrologic, geologic, and ecologic processes and properties in the mountainous rain-snow transition zone characteristic of much of the semiarid western United States.

The workshop officially concluded with a social hike at the Bogus Basin resort.



Social get together at a local restaurant in Boise, Idaho.

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Near-Surface Geophysics Community Calendar

AEM2026: 9th International Airborne Electromagnetics Workshop

<https://www.airborneem.org/>

7–10 September 2026

2026 SEG 2nd Workshop on Fiber Optics Sensing

https://seg.org/calendar_events/2026-seg-2nd-workshop-on-fiber-optics-sensing/

10–12 September 2026

Association of Environmental & Engineering Geologists (AEG) Annual Meeting

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13–19 September 2026

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20–24 September 2026

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<https://www.ngwa.org/detail/event/2026/09/21/default-calendar/26sep5017>

21–22 September 2026

Highway Geology Symposium

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28 September – 1 October 2026

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2026 SEG Summit on Drone Geophysics

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30 November – 3 December 2026

American Geophysical Union 2026 (AGU26)

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7–11 December 2026

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11–15 April 2027

Postcards from the Field

Postcards from the Field is a recurring FastTIMES feature sharing photos from recent near-surface geophysics work. Community members are invited to submit your photos for future consideration



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Geology-Informed Near-Surface Geophysics

A Resistivity Imaging Refresher: 3D Effects, Sensitivity and Error Considerations

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Abstract

Electrical resistivity tomography (ERT) has been used to investigate the subsurface, from evaluation of buried infrastructure to monitoring of groundwater processes. However, interpreting the images can be challenging when the current flow is 3D and associated surveys are commonly undertaken using 2D measurements. This article explores how 3D effects from offline features, sensitivity with depth and assumptions about modeling error can influence ERT inversions, using synthetic modeling. Using the synthetic model, and varying elements within (i.e. location of offline anomaly and depth to geological boundaries), we demonstrate that the resulting inversion may have associated artifacts that could lead to erroneous interpretations with field surveys. We also compare 2D and 3D models, highlighting that 3D models can provide more representative inversions than 2D models with fewer artifacts (e.g. from 3D effects). Understanding these limitations and utilizing ERT survey and inversion plans to account for these offline effects will produce more reliable ERT results.

Introduction

Electrical resistivity tomography (ERT) has proven to be a useful technique for subsurface visualization due to its sensitivity to moisture content, pore-water chemistry, clay content, temperature and geological composition. This has led to its use for many purposes, including identification and tracking of contamination plumes, monitoring leakage through dams, assessment of groundwater processes, characterization of geological

heterogeneity, sinkhole formation, archaeological mapping, and more. However, such visualizations are

limited by 3D effects, where offline features may influence the inversion, given that the electrical current flow is 3D, and inversions are commonly undertaken in 2D. Resolution limitations at depth, and inversion artifacts when measurement errors are not correctly quantified, further limit ERT visualizations. Here, we use synthetic models to provide a refresher for ERT practitioners on limitations in ERT acquisition and interpretation that are often overlooked. Our objective is to highlight potential overinterpretation of ERT visualizations, where interpreted features may simply be artifacts due to poor sensitivity at depth, induced by 3D effects, or the result of an inappropriate error weight in the inversion.

Methodology

A synthetic model was developed to demonstrate how overinterpretation of inverted ERT datasets may occur due to 3D effects, poor sensitivity and inappropriate error modeling. The associated model used for different inversion scenarios is shown in Figure 1 and the inversion codes used for modeling were R2 and R3t (Binley and Slater, 2020).

Changes to the model to highlight how erroneous interpretations of ERT could be made include altering the lateral offset of the ‘box’ anomaly from the ERT array in separate models. Alongside this, the depth to the geological boundary was varied, and several models were undertaken with different percentages of random Gaussian noise added to the input file for inversion to demonstrate the importance of error assessment on the.

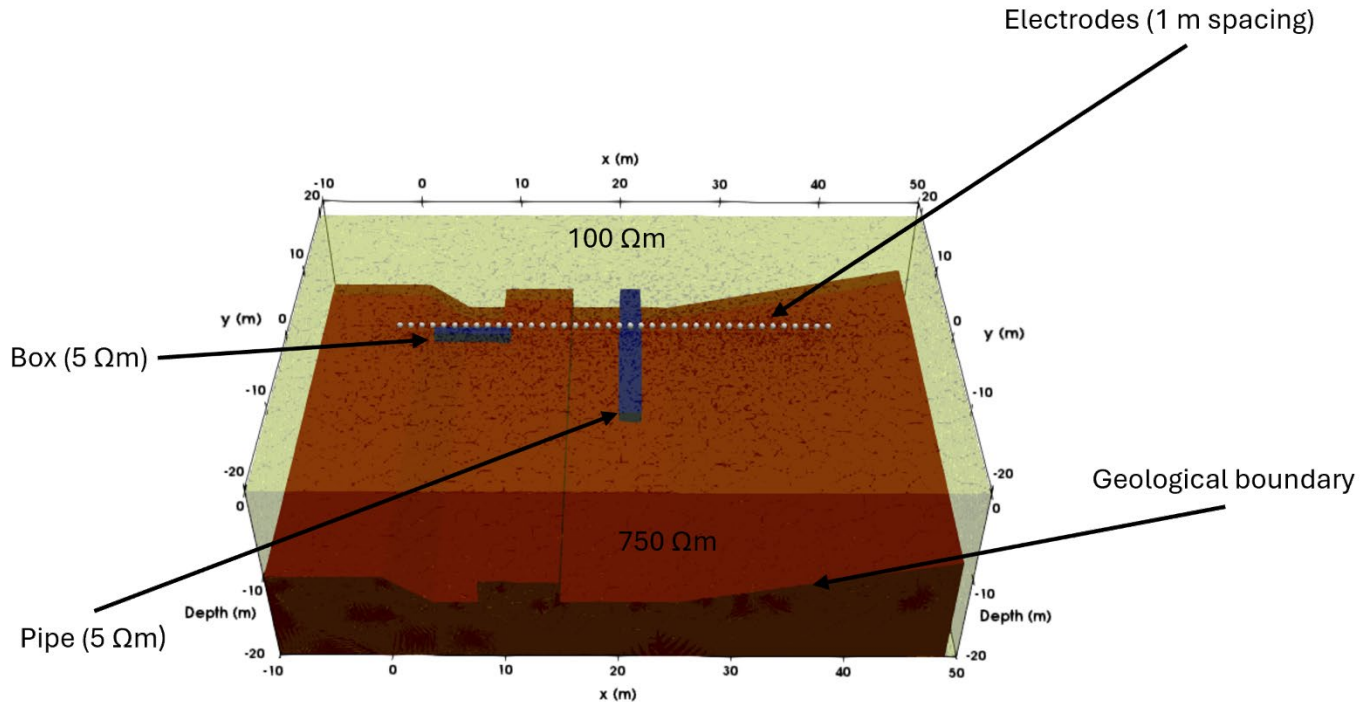


Figure 1: The default conceptual model, showing the associated features and their resistivities, to be used in the synthetic modeling case studies. For different modeling scenarios, the resistivity of the 7 x 1 x 2 m “box” anomaly and the location of the geological boundary vary. The ‘pipe’, which is a 2D feature relative to the line, has a dimension of 2 x 18 x 2 m.

inversion. For the default scenario, the random Gaussian noise was 2%. For each synthetic model, a dipole-dipole array was selected with 40 m electrode lines and 1 m electrode spacing

The associated a and n values were 1-4 and 1-9, respectively. These were chosen because the measurement scheme would produce an inversion with the greatest possible sensitivity at depth with realistic noise levels and dipole-dipole is a commonly used measurement array. In running the model, initially a 3D forward model was undertaken, followed by a 2D inversion, using the forward model as input.

Results and Discussion

The results of the inversions are shown in Figure 2 as a 2D slice along the line highlighted in Figure 1 and demonstrate a clear 3D effect induced by the offline anomaly. In Figure 2a there is a strong low resistivity feature in the location of the offline anomaly, where the electrode line is 0.2 m away, even though the anomaly does not directly underlie this line. Underneath this feature there is also a high resistivity artifact present,

which is a compensatory effect as the inversion forces a 2D representation of a 3D structure. This highlights how localized, offline features of anomalous resistivity can

have a strong impact on an inversion, in this case giving the false impression of an upward local extension of the

underlying resistive layer. For all models, the continuous ‘pipe’ anomaly, representing a 2D feature perpendicular to the image slice, was resolved successfully.

Figure 2b shows the resultant 3D effect from a more distant offline anomaly, which is 2 m from the line. There is still an associated low-resistivity artifact induced by the offline anomaly, though of reduced magnitude. The artifact is also at approximately 1.5-2 m greater depth when the anomaly is 2 m away from the survey compared to 0.2 m away. This is a result of the lateral spread of current flow and sensing of the offline anomaly with larger spaced dipoles, ultimately translating to an inferred anomaly at greater depth in the 2D section.

With an increased depth for the geological boundary, such as in Figure 2c, the associated resistivity does not

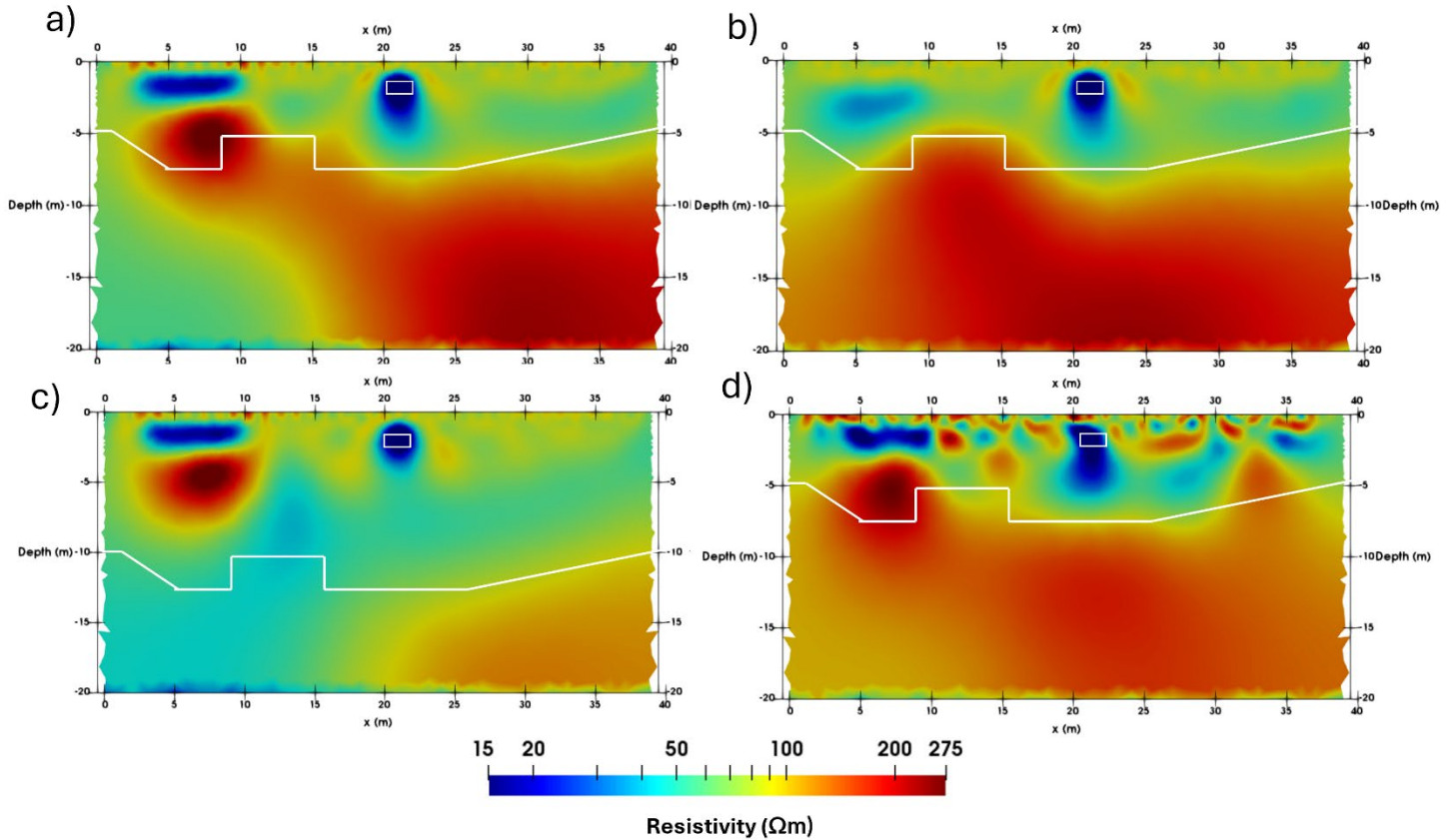


Figure 2: 2D Inversions of the synthetic models in different modeling scenarios (slice location shown as the electrode line in Figure 1). a) Where the edge of the offline anomaly was 0.2 m from the electrode line. b) Where the edge of the offline anomaly was 2 m from the electrode line. c) Where the geological boundary was moved 5 m deeper. d) Where the random Gaussian noise was 10%.

correlate well to the true boundary position, and there is a reduction in resolution beneath the artifact induced by a 3D effect. Therefore, the 3D effect will not only induce artifacts, but it can also cause the inversion to fail in correctly resolving structure beneath an artifact. This shows that, with modest increases in depth, sensitivity can decrease to such a significant extent that geological boundaries are not resolved. For larger electrode spacings, there will be increased sensitivity with depth, but at the expense of resolution in the shallow subsurface. This shows that sensitivity and depth of investigation need to be considered and modern inversion software often allows these assessments of inversion performance to be calculated, though they are often underused.

For Figures 2a-c, the error weights assumed in the inversion are consistent with the applied random noise and, as such, there are minimal artifacts. In comparison, in Figure 2d the error weight in the inversion is

underestimated relative to the applied random 10% Gaussian noise. This induces distortions of the underlying features and leads to further artifacts. In reality, correct error weighting will be unknown without undertaking appropriate error assessment, ideally based on reciprocal measurements. In our opinion, reciprocal error quantification is critical for reducing artifacts and enhancing meaningful ERT interpretation.

ERT surveys (and thus inversions) are commonly undertaken in 2D, but do not account for the actual 3D current flow. Figure 3 shows a 3D inversion of a 2D dataset from the same synthetic model (using the resistivities shown in Figure 1) along the same electrode line, allowing direct comparison with Figure 2.

For Figure 3, it is apparent that 3D models can produce more representative inversions, with fewer artifacts, and are therefore more reliable. While a 3D effect is still

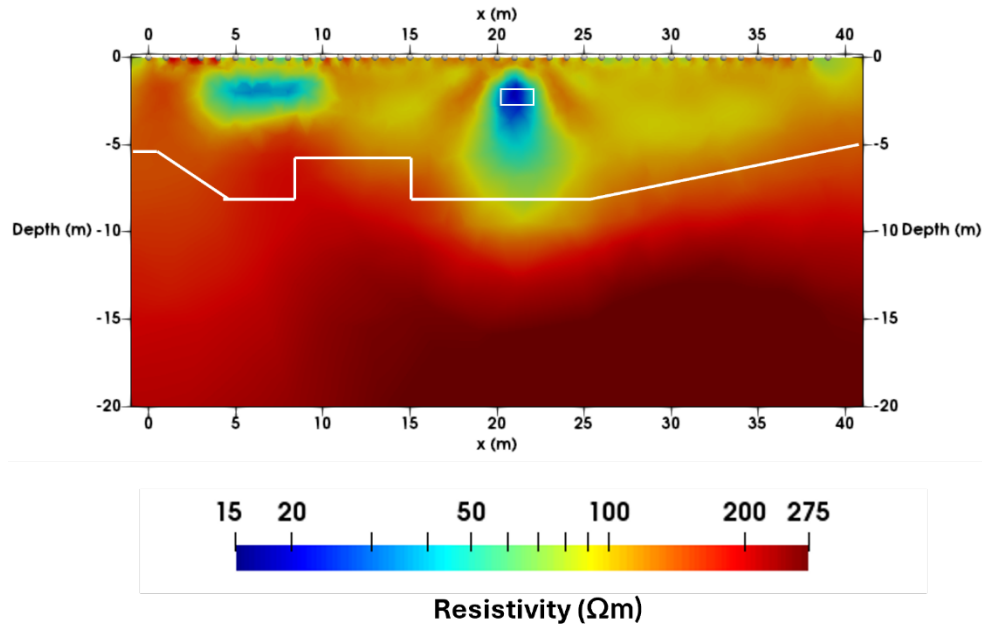


Figure 3: 3D inversion of a 2D dataset, using the synthetic model.

evident in Figure 3, there is no underlying compensatory feature, and the geological boundary is more realistic in its geometry. Moreover, in a 3D model with multiple lines, there will be a reduced 3D effect in the survey area away from the perimeter of the survey, with the influence of the resistivities present in the survey area overcoming any influence from offline features (Ball and others, 2022).

Conclusion

ERT remains a valuable geophysical technique in near-surface geophysics, but it is important to remember that ERT images can contain artifacts induced by 3D effects and improper error assessment. The synthetic modeling demonstrated that an offline anomaly could induce significant 3D effects, in this example where the offline feature is 2 m away. Artifacts will also likely be present if measurement errors are incorrectly quantified in the error model and resolution of features decreases substantially with depth. 3D inversions of 2D datasets can produce more representative results by accounting for 3D current flow and reducing associated artifacts. With a robust ERT survey and inversion framework, incorporating thorough assessment of inversions for potential 3D effects, evaluation of model sensitivity and

reciprocal measurement analysis, ERT can be undertaken with greater reliability.

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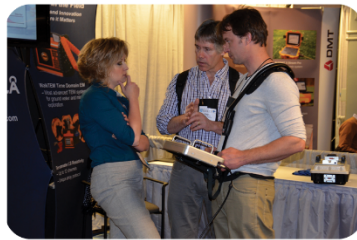
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Incorporating Critical Zone Subsurface Structure into Resistivity Inversion

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Abstract

The Critical Zone (CZ) of the Earth has its own structure, which can be incorporated in geophysical inversion to improve results and data interpretation. This article presents an example of using CZ subsurface structure to improve the resistivity inversion and interpretation in vadose zone hydrology. The same concept and workflow can be used in engineering and environmental geophysical problems.

Introduction

Electrical resistivity tomography has been frequently used in agriculture, geotechnical engineering, and environmental science to provide spatial and temporal information on the hydrologic states of the subsurface (Binley and others, 2015) because water content strongly influences soil/rock resistivity (Lesmes and Friedman, 2005). In the last ten years, significant advances have been made in resistivity instrumentation (Slater and Binley, 2021), inversion (Linde and Doetsch, 2016), and petrophysical models (Pavageau and others, 2026), and these advances contribute significantly to the increased use of the resistivity method in many field applications (e.g., Leopold and others, 2021).

There are many uncertainties that could be involved in using resistivity to infer hydrologic states (e.g., Tso and others, 2019; Chen and Niu, 2022). One important factor is the resistivity inversion process, which can introduce significant biases into the reconstructed resistivity model. This is because inversion is usually an ill-posed and underdetermined problem, and prior (or assumed) information on the resistivity distribution is required to stabilize inversion as regularization to obtain a unique solution. In recent years, many attempts have been made to improve inversion by adding geological, geophysical, or borehole data (e.g., Jessell and others, 2010). In particular, people have started to impose more realistic

geological models as regularization in the inversion instead of simply using a smooth model (i.e., minimizing the first- or second-order derivative). Examples include relaxing smoothness at some geological boundaries to allow sharp resistivity changes (Chen and Niu, 2022) or applying resistivity gradients derived from other geophysical images (Zhou and others, 2014).

Critical Zone Subsurface Structure and Determination

In near-surface environments, geological features such as faults and layering are less obvious than in deeper subsurface. Thus, the application of geological data in near-surface geophysical imaging is less straightforward. Recently, the concept of critical zones (CZs) has been popular in geoscience communities (Brantley and others, 2007). The Earth's CZ is defined as the region from the top of the tree canopy to the bottom of active groundwater circulation. Within this layer, weathering transforms fresh bedrock into the regolith (or soil). In general, the subsurface of CZs consists of three distinct layers: regolith, weathered bedrock, and intact bedrock. The site-scale CZ subsurface structures have been revealed at many intensive study sites (e.g., St. Clair and others, 2015), and some conceptual models have been developed (Riebe and others, 2017).

Figure 1 shows an example of the seismic P-wave velocity of a hillslope inverted from travel time data collected at the Dry Creek Experimental Watershed, Idaho, United States (McNamara and others, 2018). The velocity in the shallow subsurface (within ~2 to ~4 m) is very low, less than 1000 m/s. This low-velocity region corresponds to the soil or regolith layer, which was weathered from the underlying granitic bedrock (Chen and others, 2023). At the slope top, the low-velocity zone is clearly deeper than that at the middle and bottom slopes. As depth increases, velocity increases at all locations along the slope. This increase in velocity below

~4 m is related to bedrock fractures formed by physical/chemical weathering.

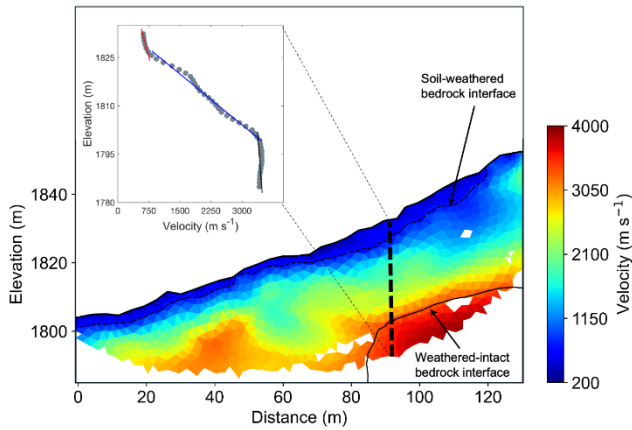


Figure 1: Determining the critical zone subsurface structure from seismic velocity image. The inset represents the velocity-elevation plots at distance $x = 90$ m.

To determine the exact location of CZ structural interfaces, the current practice is to select some representative velocity values to represent the soil-weathered rock and weathered-intact rock boundary (Chen and Niu, 2022). In the inset of Figure 1, we demonstrate how to select these values. First, we plot the depth (elevation) variation of velocity at a given location, from which we identify three distinct depth segments. Within each segment, the velocity-depth relationship has a unique variation pattern (e.g., linear). This means that the vertical velocity gradient differs in the regolith, weathered bedrock, and intact bedrock (Chen and Niu, 2022). Accordingly, we can determine the two velocity values that separate soil, weathered bedrock, and intact bedrock: $v = 750$ m/s and 3300 m/s. With these two contour lines, we then can plot the CZ subsurface structure boundaries in Figure 1.

Improved resistivity inversion with CZ structural information

With the extracted CZ subsurface structure from the seismic velocity model, we can now incorporate it into the resistivity inversion. This is done by relaxing the smoothness constraint at the soil-weathered bedrock and weathered-intact bedrock interfaces in the regularization (Doetsch and others, 2012). Figure 2a shows the resistivity inversion results of two surveys with CZ

subsurface structure incorporated. The two resistivity datasets were collected on 08/17/2023 and 09/08/2023 at the same site in Figure 1. Note that August is probably the driest month at the site and September is a bit wetter due to some precipitation. The inversion results from the traditional smoothness constraint are shown in Figure 2b for comparison.

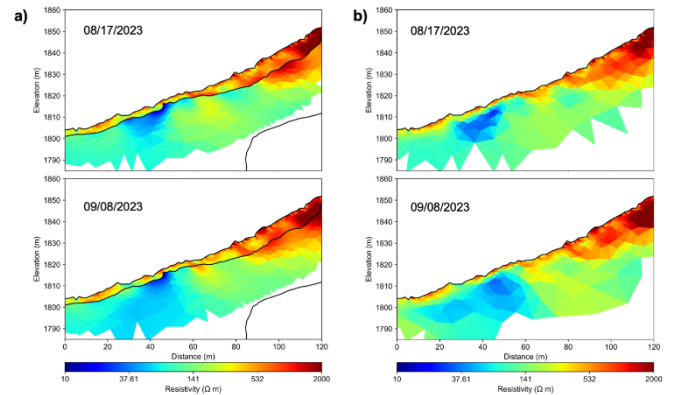


Figure 2: A comparison of inversion results of two resistivity tests (08/17/2023 and 09/08/2023): (a) incorporation of critical zone subsurface structure and b) no critical zone structure is considered.

If we compare the resistivity images from different inversions, we find two prominent features. First, abrupt resistivity changes are observed across the CZ boundaries in Figure 2a. Regolith and fractured bedrock have distinct porosity and pore connectivity, and it is expected they respond differently to hydrologic drivers (Chen and Niu, 2022); therefore, their resistivity values differ. Second, if we compare resistivity images obtained at different times, their hydrologic interpretations may differ. For Figure 2a, the low-resistivity region (less than $50 \Omega \text{ m}$) at the bottom of the slope expands both vertically and laterally over time. It is intuitive to interpret that water in the weathered rock moves primarily vertically. In Figure 2b, however, it seems the low resistivity zone extends mainly downslope. A plausible interpretation would be that the rock water moves laterally along the slope. The first interpretation might make more sense because there is no clear vertical layering at the bottom of the slope, and the rock water may flow in both vertical and lateral directions. Of

course, other hydrologic data are required to fully understand the rock water dynamics, though.

Conclusion

In this article, we demonstrated that incorporating the CZ subsurface structure into resistivity inversion may improve the hydrologic interpretation of CZ processes. The CZ subsurface structure may be from prior theoretical knowledge or other geophysical results. Understanding the CZ subsurface could help geophysical inversion and interpretation in near-surface applications, providing different perspectives from traditional methods.

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High-resolution 3D Imaging via Nodal Arrays

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Abstract

Deterministic processing of nodal array, passive electromagnetic data produces intuitive 3D sub-surface geologic imaging; presenting spatially controlled altered geology and structure geometry.

Mapping altered geology indirectly reveals fluid flow. This is of value on projects looking for site outflow or inflow, quality assurance on extraction well performance, locating optimal drill points, checking earthen dams for conditions which could lead to piping (dam failure) and more.

This article provides an overview of the nodal array technology, deployment methodology, discusses the technology's strengths and weaknesses, and reviews several case studies mapping altered geology.

Introduction

Geochemical alteration occurs as fluid flow transits chemicals and minerals across a site's soil and rock strata. Passive electromagnetic nodal array surveys can map the effects of this process. The resultant graphics indirectly present a 3D image of fluid flow to depths of several kilometers. The imaging helps identify target areas for further investigation via secondary geophysical methods. Proven altered geology imaging applications include the mapping of: (1) leakage from sewage treatment plants, (2) water intrusion within earthen dams, (3) extraction well flow characteristics and (4) geothermal processes.

For sites where terrain, vegetation, permitting, or other constraints exist, this passive (no sources), non-invasive (no drilling, excavation, or noise) surface-deployed nodal array methodology offers an excellent alternative. Think "casual use" and "no permit required" in U.S. Bureau of Land Management jargon.

A deployed array is comprised of 25 to 30 data loggers that simultaneously record electrical and magnetic properties of the ground. Each datalogger contains a GPS receiver, an internal triaxial magnetometer, and

inputs for N-S and E-W electrode wires. A small external, rechargeable battery pack provides 5 Vdc power via a USB port. The frequencies analyzed by the system are similar to the frequencies covered by magnetotelluric (MT) surveys. Of note, this methodology is sensitive to solar storms. MT surveys reportedly are not, highlighting a key difference in the technologies.

By conducting multiple overlapping episodes of measurements, large areas of 50+ km² can be presented as a single 3D image (Figure 1).

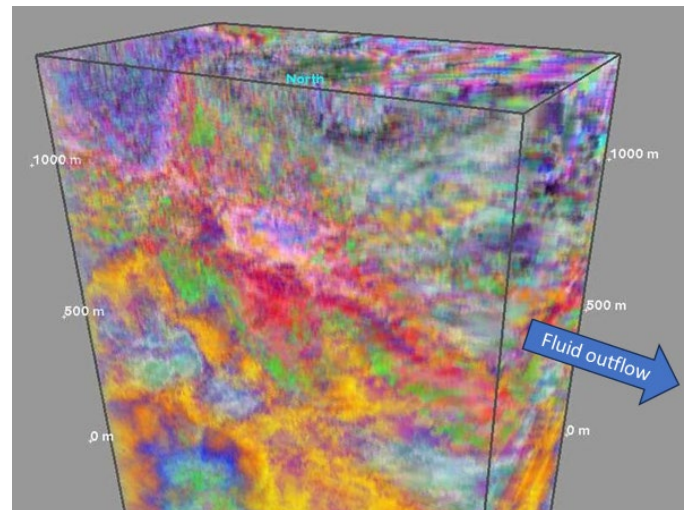


Figure 1. Upper 2 km profile view from 3D imaging of a geothermal field. Mapped altered geology indicates fluid outflow in the upper 1 km following a clay layer (arbitrary reddish color) to the west and southward. A hot spring correlates with imaged altered geology. Hints of curved listric faulting can be seen left to right in the 3D image. Credit: 3D Edge, Inc.

Each station takes about ½ hour to set up. On foot, one can deploy approximately 8 – 12 stations in a day; 10 to 14 stations by ATV. Instrument recovery takes approximately half the time it took to deploy.

Data acquisition over a 4-hour period provides high resolution imaging down to 500 m. For deeper targets (e.g. up to 4 km) a 24-hour recording period is required.

Data recovery is via a simple USB connection to a PC wherein the datalogger appears as an external drive. These instruments record large files. Plan on 15 minutes to 30 minutes per instrument to download a 24-hour data collection.

After the data is uploaded to the 3D Edge server, a data cloud is derived from a combination of data stacking and

patent-pending deterministic, vector-based processing. This methodology returns 3D imaging for altered geology, structure, temperature gradients (geothermal recharge) and more. As the Owner learns more about their site, they can update and label their 3D model accordingly (Figure 2).

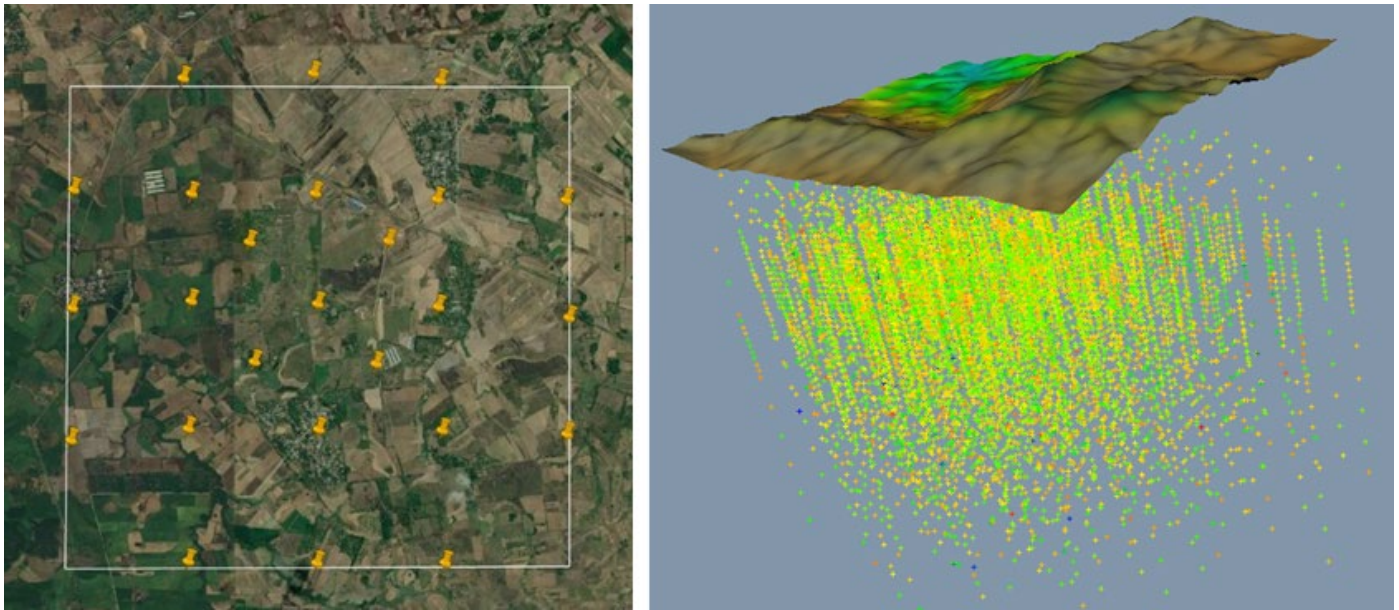


Figure 2. Data cloud conceptualized. Credit: 3D Edge, Inc.

Geophysical Instruments and Methods



Figure 3. The 3DGE data logger. A tech is shown with a 6-station pack, snake chaps and exoskeleton. Two techs (only one is required) are shown aligning the instrument with magnetic north and setting it level to within 2 degrees using a bubble level. Credit: 3D Edge, Inc., AGB Seismic, LLC and Ashlyn Kudransky Photography.

Case study: Extraction Well Performance

The path of fluids are inferred from stream-like (whispy) patterns that present in the 3D imaging. Understanding the direction of the flow can generally be resolved via comparison of the survey context (extraction pump operation, leakage from a point source, terrain, gravity, etc.) with the subsurface imaging.

The operator of an extraction well wanted to visualize the levels and directions from which the extraction pump (operated at different levels) was drawing fluid. One day of data collection produced — without guesswork or assumptions — 3D imaging of the altered geology around the extraction well and provided the information the operator required (Figure 4).

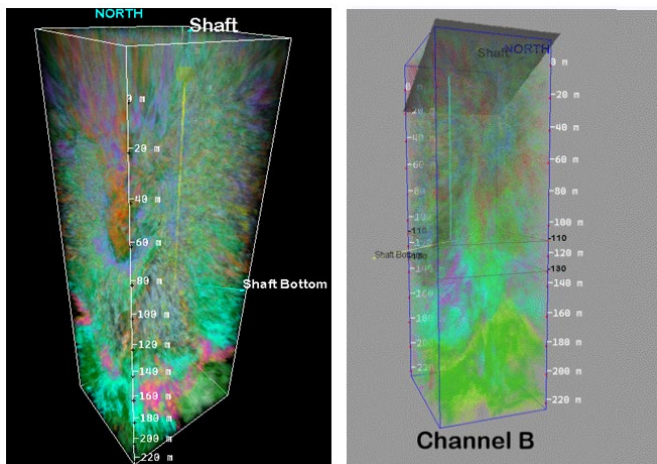


Figure 4. Extraction well with pump operated at different levels. Credit: 3D Edge, Inc.

Case study: Sewage plant leakage

A nodal array electromagnetic study conducted in Southeast Asia imaged sewage outflow from a treatment plant that was deleteriously impacting coastal waters. The model is confirmed via: (a) the hydrochemical alteration at the water's edge; most likely from saltwater drawn inland from ground water extraction, (b) the geochemical alteration narrows to within 50 m of the plant, and (c) the altered geology characteristic does not extend upslope from the treatment plant. The passively

collected data set does not indicate the composition of the plume — only its geometry (Figure 5).

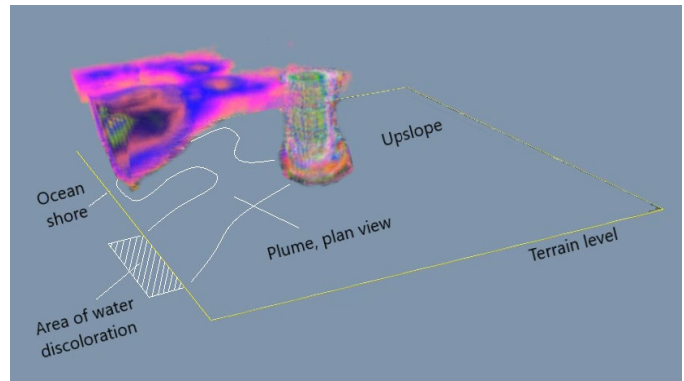


Figure 5. 3D modeling of the sewage outflow from a treatment plant. The plan view is lowered to permit a 3D view of the 'plume' of hydrochemical & geochemical alteration along with its relative position at the site. Credit: 3D Edge, Inc. and 3DGE Intl, LLC.

Case study: Earthen Dam Deformation Investigation

The Owner's earthen dam is exhibiting mild deformation at the crest of the dam. A low resolution (survey team's access limited to only 'safe' locations on the downstream face of the dam) test survey was conducted to see whether the nodal array imaging system would provide useful results. The results were very promising. The imaging presented an altered geology anomaly at the crest location corresponding to the deformation as shown in Figure 6 below. Also, the slope protection is clearly differentiated from the dam's core as shown in the right-most image below. Upon presentation of the test survey results, the Owner requested a proposal for a high resolution survey using the nodal array methodology (Figure 6).

Discussion

Because it is passive and does not use a known input voltage or current source, this system returns a site-tuned, spatially controlled, unlabeled 3D image (like an MRI). Further, its passive design makes it susceptible to solar CME activity. Surveys must be performed during periods in which the Kp space weather index is < 3.

This methodology does not map infrastructure, but rather the location and geometry of geological features (i.e.

folds, strata, faults, etc.), altered geology, pseudo-resistivity and site heat mapping; up to 4 km depth.

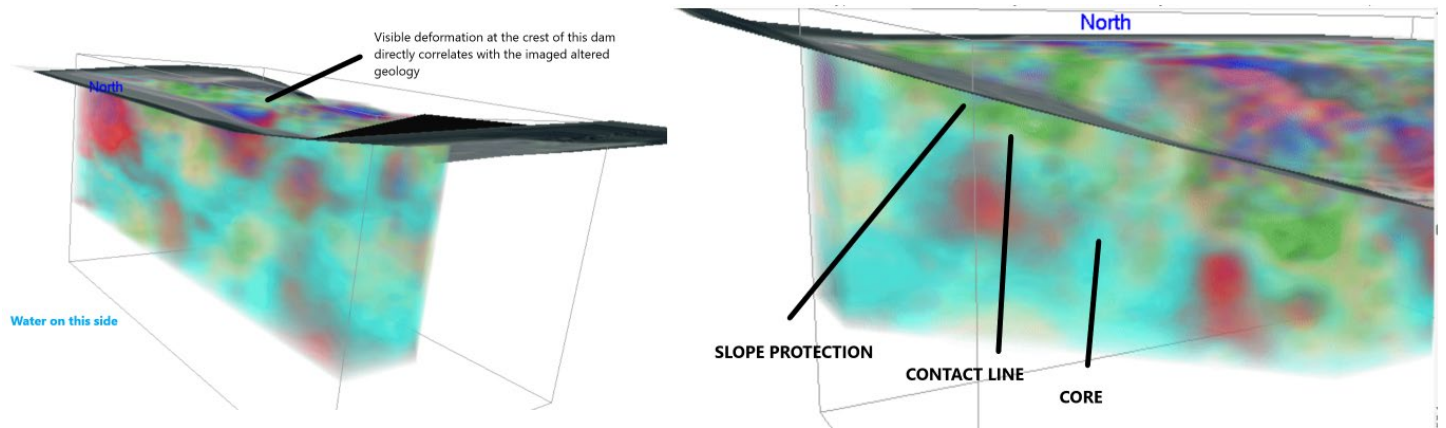


Figure 6. Earthen dam's visible deformation at the crest directly correlates to the location indicated by the imaged altered geology; obtained from a low resolution test of nodal array 3D imaging. The earthen dam structure is also observable from the same dataset. Credit: 3D Edge, Inc.

It excels in identifying steep verticals (i.e. dikes, diatremes) that classic 2D geophysical profiles can miss.

Using a GPS handheld receiver and uploading files using an FTP Client are the field operator's two most technical tasks. If you can handle those things, you can perform the data acquisition for a nodal array subsurface imaging survey.

Conclusion

3D imaging via nodal array data acquisition and deterministic analysis methods is a robust, turnkey methodology. It has a very low impact on the environment, is relatively fast, the data loggers are deployable with minimal training, and the data is processed blindly- in the sense that the data processing analyst (generally not a geophysicist) does not make any assumptions about initial conditions when processing the data. This approach reduces the potential for human error or bias. Some background information about the site (direction of slope, known faults, hot springs, etc.) can prove helpful for quality assurance, preliminary color selection and annotation for the original imaged dataset.

Supplementing the 3D imaging with information from secondary geophysical methods is generally necessary to resolve the site model.

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Geology-Guided Characterisation of a Discontinuous Pleistocene Aquitard

Jordy de Vries, Wiertsema & Partners B.V. (j.devries@wiertsema.nl); Jaap Bongers, Wiertsema & Partners B.V.; and Michel Groen, Groenstaal

Abstract

A planned groundwater abstraction near Schalkhaar, the Netherlands, required a detailed understanding of the Laagpakket van Zutphen, a discontinuous aquitard that locally separates the phreatic groundwater system from a deeper aquifer. A geological desk study suggested that the aquitard is characterised by sharp erosional boundaries and identified areas where its presence was uncertain. Surface time-domain electromagnetic (sTEM) measurements were subsequently deployed to test this geological hypothesis, while CPT data were used for validation. The combined dataset resulted in a revised aquitard distribution model for groundwater modelling and demonstrates the value of integrating geological, geotechnical and geophysical information.

Introduction

Although the Netherlands is generally rich in both surface water and groundwater resources, drinking-water supplies are increasingly under pressure due to a variety of factors. To mitigate this, several new groundwater well fields are being developed or reactivated. One such example is Schalkhaar, a site owned by Vitens N.V., where groundwater abstraction wells screened below an aquitard are being considered for reactivation. Earlier abstraction at this site was discontinued because of unexpected water quality issues and uncertainties about groundwater level declines in the surrounding phreatic aquifer. Reactivation therefore requires improved constraints on the distribution and continuity of this aquitard, which locally forms a hydraulic barrier between the phreatic groundwater system and the deeper aquifer. To achieve this, a geological desk study was carried out using historical cone penetration tests (CPTs) and boreholes, followed by a targeted surface time-

domain electromagnetic (sTEM) survey and additional CPT investigations. This article shows how geological interpretation guided survey design, how selected sTEM profiles were used to test the interpreted aquitard boundary, how CPT data validated key interpretations, and how the resulting insights were incorporated into a revised aquitard distribution model.

Geological Setting

The Pleistocene aquitard (at 5 to 20 m depth?) is formed by the Laagpakket van Zutphen, part of the Kreftenheye Formation (KRZU). It consists mainly of clay and peat, locally interrupted by sandy intervals. It was deposited primarily as fine-grained floodbasin material associated with a meandering Rhine system. During a later (colder) phase with braided-channel activity, parts of the fine-grained succession were eroded. The resulting aquitard geometry is therefore not a smooth regional blanket, but a discontinuous body with sharp boundaries between preserved clay-rich zones and eroded sandy zones. Delineating these boundaries formed one of the main objectives of the field investigations described in this paper.

Methodology

- (1) The desk study used historical CPTs and boreholes to reconstruct the top, base, thickness and clay-and-peat content of the Zutphen member. It also identified zones where the aquitard boundary was uncertain because data density was low or because channel erosion was expected to have removed the unit. These zones formed the basis for the targeted sTEM survey.
- (2) The sTEM profiles were placed to test the expected distribution of the Zutphen member.

Smooth inversions were used as the primary visual tool for recognising low-resistivity intervals at the expected stratigraphic level. Layered inversions were then used to translate the geophysical response into simplified layer models. Interpretation remained geologically constrained because resistivity is inherently non-unique and may reflect factors other than lithology.

- (3) New CPTs were used to test the sTEM interpretation and refine the final aquitard model. Additional CPTs were conducted at locations where sTEM measurements were not feasible due to underground infrastructure.

Results and Discussion

Five sTEM profile lines were acquired across the study area. Figure 1 compares the thickness map produced during the geological desk study with the thickness map made after the field survey. In many areas, the sTEM results are consistent with the expected extent of the Zutphen member. Even in these locations, the measurements nevertheless provide valuable information, as the interpreted contours were largely based on sparse data and contained considerable uncertainty. The most notable exception is profile L005, where the results differ substantially from the hypothesised extent. Along this profile, the Zutphen member appears to be entirely absent.

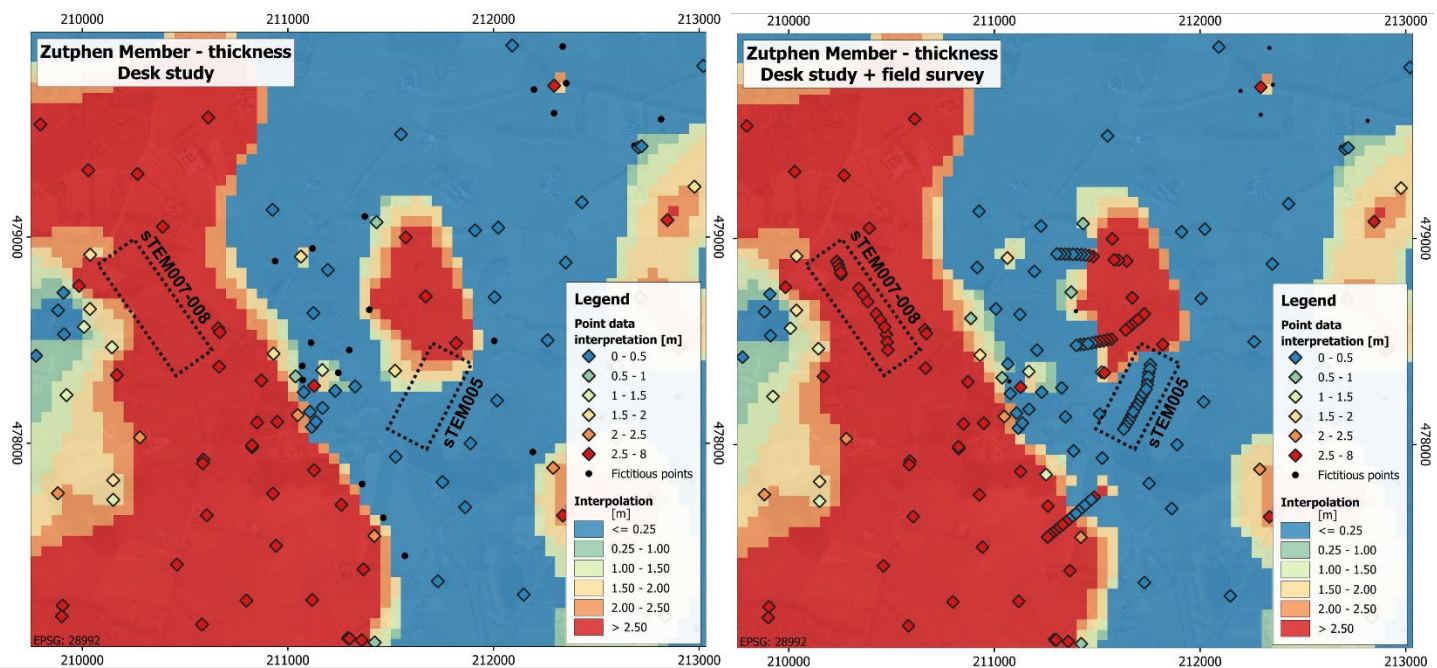


Figure 1. Left: interpreted thickness of the Zutphen member at historical data points (CPTs and boreholes), with in the background the interpolated map. Right: updated thickness map of the Zutphen member, with sTEM data and additional CPTs added.

Figure 2 compares profile L005 with profiles L007-L008, where the Zutphen member is interpreted to be continuously present. The contrast between the profiles is evident. The low-resistivity interval associated with the Zutphen member at L007-L008 is absent along profile L005, indicating a major change in geological conditions over a relatively short distance.

Figure 3 compares selected sTEM measurements with CPTs acquired along the survey lines. Overall, the agreement between both methods is good. At L005, both the CPT and the sTEM data indicate that the Zutphen member is absent, supporting a revision of the previously interpreted aquitard boundary. At L008, both methods identify the Zutphen member at broadly comparable depth, providing confidence in the geophysical interpretation. The CPT at DKMP010

further illustrates the internal heterogeneity of the Zutphen member, which consists of alternating peat, clay, silt, silty sand and sand layers. This variability

highlights the importance of geological constraints when translating geophysical responses into stratigraphic and hydrogeological model layers.

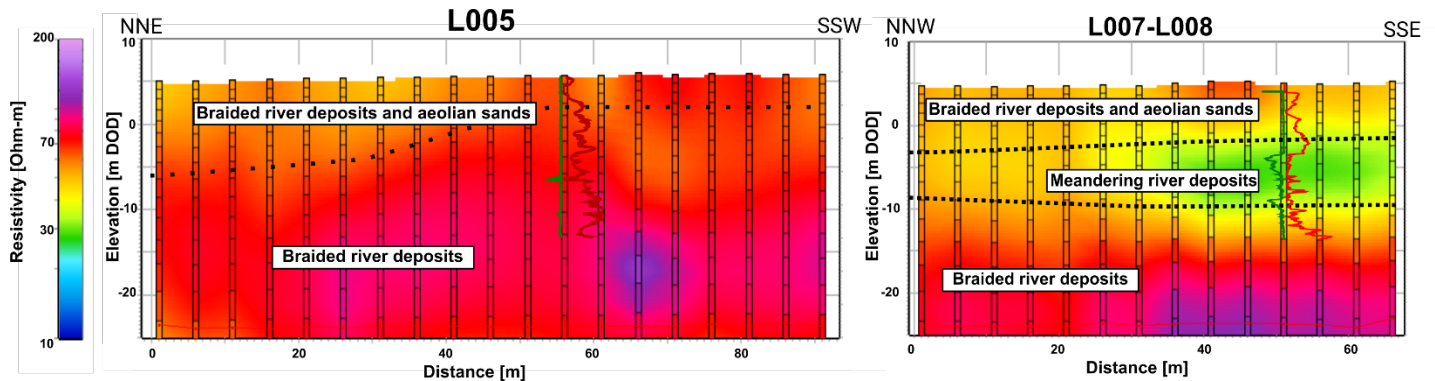


Figure 2. Selected sTEM smooth-inversion profiles for L005, and L007-L008.

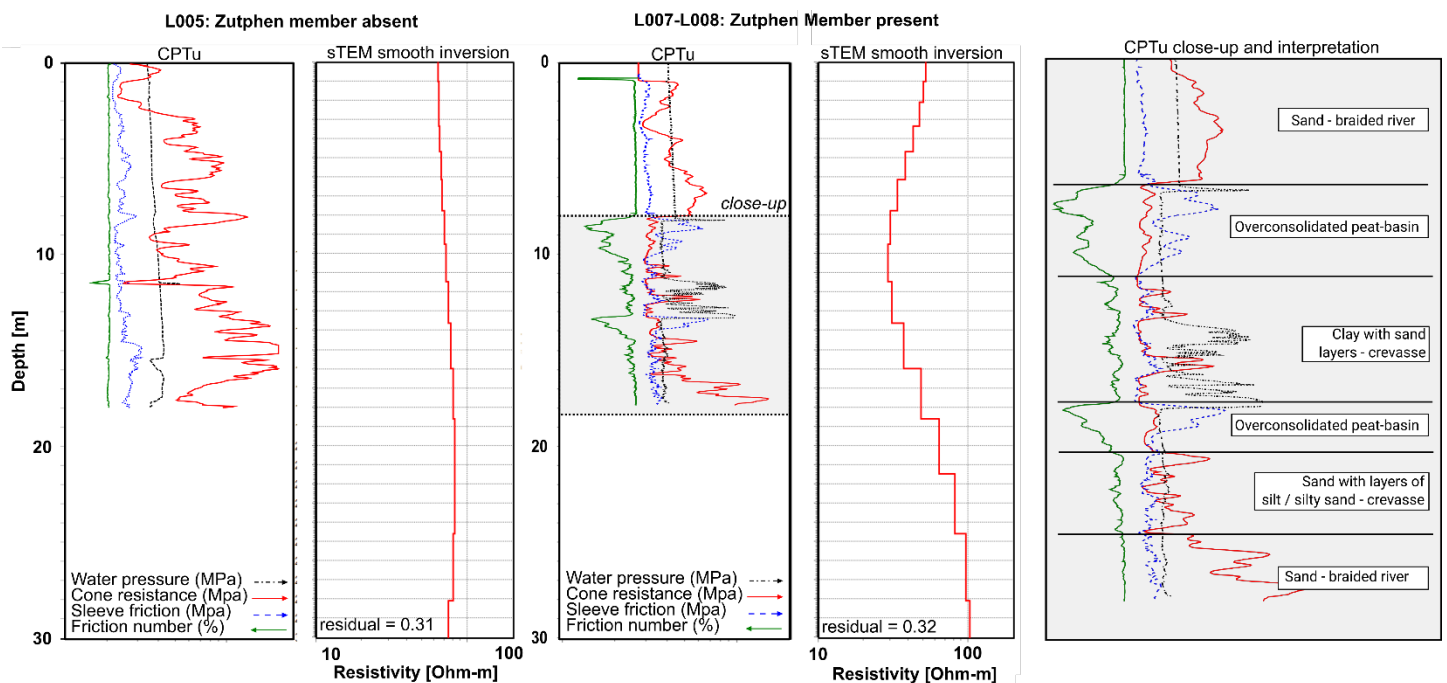


Figure 3. Left: CPT validation near L005: the Zutphen member is not identified in either CPT or sTEM data. Right: CPT validation near L008: the Zutphen member is present in both CPT and sTEM data.

The final thickness map synthesises the desk study, sTEM survey, CPT validation and updated geological interpretation (figure 1, right part). In the earlier version of the model, fictitious interpolation points were required to align the interpolation results with geological constraints, despite the use of a method specifically designed to account for the strongly zero-inflated nature of the dataset (after all, a river channel cannot simply stop). Incorporation of the additional field data

substantially reduced this requirement. In the areas where accurate delineation is most critical, particularly around the abstraction wells and the associated 5 cm drawdown contour, fictitious points were largely no longer needed. This indicates a significant reduction in geological uncertainty and increased confidence in the resulting aquitard distribution model.

Conclusion

This study demonstrates the value of an integrated geological, geophysical and hydrogeological approach for characterising discontinuous aquitards. Historical CPTs and boreholes were used to develop a geological model of the Zutphen member, which subsequently guided the design of a targeted sTEM survey and follow-up CPT investigations. Together, these datasets provided stronger constraints on the lateral continuity and thickness of the aquitard than any individual method could have achieved.

The geological desk study proved particularly important for the geophysical investigation. It identified the key uncertainties, guided survey design, and provided the geological framework required to interpret the sTEM data. The field measurements subsequently tested and refined the geological model, most notably at profile L005, where both sTEM and CPT data demonstrated that the Zutphen member is absent despite its predicted presence in the preliminary interpretation.

More broadly, the case study shows how geological understanding provides the framework needed to bridge data gaps and ensure that resulting models remain consistent with depositional history and channel evolution. This proved particularly important when modelling the discontinuous Zutphen member, where geological constraints were required to distinguish realistic channel geometries from interpolation artefacts. As a result, geological uncertainty was substantially reduced and a more robust aquitard model could be developed for groundwater-modelling purposes.

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Interpretation of Time-Lapse Electrical Resistivity Tomography of a Swale

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Abstract

The Edwards Aquifer Authority is evaluating the potential effects of various techniques to manage runoff retention and infiltration at the hillslope scale. We used time-lapse electrical resistivity tomography to image a swale before and after rain events. Difference-tomography results suggest that the swale induced a measurable hydrologic effect. We show independent geologic observations, including borehole cuttings and a gamma log, and discuss how they constrain our hydrogeologic interpretation.

Introduction

The Edwards Aquifer Authority (EAA) is a regional groundwater conservation district that regulates withdrawals from the Edwards (Balcones Fault Zone) Aquifer, a prolific karst aquifer that supplies water to more than 2.5 million people in south-central Texas and sustains flows to springs that host several threatened and endangered species (Green and others, 2019). An important concern for the EAA is the sustainability of the aquifer given continued development in the region and potential impacts due to a changing climate. As part of our sustainability studies, the EAA is evaluating the effects of various land management techniques on the water balance. The EAA has established a field research site on the recharge zone of the aquifer where various land management techniques are being tested.

A common land management technique to capture runoff is construction of a “berm and swale pair” (e.g., Lancaster, 2008) (Figure 1). While similar features have been used for centuries worldwide, quantitative measurement of their effect on the water balance is rarely done. Here, we present a geology-informed

interpretation of a time-lapse electrical resistivity tomography (ERT) experiment designed to evaluate the hydrologic effect of one of our constructed swales.

Experimental Design

We installed an ERT line across the short axis of the swale (Figure 2) and imaged the subsurface before and after rain events (Figure 1). Time-lapse conductivity data were acquired with a SuperSting R8 system (Advanced Geophysics, Inc. (AGI), Austin, TX) along a 137.5-ft line with 2.5-ft electrode spacing, then inverted in AGI EarthImager 2D using default parameters and a terrain correction derived from surveyed electrode elevations. We used the software's time-lapse difference-inversion module to model the percent increase in conductivity between image pairs (Figure 1), producing a difference-tomography model of where, and by how much, conductivity increased in the near-surface between imaging events (Figure 3). In this study, a change in electrical conductivity in the imaged zone is expected to be correlated with a change in water storage. Difference-tomography is therefore a proxy for the spatial pattern of water-storage change during the monitoring period (Binley and others, 2015).

Geologic Observations

To interpret the tomography results, we independently characterized the near-surface geology at the site (Figure 2). The study swale is located on a fluvial terrace within the Cibolo Creek watershed, which we interpret as alluvium overlying Edwards Group limestone bedrock. Geoprobe refusal depths and cuttings from six shallow boreholes show roughly 20–30 ft of unconsolidated sediment above bedrock beneath the tomography line, with texture that varies with depth and

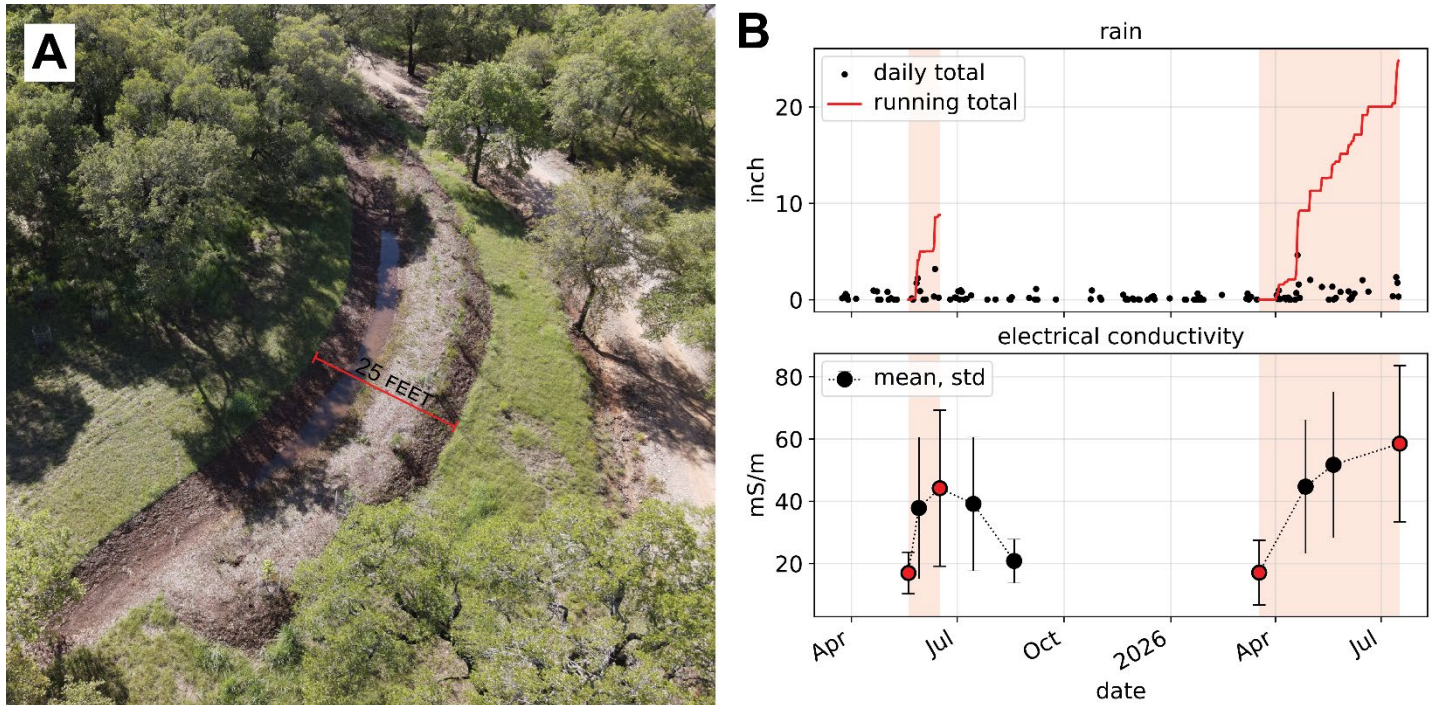


Figure 1: Panel A: aerial photograph of the study swale soon after its construction in 2021. Panel B, upper: daily rainfall from a tipping-bucket gauge. Panel B, lower: spatial mean $\pm$ standard deviation of electrical conductivity for nine imaging events; red markers denote the four images used for the two difference-tomography models (see Figure 3). Light red boxes mark the two monitoring periods; red lines show cumulative rainfall during those periods.

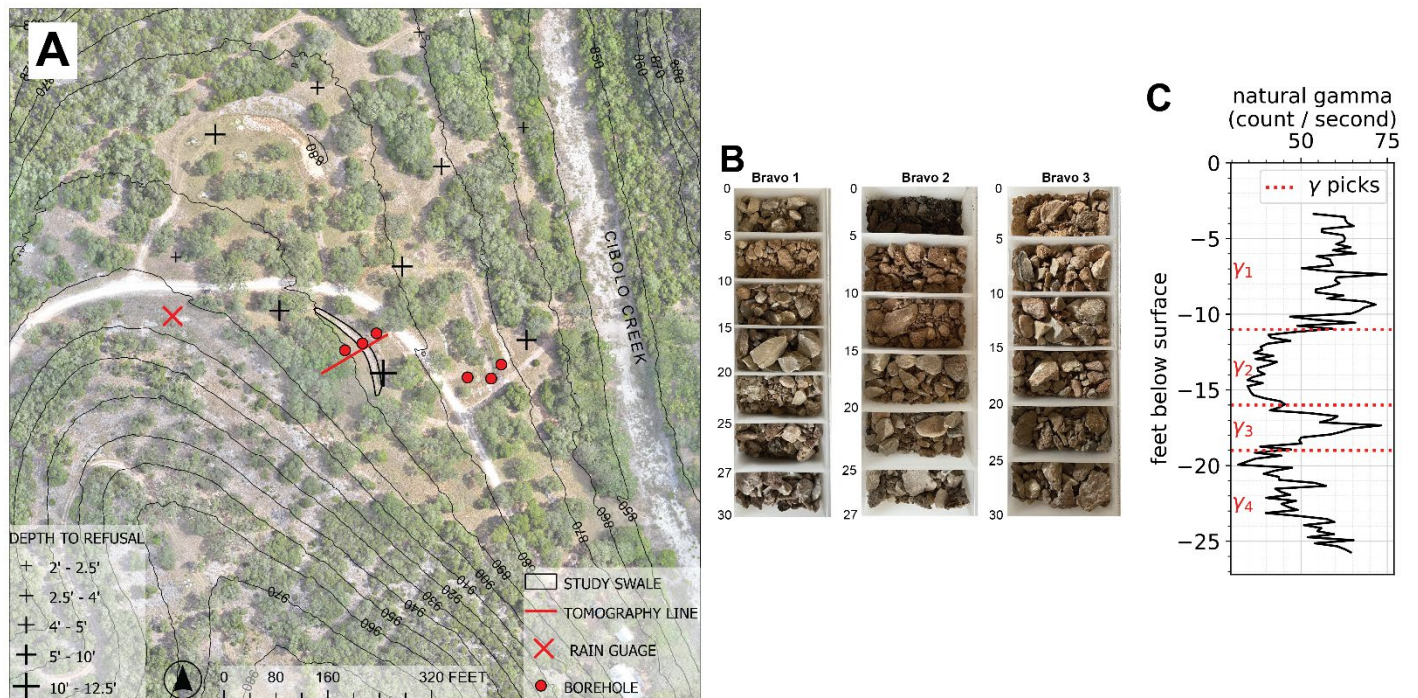


Figure 2: Panel A: map of observations used to characterize near-surface geology; black crosses show locations and relative magnitude of depth-to-refusal for geoprobe measurements. Panel B: photos of drill cuttings in sample trays from the three swale-adjacent boreholes shown in Panel A; each tray cell represents a depth interval, in feet, indicated at left. Panel C: natural gamma-ray log acquired in the borehole drilled through the study swale; red dotted lines define four gamma facies, γ_1 – γ_4 .

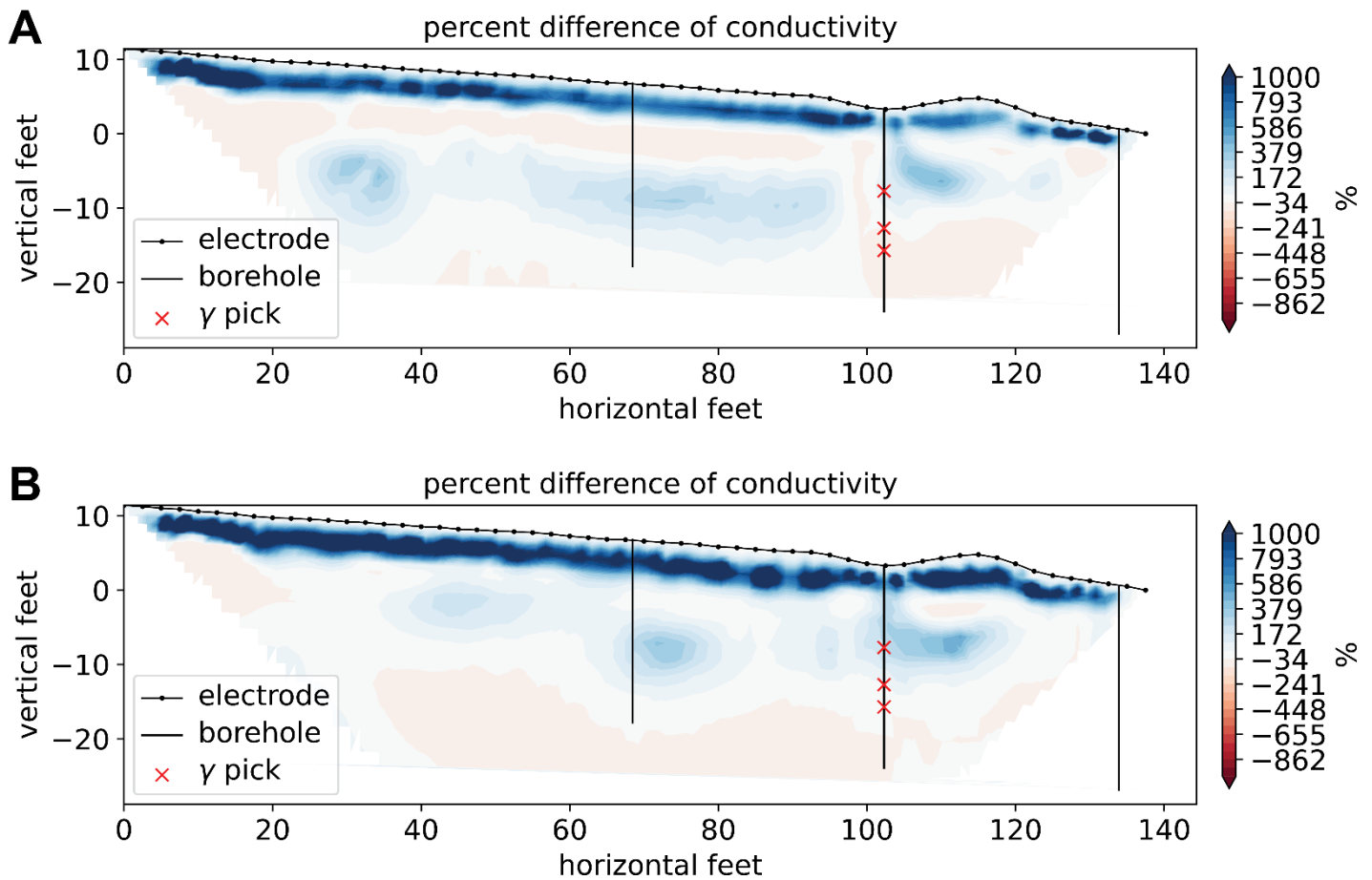


Figure 3: Panels A and B: difference tomography for the first and second monitoring period, respectively (see Figure 1). Vertical black lines are boreholes shown in Figure 2; red crosses are gamma picks shown in Figure 2.

often includes significant clay and gravel. A natural gamma-ray log acquired in a borehole drilled through the swale confirms this vertical organization. We picked three contacts that divide the alluvium into four gamma facies, labeled $\gamma 1$ through $\gamma 4$ (Figure 2).

Combined Interpretation

Difference-tomography results for the two monitoring periods are shown in Figure 3. Upslope of the swale, the vertical conductivity-change profile is essentially invariant along slope. The pattern breaks beneath the swale, where the conductivity increase extends significantly deeper. This along-slope-discontinuity is the central result of this study.

The lateral pattern in the post-rain event difference-tomography (Figure 3) is best explained as a hydrologic effect of the swale, given our geologic interpretation of

the imaged zone as vertically layered alluvium. Because alluvial flow properties can be assumed laterally uniform at the scale of the tomography line, lateral subsurface flow should be near steady-state, and any difference in subsurface water-storage change must instead originate at the surface. Precipitation and evapotranspiration are also reasonably uniform at this scale, so the remaining explanation is a contrast in runoff and ponding. The swale creates such a contrast by intercepting downslope runoff. This is consistent with difference-tomography results; swale-induced ponding appears to drive deeper infiltration than on the untreated upslope surface. The ERT results constrain the depth and direction of swale-induced water-storage increase.

The vertical pattern also tracks the gamma facies. The variable, high gamma counts in the shallowest facies ($\gamma 1$) suggest clay-rich, retentive material, consistent with

large storage increases occurring there. The γ_1/γ_2 contact, at about 11 ft below ground surface, coincides with both the base of the conductivity increase beneath the swale and a shift from negligible to positive values upslope. The underlying γ_2 facies (uniform, low counts) also shows positive values upslope, raising the question of whether downward flow is perching at the γ_2/γ_3 contact upslope or at the γ_1/γ_2 contact beneath the swale; additional modeling is needed to resolve this.

Geologic Constraints on the Method

Our interpretation depends on treating the imaged zone as alluvium with laterally uniform flow properties. The slope of the layers and vertical hydraulic conductivity differences are consistent with that interpretation. In laterally heterogeneous material, such as fractured bedrock, the same lateral discontinuity could instead reflect variation in flow properties rather than a swale-driven hydrologic effect.

Thus, geology can constrain where difference-tomography is most useful for studying land management hydrology. In a transmissive but non-retentive medium, such as fractured bedrock, swale-induced infiltration could plausibly drain out of the imaged zone before it is detected as a measurable increase in water-storage.

Conclusions

Time-lapse electrical tomography, interpreted alongside independent geologic observations, provides evidence that the study swale drives deeper infiltration than the surrounding hillslope. Additionally, the vertical and lateral changes in conductivity are reasonably explained by the clay/gravel contrasts in the underlying sediments. As we develop models of the water balance at the site, we will be able to quantify the effects of land management features like this berm and swale pair. Local geologic constraints such as layering, retentiveness, and lateral continuity will likely determine whether this approach will work for evaluating runoff retention and infiltration at other sites.

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Resolving Ambiguity in TDEM Soundings

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Abstract

In shallow studies, TDEM is often measured only inside the loop and inverted for layered models. We examine some critical issues associated with 1D inversion of INLOOP data as this approach often leads to misleading models. This issue is due to the non-uniqueness of 1D INLOOP inversion. Without the ability to constrain the model to known geological parameters, the derived models will often be distortions of the true structure. The use of multiple data components in conjunction with a survey design deriving from geological knowledge helps locate more correct models.

Introduction

This situation arose as inversions were for a long time only available for central loop readings (Anderson, 1993). For our studies, we consider the standard impulse response. The current directed into a loop is turned off during each cycle and the magnetic response is measured with a coil with the current off. The currents subsequently produced in the earth migrate outwards and downwards with time with the rate of migration dependent on the resistivity structure. Thus, a sensor positioned inside the loop is further from the strongest current concentrations as time progresses. Therefore, receivers outside the loop will be more sensitive to the deeper materials as they are closer to current concentrations at depth (Fig. 1).

Simple simulation of current migration beneath the ground will demonstrate. The amplitude of the horizontal electric field to our standard model (Fig. 2) is computed using a 100m square loop, a base frequency of 2.5Hz and current of 25Amps. The horizontal current density (Fig.1) is shown as a function of depth at two stations; 25E inside loop (blue) and 200E outside (red). At early time (0.18ms) and shallow, the induced currents are more concentrated close to the loop center but at

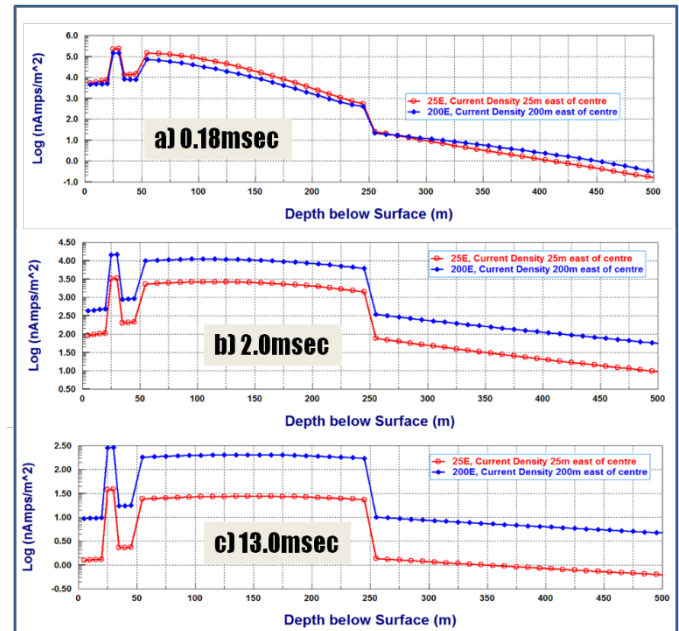


Figure 1: Current Density vs. Depth; (a) Early time (b) Late early time (c) mid-late time.

depth the current outside can exceed the current under the loop. By late early time (2 ms), the currents have migrated down to be concentrated in the conducting zone between 45m and 245m (Fig. 2). Now the currents below the outside station are an order of magnitude greater than those below the loop and this difference increases to almost 2 orders by 13ms. In addition, for in loop data, we are limited to vertical components and only the decay rates and data amplitudes are targets of inversion. This is opposed to the use of OUTLOOP data which has additional inversion targets. Inversions can use multiple vertical data measurements as well as horizontal components for receivers outside. This allows for the extension of the search for the best fitting model to a significantly increased number of data. This now allows for under parameterized model inversions which have significant resolution benefits over smoothed parameter methods. Also two critical physical effects are readily observed in OUTLOOP data which when utilized in inversion increase the accuracy of the inversions. The first effect, observed in off time data, is the migration

with time of a sign crossover in the vertical field. The second effect, in the horizontal component, is the time migration of the peak response outwards from the loop. These effects are simply the result of the induced currents migrating away from the loop with increasing time.

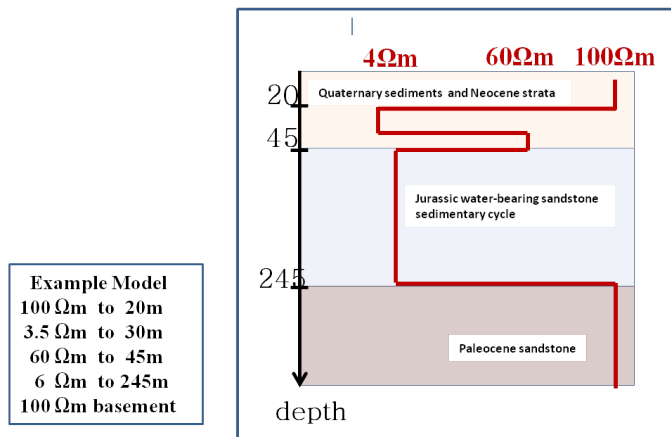


Figure 2: Synthetic Model Migration Studies.

Utilization of Current Migration

We utilize the synthetic model in Figure 2. This model is site specific deriving from the understanding of shallow strata in the area north of the Taklimakan desert. The surface is covered with weathered volcanics and resistive due to dry conditions. Below, a local water table is observed as a thin conductive layer in the Quaternary sediments. Our target is the saturated or partially saturated deeper Jurassic sandstone which is the regional aquifer beneath the Neocene strata. This aquifer is not a single strata but rather a series of sandstone, mudstone and siltstone sedimentary layers with conductivities dependent upon water content. Below are unconsolidated, impermeable Paleocene rocks. The field data site is extremely flat with surficial vertical gradients of order 1.2° . Our synthetic instrumentation will emulate our field equipment. We utilize a small loop (100x100m) common to studies within this area, with a bipolar current waveform (2.5Hz) and a sharp linear turn-off (ramp). Synthetic INLOOP measurements of dBz/dt (Fig. 3) are in off-time. We utilize standard time windows with no extremely early windows so as not to overcomplicate the analyzes. Forward modeling algorithms use standard frequency domain simulations

(e.g. Boerner, 1984) with a time transform accurately simulating our instrument's system response.

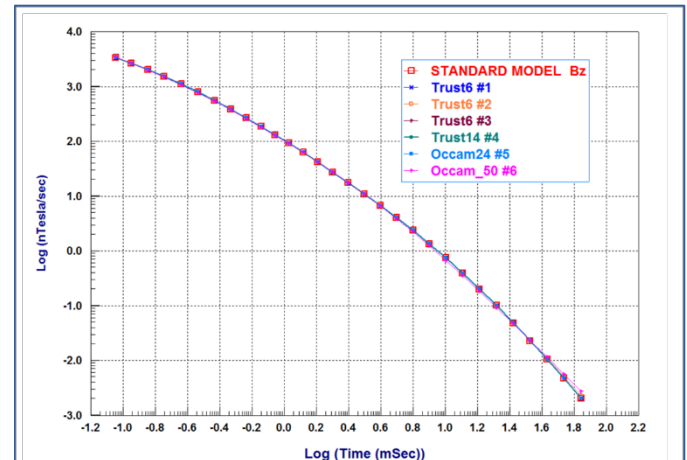


Figure 3: Model and Inversion responses.

Figure 3 is the model response (red) with six model responses selected from our many inversion models using two applications (1X1D, EMIGMA). Displayed models (Fig. 4) all differ significantly from our model. Synthetic data from five models are indistinguishable from the model's data while the sixth is indistinguishable in practice. The misfit in all cases was less than 1.6% (LS). All inversions used a uniform resistivity starting model. The first three inversions are five layers over basement utilizing a trust region technique (Jia and others, 2009) with different starting models. This technique allows for both thicknesses and resistivities to vary with constraints although no constraints were applied. All three detect the resistivity of the main conductive layer but not the correct boundaries. The fourth model is a 14 layer trust region model. Inversions 5 and 6 are smooth Occam type inversions. Generally, both inversions styles show a resistor at top, a conductive zone and resistor at the bottom. In the second experiment, we perform the inversion adding two measurements outside at 150m and 250m from centre with a base frequency of 25Hz. Groom and Jia (2005) applied inversions to combined INLOOP and OUTLOOP data to demonstrate that outside data can accurately resolve deep structures. Auken and others (2005) studied the control of inversion depths using laterally constrained inversions with central loop data.

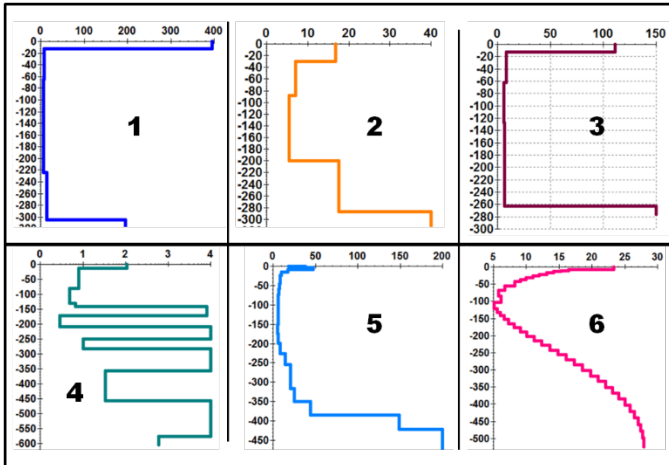


Figure 4: Six inversion models of the INLOOP response of our standard model.

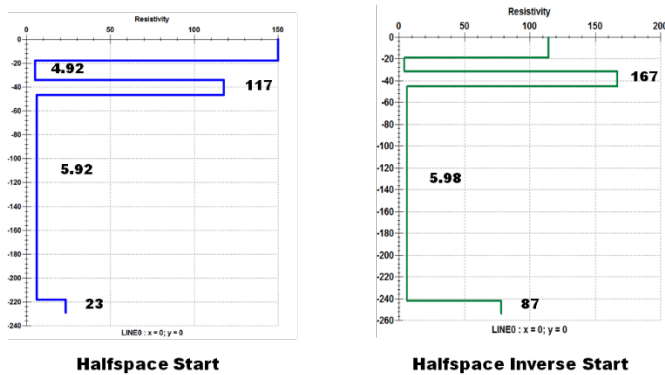


Figure 5: Comparison of model results from multi-separation strategy.

The first inversion (Fig. 5 left), is a 4 layers over basement, 3 station dBz/dt inversion (Fig. 5, left) with a uniform starting model without constraints. The layers are well resolved in depth but resistivities are not optimum. In the second inversion, we incorporate Bx (Jia et al, 2009). Now depths are well resolved (Fig. 5 right). Conductive layer resistivities are accurate but resistive layers are not as accurate. The misfit criteria for both inversions was set very low and thus the fits are almost exact.

Case Study 1 – 2016 Survey

After some years working with survey strategies, we undertook field experiments near Hami, 17km from the northern edge of the Turpan-Hami basin bordered by the Tian Sian range. Four small loop surveys were collected at two base frequencies with varying station locations (Geonics EM67, Protem). Loop and station positions were surveyed to eliminate as much survey noise as

possible. We anticipated that the ground to be highly one dimensional but the surveys were designed to verify the hypothesis. In this report, we will describe our results for 2 surveys. After our synthetic studies of the geologically based model (Fig. 2), we increased the loop to be 200m square. The first survey at 6.25Hz (S1, Fig. 6) measured (Bx/dt, Bz/dt) for 3 stations on L0N (400E, OE, 400W) with (0E,0N) being loop center. S2 measured 13 stations, 6 on L0N and 7 on L0E at 25Hz. 2048 stacks were read at all stations with 3 repeats using approximately 12A. The extra stations were measured to check the one dimensionality of the response as stations at equal distance should have identical vertical component responses with the horizontal responses flipping in sign. We show a portion of our inversion studies with the central loop studies with the central loop data of S1 (Fig. 7). All 11 models fit the data almost exactly but apart from some agreement on resistivities between 50 and 125m, there is no consensus. Depth to the strong conducting zone varies between 35 and 60m and the depth to the bottom of the conductor vary between 125 to 142m while the resistivity varies between 7.7 and 12.9 Ω m.

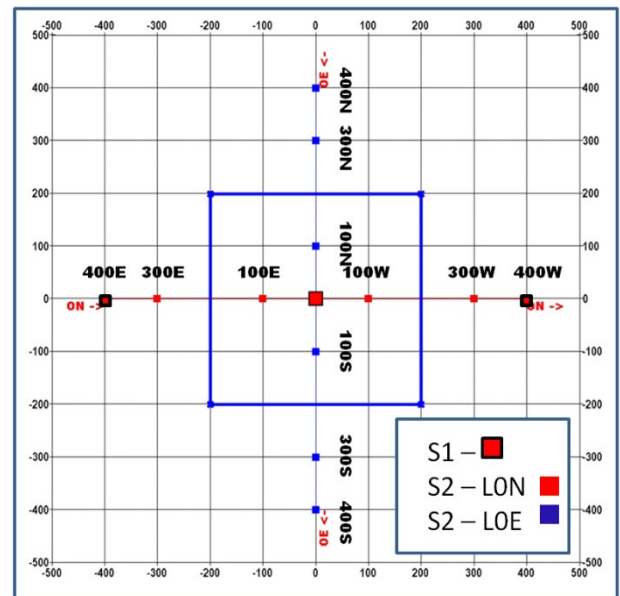


Figure 6: Survey 1 (6.25Hz) and Survey 2 (25Hz) stations.

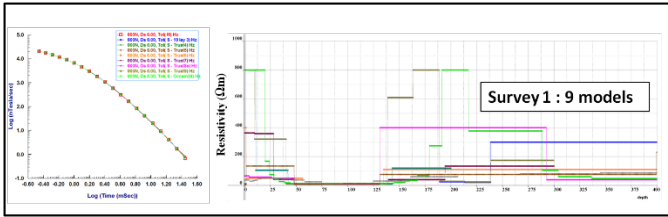


Figure 7: Survey1 (6.25Hz) 11 models: Left: Model fits to data, Right: Resistivity to Depth.

The next step was to check that the responses at the reciprocal stations matched sufficiently closely to verify our layered resistivity assumption. We then further averaged and differenced the responses producing the compressed surveys with 2 stations for S1 (0E,400E) and 4 stations for S2 (0,100,300,400E). The next stage was to jointly invert the resulting data utilizing both vertical and horizontal field components. Our standard model derived from geological knowledge (Fig 2) was the starting model. The results are shown in Figure 8. Simulation studies were then performed which verified that the model parameters were well determined except for the basement resistivity. Upon examining the remaining surveys, it was determined that the 4th zone must be sub-divided into two zones, the upper slightly more resistive layer and a lower slightly more conductive zone. A 5 layer over a basement inversion model resolved the depth to the basement as 615m (+/- 10) and the resistivity to be greater than 800Ωm.

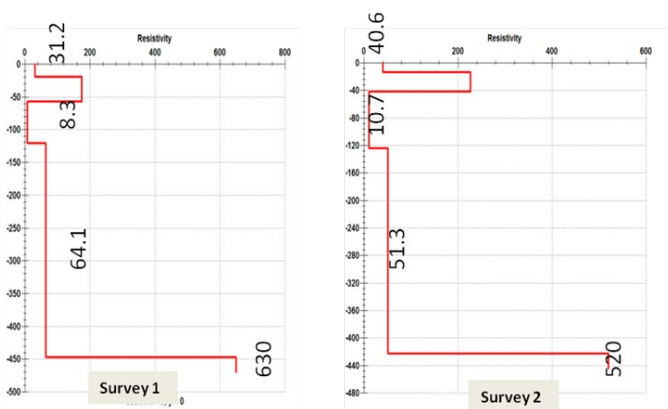


Figure 8: Joint Component and Station Inversions for S1 and S2.

Conclusions

For TDEM soundings, the use of only a single measurement whether INLOOP or OUTLOOP leads to much ambiguity in the interpretation. Utilization of both

INLOOP and OUTLOOP measurements and combining horizontal and magnetic components significantly lowers this ambiguity. The use of geological information both in survey design and in the inversion process are critical to accurate results.

Acknowledgements

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Monocomponent Downhole Seismic Investigation

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Abstract

This paper first discusses the relationships between seismic elastic parameters and geological properties, and maps the key empirical parameter relations in conjunction with lithologic classification. Subsequently, the results of a typical downhole seismic survey are interpreted to look into the subsurface geological structure. In this study, I attempt to extract S-wave arrival times from single component seismic data recorded using a P-wave receiver. After picking both compressional and shear wave arrival times from monocomponent downhole seismic data, I use them to examine subsurface lithology through computed geophysical properties, thereby gaining a broader understanding for static datum investigation.

Introduction

Near-surface seismic survey has several applications in reflection seismic, environmental investigation, geotechnics and civil engineering. It is used to determine the weathering zone parameters which are essential parameters for static corrections. Bedrock and waterbed depth determination can be possible through this method as well. Geotechnique tends to focus on site classification for applications requiring a detailed evaluation of subsoil stiffness and strength as a function of depth to model ground response for construction design purposes. Most of the civil engineering projects, challenge by complex and unique geological settings require subsurface information prior to design and construction. The failures associated with civil engineering structures with specific reference to roads and buildings has been attributed to lack of understanding of the soil structure among others.

Downhole seismic is of the simplest but invasive seismic methods to investigate physical properties of shallow subsurface layers of the earth. It requires only a single borehole where seismic sensors locate in different depths

to receive seismic energy generated on surface at a fixed distance from the top of the borehole. Physical properties lead us to elastic parameters which can be linked to geological features to understand subsurface structure and lithology. Calculating compressional wave velocity and shear wave velocity, downhole seismic enables us to explore geology of the site under study. While compressional wave velocity is more useful for reflection seismology, datum correction and velocity analysis, shear wave velocity is far useful engineering property of soil and rock because they are closely related to the shear strength of a material, and shear strength is what supports structures. For this, compressional wave velocities are not a reliable indicator of material type or foundation quality. Even though S-wave velocity increases rapidly in the shallow subsurface, their values are still low compared to P-wave velocities, which suggest that S-wave data have higher vertical resolution.

Several empirical equations have been extracted between seismic parameters and rock physics for years which are based on experimental measurements and statistics, but each one has its own limitations. Since laboratory and actual subsurface differs in many aspects such as confining pressure, pore pressure, temperature, and so on, these equations might not have pure correlation with measured field observations like well logs which record continuous variations of the target formations and investigate systematically rock physics properties. Figure 1 is an informative integrated plot that contains extensive major rock type velocity-density relations (Mavko and others, 2020) as well as extra useful information.

One of the experimental equations that is shown in Figure 1 is the equation obtained by Gardner (Gardner and others, 1974). as following:

$$\rho = 0.31V_p^{0.25} \quad (1)$$

which is between the P-wave velocity $V_p(m/s)$ and density $\rho(Mg/m^3)$ of rock samples through a wide range

of basins, geologic ages, and depths. Equation 1 is based on statistics and obtained through analyzing the

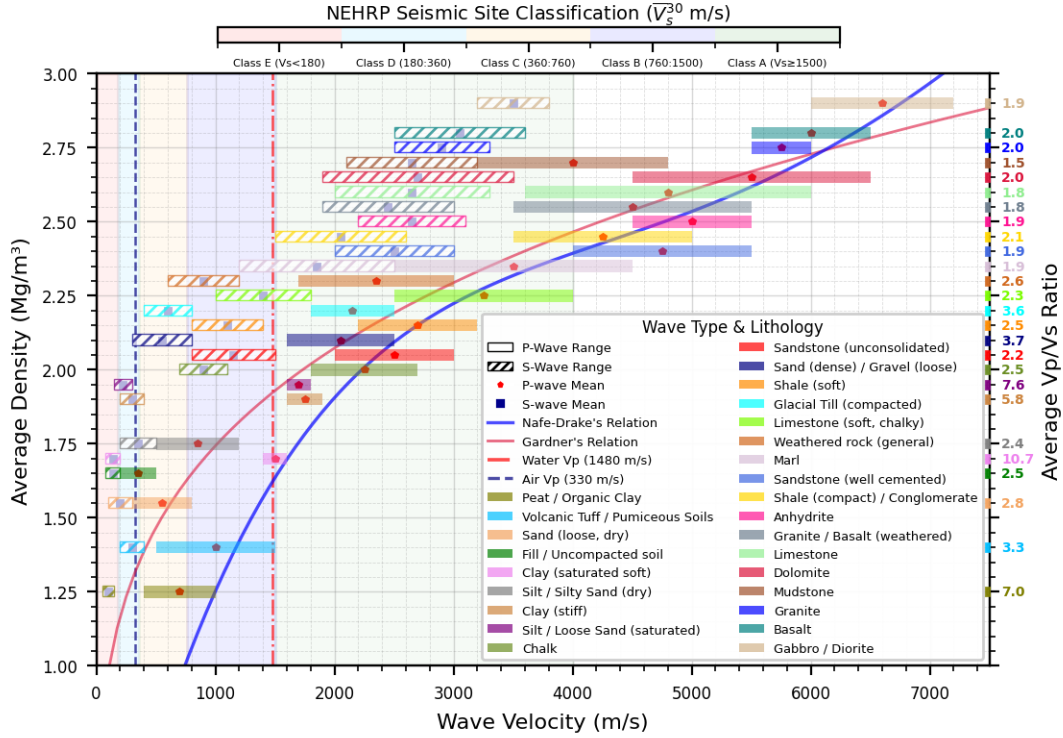


Figure 1: Integrated of illustration relations between density, seismic velocities, and lithologies.

distribution rules of velocity-density cross plot without considering the effect of clay content, pressure, temperature and etc. and this is why in Figure 1, it differs with ranges of P-wave velocities whereas it has good interpolation of some of them.

Brocher (2005) computed the following polynomial fit to the Nafe-Drake curve (Ludwig and others, 1970) relating P-wave velocity and bulk density, previously presented only graphically:

$$\begin{aligned} \rho = & 0.31V_p - 4.721 \times 10^{-7}V_p^2 + 6.71 \times 10^{-11}V_p^3 \\ & - 4.3 \times 10^{-15}V_p^4 \\ & + 1.06 \times 10^{-19}V_p^5 \end{aligned} \quad (2)$$

The average shear wave velocity down to 30 m depth $\bar{V}_s^{30}$ (which is computed by dividing 30 m by the one-way traveltime from the source to that depth) is a widely used parameter for classifying sites to predict their potential to amplify seismic shaking. It is an important parameter used in classifying sites in recent building codes (Dobry and others, 2000; BSSC, 2001) to specific sites. The site classes estimated from shallow shear-wave velocity models are also important in construction of

maps of National Earthquake Hazard Reduction Program (NEHRP) site classes (Wills and others, 2000). NEHRP site classes in terms of $\bar{V}_s^{30}$ are indicated in color bar ranges of Figure 1.

Data Acquisition

This study investigates the velocity, depth, thickness and finally lithology of the weathered layer in a specific point of south west of Iran. A borehole was drilled to a depth of about 80 m and plastic casings made up of PVC pipe were installed in the hole to prevent it from collapsing. A standard 7 kg sledgehammer as a monopole vertical source was used to generate seismic waves and a moving cabled tool equipped by a vertical geophone inside the hole to receive them. The schematic diagram of a cased borehole is shown in Figure 2 displaying longer intervals of deeper receiver locations.

The one-way travel time was recorded as a single channel at different depths in order to build up a continuous profile. For each trace, 2048 samples of data were recorded by a 24-channel ABEM Terraloc Mk 8 instrument with Sampling rate 0.1 μs . Figure 3

demonstrates recorded data and picked arrival times of both P- and S- waves.

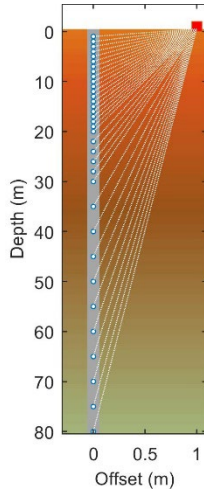


Figure 2: The schematic diagram of source and receiver configuration in this borehole investigation.

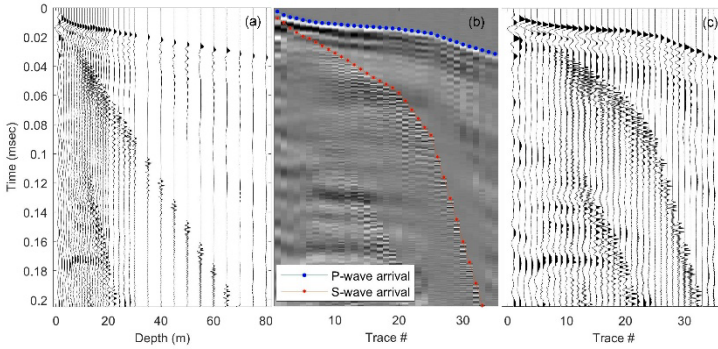


Figure 3: (a) Downhole seismic record based on acquisition geometry. (b) P and S wave arrivals. (c) Downhole seismic record based on trace number.

Results and Interpretation

Given the P- and S- wave velocities and the density of the material, the elastic properties that relate the magnitude of strain response to the applied stress can be calculated. For elastic, isotropic materials, these properties are derived directly from the seismic velocities (see Table 1 for formulas), where V_p , V_s , and ρ denote P-wave velocity, S-wave velocity, and density, respectively. These are, of course, linear dynamic elastic characteristics and are not always applicable to foundation material behavior under large static or dynamic loads. Nevertheless, they are the primary

parameters used to predict ground spectral amplification ratios for earthquake site response (Crice, 2011).

Compared to the more detailed crosshole survey, the downhole test is faster and more economical, and it provides better resolution than surface wave methods. The standard testing procedure follows ASTM (ASTM, 2019). Also, different interpretation methods for vertical and inclined boreholes are described and compared in (Kumar and others, 2025) and (Bautista and others, 2023), respectively.

Table 1: The elastic parameters for elastic, homogeneous, and isotropic media.

#	Parameter	Relation
1	Poissons ratio	$\sigma_p = \frac{\left(\frac{V_p}{V_s}\right)^2 - 2}{2\left(\frac{V_p}{V_s}\right)^2 - 2}$
2	Shear modulus	$G = \rho \cdot V_s^2$
3	Youngs modulus	$E = 2G(1 + \sigma_p)$
4	Bulk modulus	$K = \frac{1}{3} \left(\frac{E}{1 - 2\sigma_p} \right)$

The data were interpreted graphically by plotting one-way travel time against receiver depth (Figure 4). In this method, the key parameter is the time-averaged velocity to depth d , defined as $V_{avg} = \frac{\Delta d}{\Delta t}$. The slope of the depth-traveltime curve over each segment gives the average velocity for that interval. Because the source offset from the borehole top is negligible (1 m), the conventional downhole survey interpretation assumes a straight raypath from source to receiver and ignores subsurface refractions. Consequently, it is appropriate to use the recorded arrival time t rather than the corrected arrival time t_c defined in (Kumar and others, 2025).

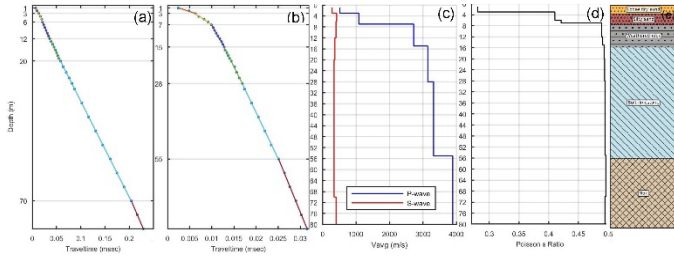


Figure 4: (a) S-wave traveltime. (b) P-wave traveltime. (c) Average velocity. (d) Poisson ratio. (e) estimated lithology of the subsurface layers.

Root-mean-square velocity is $V_{rms} = \frac{r}{t}$ where r is the direct distance between source and receiver ($r = \sqrt{d^2 + Offset^2}$). To calculate interval velocity, we propose using Dix's equation (Dix, 1955), which assumes that the subsurface consists of a series of flat, parallel layers. In reflection seismology, Dix's equation converts RMS velocity (V_{rms}) to interval velocity (V_{int}) using two-way travel time (TWT). Downhole seismology is analogous to reflection seismology, except that the recorded time is one-way travel time (OWT) and the receivers effectively capture half of a reflected raypath. Accordingly, we modify Dix's equation for downhole applications by substituting OWT for TWT as follows in Equation 3 where t_i is the traveltime received by i^{th} receiver in the depth d_i . Figure 5 displays these two types of velocity for the data.

$$V_{int(i)} = \left[\frac{t_{(i)} V_{rms(i)}^2 - t_{(i-1)} V_{rms(i-1)}^2}{t_{(i)} - t_{(i-1)}} \right]^{\frac{1}{2}} \quad (3)$$

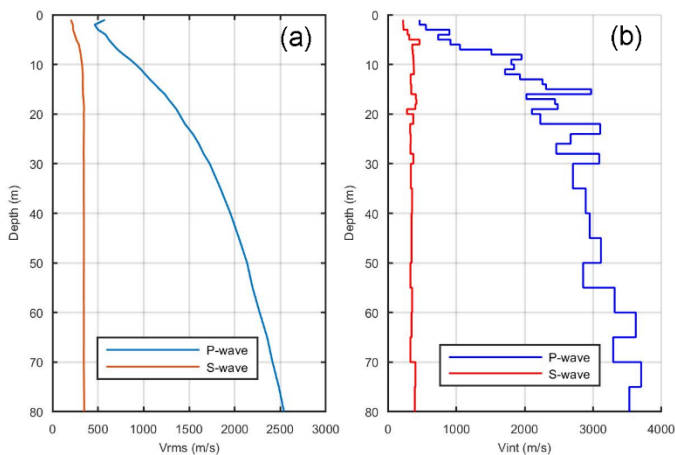


Figure 5: (a) RMS velocity. (b) Interval velocity.

Conclusion

Downhole seismic measurements were performed in a single borehole drilled in southwestern Iran. Processing and interpretation of the data indicate that the shallow subsurface, down to 80 m depth, consists of several layers, and the sedimentary rocks in the area can be considered to have moderate elasticity. The seismic wave velocity and bulk density values presented in this paper, in conjunction with the local geology, provide useful primary data for seismic microzonation of the region. Three velocity types are introduced and calculated in this study to gain a more comprehensive understanding of velocity variations from different conceptual perspectives.

Interpretation results show that the weathered-layer velocity ranges from 500 to 1100 m/s, with an average value of 800 m/s. The results also reveal that the weathered layer is approximately 7 m thick, with velocity increasing with depth. Accordingly, it is recommended that seismic survey shots be placed at depths greater than 7 m to mitigate the effects associated with the low-velocity layer. It is also recommended that the foundations of heavy buildings and roads, particularly bridges, be constructed to a depth of at least 7 m to ensure that the infrastructure rests on the consolidated layer.

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☐ Other	☐ Mining	☐ Seismic	☐ GSA	
	☐ Shallow Oil & Gas	☐ Other	☐ NGWA	
	☐ UXO		☐ NSG	
	☐ Aerial Geophysics		☐ SEG	
	☐ Agriculture		☐ SSA	
	☐ Renewable Energy		☐ SPWLA	
	☐ Other		☐ NAOC	

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Environmental and Engineering Geophysical Society

2026 EEGS Membership ApplicationRenew or Join Online www.eegs.org**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: \$ _____

STUDENT SUPPORT ENDOWMENT

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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, 1391 Speer Boulevard, Suite #450, Denver, CO 80204 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

2026 Corporate Membership Application

<https://www.eegs.org/join-or-renew->



EEGS is the premier organization for geophysics applied to engineering and environmental problems. Our multidisciplinary 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 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. We strive to continuously add value to all the Corporate Membership categories. For the best value, we offer the Basic + Web ad Package Website Advertising opportunities. Please select (circle) your membership category and rate. EEGS is also offering an opportunity for all EEGS members to help support student(s) at \$20 each. Please indicate your willingness to contribute to support of student members below:

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

Category	2026 Basic Dues Rate	2026 Basic + Web Ad Package
Corporate Student Sponsor <i>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 and a 10% discount on advertising in JEEG and FastTIMES and Sponsorship of 10 student memberships</i>	\$320	\$870
Corporate Donor <i>Includes one (1) individual EEGS membership, one (1) full conference registration 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 and a 10% discount on advertising in JEEG and FastTIMES</i>	\$685	\$1235
Corporate Associate <i>Includes two (2) individual EEGS memberships, an exhibit booth and registration 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 and a 10% discount on advertising in JEEG and FastTIMES</i>	\$3210	\$3760
Corporate Benefactor <i>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 and a 10% discount on advertising in JEEG and FastTIMES</i>	\$4035	\$4585
Website Advertising <i>One (1) Pop-Under, scrolling marquee style ad with tag line on Home page, logo linked to Company web site</i> <i>One (1) Button sized ad, linked logo, right rail on each web page</i>	\$600/yr. \$250/yr.	Purchase Separately Package Rates include both web site ad locations

Environmental and Engineering Geophysical Society
2026 Corporate Membership Application

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CONTACT INFORMATION (Corporate Memberships are based on a Primary Member's 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	☐ GeolInstitute	
☐ Other	☐ Mining	☐ Seismic	☐ GSA	
	☐ Shallow Oil & Gas	☐ Other	☐ NGWA	
	☐ UXO		☐ NSG	
	☐ Aerial Geophysics		☐ SEG	
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Foundation Total: \$ _____

PAYMENT INFORMATION

Subtotals

Membership: \$ _____

Total Student Sponsorship @ \$20 ea. \$ _____

Foundation Contributions: \$ _____

Grand Total: \$ _____

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

Card Number

Exp. Date

CVV #:

Name on Card

Signature

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