1 | Title

Electrical Resistivity Tomography (ERT) Parameter Adaptation for Seasonal Variations

2 | Project Type

Research

3 | Focus Categories

1) GEOMOR	Geomorphological Processes
2) GW	Groundwater
3) HYDROL	Hydrology

4 | Research Categories

Groundwater Flow and Transport

5 | Keywords

Geophysics, electrical resistivity tomography, aquifer, floodplain, alluvial architecture, time-lapse, seasonal variation

6 | Start Date

06 / 01 / 2019

7 | End Date

05 / 31 / 2020

8 | Principal Investigators

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(979) 218-5153	PhD | Geophysics | 2017 – 2022

9 | Congressional District

17th Congressional District of Texas

10 | Abstract

If the upper few meters of soil have a low electrical conductivity (ie. are relatively dry), electrical resistivity tomography can characterize groundwater sources down to the bedrock (~100 m deep) of the Brazos River Alluvial Aquifer. However, after a heavy rainstorm, the upper few meters of the soil become saturated, thereby raising electrical conductivity and decreasing electrical penetration depth to only a few meters under current parameters. We will conduct repeated ERT surveys adjacent to water monitoring wells over several seasons, systemically varying instrument parameters to determine which configurations generate

electrical resistivity tomograms matching the adjacent water well ground truth and under which conditions. We will use these results to make the ERT deployable under a wide range of soil conductivities and thereby deployable to study fluvial stratigraphy and groundwater flow in similar floodplains worldwide. According to the 2017 Texas State Water Plan, planning for future use necessitates knowing the volume of available groundwater. The volume of available groundwater is a dynamic value, and this research will provide Texas and other regions with a non-invasive, geophysical method that is capable both of accurately providing these dynamic values for groundwater volumes and flow rates and of operating year round.

11 | Statement of Regional of State Water Problem

The TWRI sets forth "developing innovative water management strategies to aid in implementing the Texas State Water Plan [TSWP] that addresses…identifying new surface and groundwater sources…" as a research priority, especially in its scientific, technological, political, and socio-economic facets. Our current research fits within the scientific and technological facets of this research priority, and more broadly addresses two fundamental questions posed in Chapter 6 of the 2017 TSWP:

1) "…how much water do we already have?" (p. 61)
2) "…how much water moves in and through Texas'…aquifers?" (p. 75)

Our research uses non-invasive, electrical resistivity tomography (ERT) to map and characterize groundwater fast flow paths in the Brazos River Alluvial Aquifer (BRAA). These fast flow paths are antecedent, buried sand channel-belts (old, buried, sand-filled courses of the Brazos and older rivers) and likely behave like surface rivers, particularly with volume surges after recharge events (eg. rainstorms or floods). Therefore, the groundwater volume in these channel-belts is a dynamic value dependent on the season, and accurately calculating the groundwater storage of the BRAA requires electrically surveying the channel-belts in all seasons to mitigate the biasing effect of the recharge surges. We are collaborating with the Texas Water Observatory (TWO) at Texas A&M University (TAMU) to provide seasonal groundwater data for their groundwater-surface water-atmospheric water interaction studies.

12 | Statement of Results or Benefits

Two types of information will be gained: groundwater volume and flow rate patterns over several seasons as well as instrument parameters necessary to operate the ERT method in a variety of soil moisture and air humidity levels. This will allow the ERT method—a non-invasive, inexpensive method for identifying dynamic groundwater volumes and flow rates as well as characterizing floodplain architecture—to be accurately and precisely operated far away from the ground truths of monitoring wells and in a wide variety of fluvial environments worldwide. With such a method, Texas and other regions will be able to accurately determine how much near-surface groundwater is available and how that groundwater is moving through the subsurface.

13 | Nature, Scope, and Objectives of the Project

This data will be provided by geophysically surveying the TWO sites TAMU Farm (on the Brazos' banks), Riesel, TX (also near the Brazos' banks), and Stiles, TX (near the western edge of the Brazos watershed). Our goal is to survey these sites adjacent to monitoring wells (ie. the ground truth) every few weeks and determine instrument parameters necessary for the AGI SuperSting™ to operate over a wide ranges of soil moisture and air humidity levels, detailed as a problem in Grygar et al (2015). These results will be compared against time-domain electromagnetic surveys (via Geonics' G-TEM) to verify validity of the ERT data. Both instruments are owned by Prof. Mark Everett and freely available for research on this project.

Timeline of Activities

2019

Jun-Aug | Monitor regions near TWO water wells; establish baselines and confirm ability to pinpoint the water table and other subsurface features using ERT and TDEM

Sep-Nov | Continue monitoring regions near TWO water wells; systematically adjust parameters to continue pinpointing the water table and other subsurface features during the fall and winter rains and the consequent saturation of the soil

Dec | Begin aggregating and analyzing the time-lapse ERT and TDEM results

2020

Jan-Mar | Continue analyzing the time-lapse ERT and TDEM results; present preliminary results at SAGEEP 2020

Apr-May| Write publication on ERT parameter adaption for seasonal variations

14 | Methods, Procedures, and Facilities

ERT will be run using the dipole-dipole method, an ERT method especially good at detecting horizontal changes (Alwan IAK 2013) such as dykes, cavities, and channel-belts, as well as time-domain electromagnetics to provide verification of ERT data far away from the monitoring well. These datasets will be processed through AGI's EarthImager 2D and IXG-TEM, respectively, values correlated to the known resistivity values for various geologic materials, and then visualized in 3D with AutoCAD 2018. 3D diagrams will sequenced over time to show how the visualized groundwater volume fluctuates throughout seasons. These datasets will also be compared with local rainfall and Brazos river-head data to identify any lagged patterns.

15 | Related Research

Two sets of researchers in the Czech Republic (Grygar et al 2015 and Babek et al 2018) are also using ERT to investigate floodplain architecture, particularly the sand-gravel deposits of abandoned meanders. Grygar et al focuses on the pollution and chemostratigraphy aspects of these abandoned meanders while Babek et al focuses on the controls that factored into the formation of these abandoned meanders. In both, the focus is more geologic than hydrologic. Our research investigates the same type of floodplain architecture, the buried sand-gravel deposits of the abandoned meanders, but then focuses on the hydrology of them: particularly hydraulic conductivity inside the buried deposits, outside of the buried deposits, and between the inside and outside. We then address a basic problem of conducting ERT research on this fluvial stratigraphy, namely the diminishing sensitivity of the model at depth with increasing soil moisture content. Our goal is find instrument parameters so that ERT can be used to monitor changes in the groundwater within floodplain architecture without losing data resolution in the rainy months of a year.

16 | Training Potential

Graduate Students: 1 (PhD)
Undergraduate Students: ~2 (BS)
Total Students: ~3

19 | Investigator's Qualifications

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A. Education
PhD 1991 in Geophysics at University of Toronto
MSc 1987 in Physics at York University (Canada)
BSc 1985 in Physics at York University (Canada)

B. Positions and Employment
2003-present Professor, Geology and Geophysics, Texas A&M University
2014 Visiting Professor, Dept. of Geotechnology, Khon Kaen University, Thailand
2011-2014 Graduate Director, Geology and Geophysics, Texas A&M
2010 Guest Professor, Institut fur Geophysik, ETH Zurich, Switzerland
1997-2003 Associate Professor, Geology and Geophysics, Texas A&M
1995-1997 Assistant Professor, Geology and Geophysics, Texas A&M
1993-1994 Post—doctoral Scientist, University of Cambridge, U.K.
1991-1992 Green Scholar, Scripps Institution of Oceanography, UCSD

C(i). Publications (most closely related)
2017 DGBeskardes CJWeiss **MEEverett**
Estimating the power law distribution of Earth electrical conductivity from low-frequency, controlled-source electromagnetic responses *Geophys J Int* **208** 639-65

2015 JGe **MEEverett** CJWeiss
Fractional diffusion analysis of the electromagnetic field in fractured media Part II: 3-D approach *Geophysics* **80** E175-E185

2009 **MEEverett**
Transient electromagnetic response of a loop source over a rough geological medium *Geophys J Int* **177** 421—429

2007 CJWeiss**MEEverett**
Anomalous diffusion of electromagnetic eddy currents in geologic formations *J Geophys Res* **112** 2006JB004475

2002 **MEEverett**CJWeiss
Geological noise in near-surface electromagnetic induction data *Geophys*s *Res Lett* **29** 2001GL014049

C(ii). Publications (significant other)

2016 BAWeymer **MEEverett** CHouser PWernette PBarrineau Differentiating tidal and seasonal effects on barrier island hydrogeology: testing the utility of portable multi-frequency EMI profilers *Geophysics* **81** E347-E361

2015 BWeymer **MEEverett** TSdeSmet CHouser
Review of electromagnetic induction for mapping barrier island framework geology *Sed Geol* **321** 11-24

2012 JGe **MEEverett** CJWeiss
Fractional diffusion analysis of the electromagnetic field in fractured media Part I: 2-D approach *Geophysics* **77** WB213-WB218

2011 SMukherjee **MEEverett**
3D controlled-source electromagnetic edge-based finite element modeling of conductive and permeable heterogeneities *Geophysics* **76** F215-F226

2009 DSSassen **MEEverett**
3D Polarimetric GPR coherency attributes and full-waveform inversion of transmission data for characterization of fractured rock *Geophysics* **74** J23-J34

D. Synergistic Activities

State of Texas Professional Geoscientist No. 5141
Co-Editor-in-Chief *Journal of Applied Geophysics*
Technical Advisory Board member, Deep Imaging Technologies (Tomball TX)
Expert Witness, PGS-EMS Patent Infringement Proceedings (Oslo, Norway)
Course Instructor, Schlumberger (Abingdon UK, Houston, Abu Dhabi UAE)

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- Bábek O, Sedláček J, Novák A, Létal A 2018. *Electrical resistivity imaging of anastomosing river subsurface stratigraphy and possible controls of fluvial style change in a graben-like basin, Czech Republic*. Geomorphology 317, 139-156
- Grygar TM, Elznicová J, Tûmová, Faměra M, Balogh, M, & Kiss T 2015. *Floodplain architecture of an actively meandering river (the Ploučnice River, the Czech Republic) as revealed by the distribution of pollution and electrical resistivity tomography*. Geomorphology 254, 41-56
- Texas Water Development Board 2017. *State water plan: water for Texas*. Texas Water Development Board, Austin, TX