SEASIDE BASIN WATERMASTER
REQUEST FOR SERVICE

DATE: March 6, 2025

RFS NO. 2025-01
(To be filled in by WATERMASTER)

TO: Ahmad-Ali Behroozmand
Geophysical Imaging Partners
PROFESSIONAL

FROM: Robert Jaques
WATERMASTER

Services Needed and Purpose: Perform a pilot geophysical survey near WATERMASTER's Sentinel Well No. 4 located in Seaside, California. See Scope of Work in Attachments 1 and 2.

Completion Date: Assuming that access permission is received from the landowners where the work is to be performed within 30 days from the date of execution of this RFS No. 2025-01, all work of this RFS shall be completed within 120 days from the date of execution of this RFS No. 2025-01. If access permission is delayed, the completion deadline will be extended accordingly. The work shall be performed in accordance with the Schedule described in Attachment 1.

Method of Compensation: Time and Materials (As defined in Section V of Agreement.)

Total Price Authorized by this RFS: $ 15,500.00 (Cost is authorized only when evidenced by signature below.) (See Attachment 2 for Estimated Costs).

Total Price may not be exceeded without prior written authorization by WATERMASTER in accordance with Section V. COMPENSATION.

Requested by: [signature] Date: 3/5/25.
WATERMASTER Technical Program Manager

Agreed to by: [signature] Date: 3/9/25.
PROFESSIONAL

ATTACHMENT 1

SCOPE OF WORK

Recent data from WATERMASTER's Sentinel Well No. 4 suggests increasing salinity is occurring in some portions of the underlying strata, however the extent of potential seawater intrusion in the monitored aquifer(s) around this well is currently unknown. The purpose of the geophysical survey to be performed under this RFS No. 2025-01 is to confirm the applicability of time-domain electromagnetic (TEM) imaging as a tool to investigate the presence and map the extent of seawater intrusion in the vicinity of Sentinel Well No. 4. The Scope of Work is described in detail below in the Proposal from PROFESSIONAL dated June 2024.

PROPOSAL: sTEM GEOPHYSICAL SURVEY TO MAP SALTWATER INTRUSION

June 2024

Seaside Basin Watermaster
83 Via Encanto
Monterey, CA 93940

GEOPHYSICAL IMAGING PARTNERS

Dear Mr. Robert S. Jaques,

Following recent meetings held between Seaside Basin Watermaster (the Client), and Geophysical Imaging Partners (GIP) and Haley & Aldrich (H&A), this proposal is prepared for the Client in response to a request for a pilot geophysical survey near a sentinel well in Seaside, California. Recent data from the sentinel well suggests increasing salinity, however the extent of potential seawater intrusion in the monitored aquifer(s) around this well is currently unknown. The purpose of the geophysical surveys is to confirm the applicability of time-domain electromagnetic (TEM) imaging as a tool to investigate the presence and map the extent of seawater intrusion in the vicinity of the affected sentinel well.

Taking the scope of work and the expected geological settings into consideration, we propose a one-day preliminary geophysical survey the area near the well using the stationary time-domain electromagnetic (sTEM) method, sTEM (see Figure 1).

This pilot survey will be conducted using a sTEM system from TEMCompany, which provides point measurements down to maximum depths of 200-300 meters.

This pilot geophysical survey will provide an electrical resistivity model of the subsurface at each measuring point, which can then be transformed and interpreted to estimate lithology and relative pore fluid salinity. The primary objective of this initial pilot is to determine if the resulting geophysical profiles and interpretations provide meaningful insight to the Client toward understanding seawater intrusion in the study area, and warrant additional geophysical investigations.

Figure 1 The sTEM system, STEM, in operation during a recent project in Livermore, California.

It is not feasible to collect useful TEM data in the vicinity of powerlines and other installations due to interference from these sources. As a general rule, we will need to maintain a distance from powerlines that is similar to the depth of investigation.

Proposed sTEM sounding locations are shown in Figure 2. The number of proposed locations is higher than averaged daily coverage. We understand that vegetation can be dense in the study area, and actual survey locations may be adjusted based on local obstructions and/or access issues. Overall, we will make efforts to conduct measurements at as many locations as possible during one survey day and wherever possible near the well within the pilot study timeframe.

Our team has worked on geophysical saltwater intrusion projects in northern Monterey Bay, both by applying ground-based TEM like the proposed sTEM system and by flying offshore airborne EM (AEM) survey in 2017, as well as the statewide AEM survey on behalf of DWR until late 2022. Furthermore, the team has recently worked on the deep aquifer study in Salinas Valley using AEM.

Existing geophysical data near the survey area will be revisited to optimize field setup and help with the interpretation of the sTEM results. Existing data include:

- ERT vertical section performed along the beach by Stanford University (2015)
- Airborne Electromagnetic (AEM) SkyTEM 2017 performed by Stanford University
- AEM SkyTEM 2019 performed by Stanford University
- AEM SkyTEM 2022 performed by DWR

A preliminary hydrogeologic interpretation of the pilot study results will be included in our final report, correlating our measured electrical resistivity profiles to known stratigraphy in the study area. We ask that the Client provide well logs, along with monitoring data and all other existing information about the affected sentinel well (and any other pertinent wells within or directly adjacent to the pilot study area). These data, along with publicly available data from the previous geophysical surveys noted above, will be used to generate a preliminary interpretation of lithology, including depth intervals corresponding to key regional aquifers. If data are able to substantiate an estimation of relative areas of higher vs lower pore fluid resistivity (correlating with salinity) within these key aquifers, a preliminary interpretation of seawater intrusion indications will also be included.

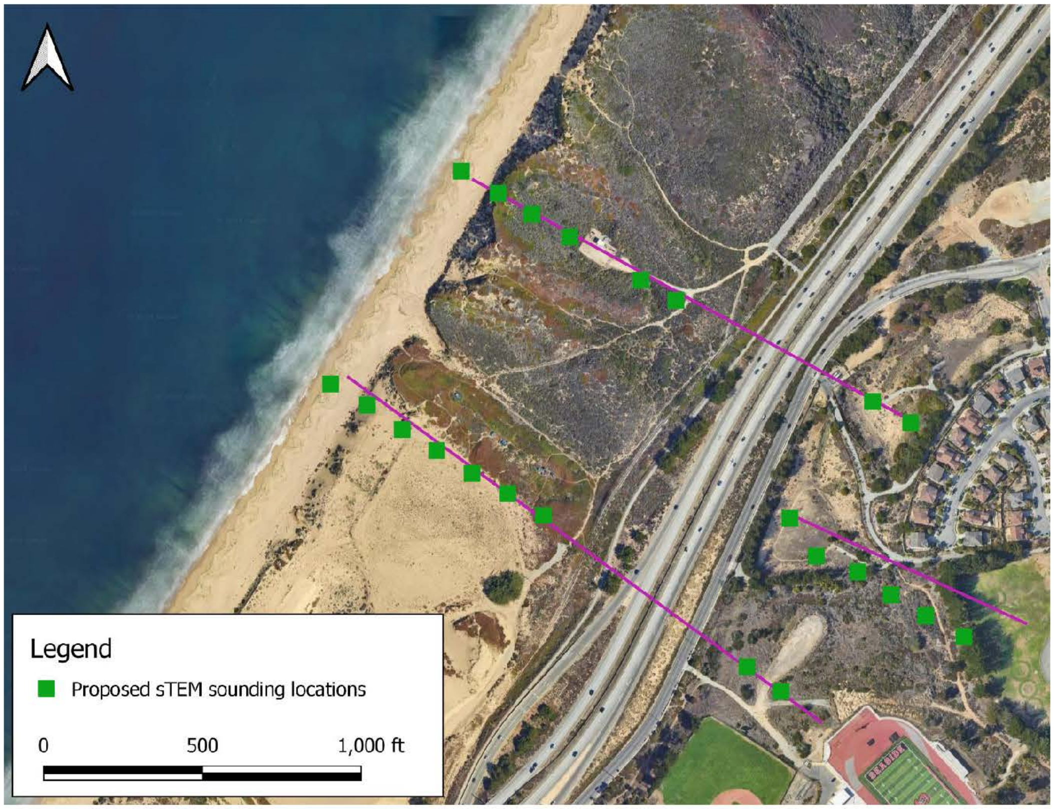

Figure 2 Proposed sTEM sounding locations.

The Stationary Time-Domain Electromagnetics (sTEM)

The sTEM is a hand carried system that involves laying out a 40 x 40 m (130x130 ft) square-shaped transmitter loop, along with a receiver placed at the center of the transmitter loop for each measurement (see Figure 3). These measurements are referred to as 'soundings' and provide subsurface information beneath the transmitter loop to depths of approximately 200-300 meters. The depth of investigation depends on the geological conditions, the water quality (salinity) and signal-to-noise ratio. In the presence of seawater in the formation, the resistivity will be in the range of 1 ohm-m. The electrically conductive saltwater will prevent the EM signal from penetrating a thick conductive layer (e.g., 100+ft) of seawater.

Depending on the distance between the soundings and the terrain, about 10-20 soundings can be conducted in a day. The instrument is lightweight and can also be hand carried in the field by a crew of two people, as illustrated in Figure 4. By hand carrying the instrument and placing only thin cables on the ground for a short period (up to 20 minutes), no damage to the environment is expected.

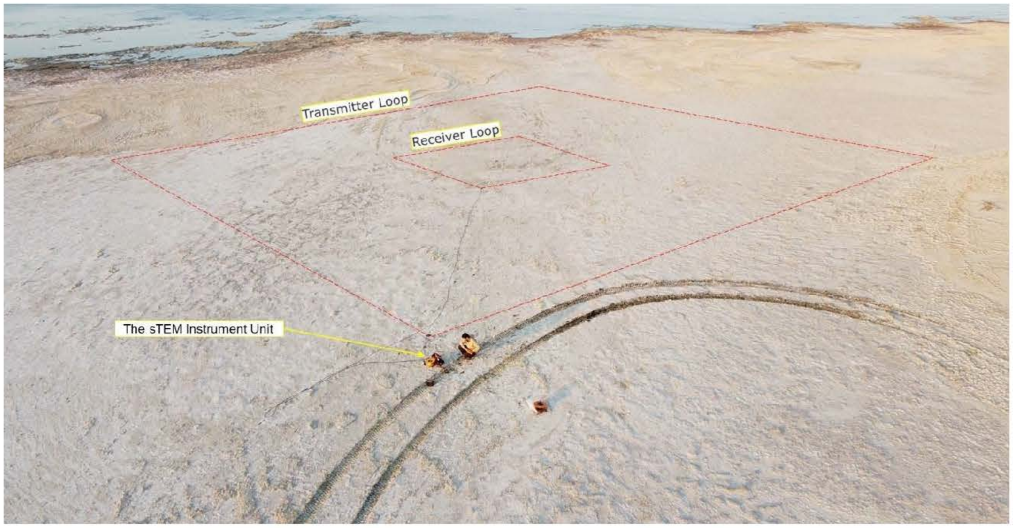

Figure 3 Configuration of the sTEM system.

sTEM data processing steps

The collected STEM data undergo the following processing steps:

1. Manually inspect each dataset for both low-moment (LM) and high-moment (HM) sounding curves.
2. Remove noisy data. The noise can be due to overhead powerlines, buried power cables, metal fences, and other man-made sources.
3. Assign a standard uniform 3% noise to all data.
4. Assign transmitter loop center coordinates (acquired in the field) and Digital Elevation Model (DEM) elevation to the sounding positions.

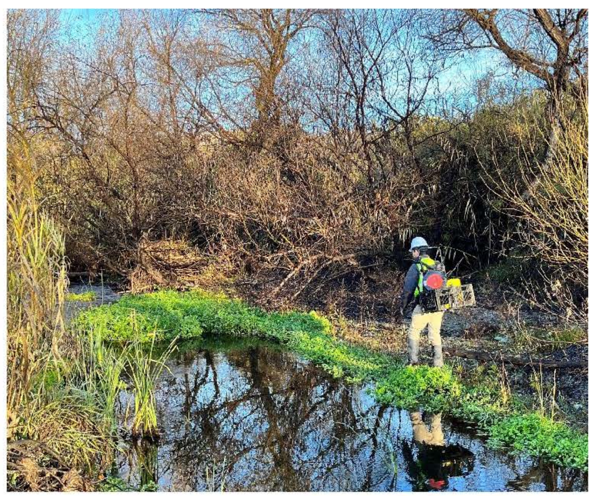

Figure 4 A sTEM system, STEM, being carried with a two-person team during a recent well siting project in Livermore, California.

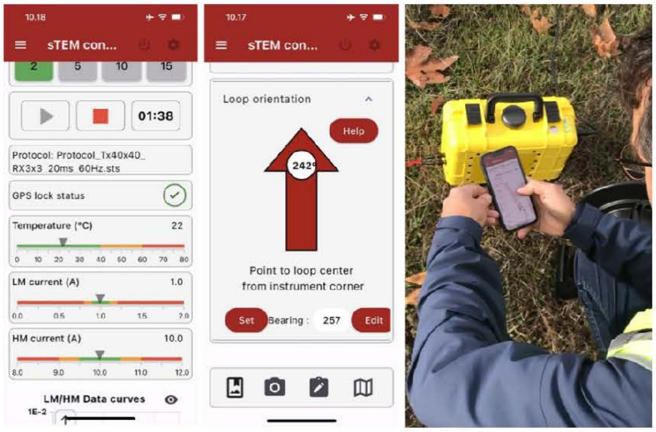

Figure 5 The user interface when operating the sTEM instrument.

sTEM data inversion steps

The processed STEM data will then be used in the following inversion scheme:

1. Define vertical constraints on the resistivities as well as the number of model layers and layer thicknesses.
2. Invert the processed data for smooth (multi-layer) resistivity models.
3. Present the results as line models. If the results are not satisfactory (e.g., due to high data residual), the inversion setup is revisited, and the data are re-inverted.
4. Calculate the data residual (data fit), which represents the difference between the observed data and the mapping of the estimated model to the data space.
5. Calculate the depth of investigation (DOI), based on a sensitivity analysis of the model.

sTEM Results

The processing and inversion of the STEM data will be performed using the software packages Aarhus SPIA (https://www.aarhusgeosoftware.dk/aarhus-spia-tem) and Aarhus Workbench (https://www.aarhusgeosoftware.dk/aarhus-workbench). The SPIA and Workbench are well-documented and technically sound software packages used for processing and inversion of ground-based and airborne electromagnetic and geoelectrical data. We utilized an application that is specifically designed for the processing and inversion of STEM data.

As described in the previous sections, the measured data are modeled to represent electrical resistivities at various depths, which can then be interpreted as lithology to get an understanding of the site geology. The inversion of STEM data results in one-dimensional (1D) resistivity models at each sounding location.

The STEM results will be presented as vertical resistivity sections, mean resistivity plan-view maps, and resistivity model reports.

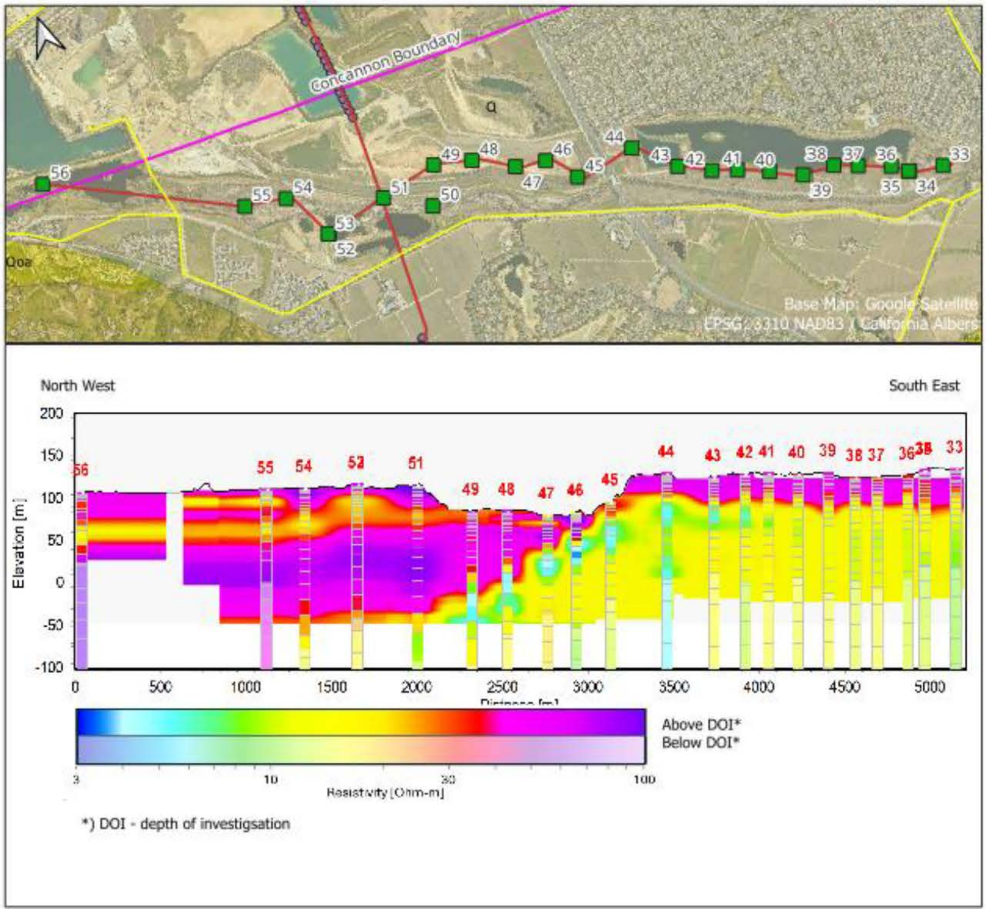

Figure 6 Example showing the sTEM models as a vertical section.

Data Deliverables

The following files will be provided as project deliverables.

1. Raw data, including files extracted from the instruments and supporting configuration files.
2. A GERDA Firebird database containing the acquired data, processed data, and the inverted model results.
3. ArcGIS layers, which include:
   a. Layout: ArcGIS shape files ("*.shp") containing general information about the surveyed area (AOI, well locations etc.) and location of the collected data.
   b. Georeferenced TIFF files for mean resistivity slices
   c. Model Sections: ArcGIS shape files ("*.shp") providing location information for the vertical sections presented in this report.

4. Google Earth KMZ files.
5. The project report, delivered as a PDF file.

The project report contains basic interpretations of the data based on our general understanding of the geological and hydrogeological settings in the study area, with specific correlations to data provided by the Client on the affected sentinel well and any other pertinent wells within the pilot study area. We will participate in one or two meetings to discuss the interpretations further.

Time schedule

We are prepared to discuss the project timeline and schedule the fieldwork according to the needs. Initial inversion results will be shared within two-three weeks after demobilization. A virtual meeting will be held with the Client to present the results. The final project deliverables will be provided within 4-8 weeks after demobilization. Please do not hesitate to reach out if you would like to discuss the project plan further.

Team

Ahmad-Ali Behroozmand, Max Halkjaer and Jesse Crews will be in charge of the field operations and managing data processing, inversion, and reporting of results. The team members bring years of experience in TEM investigations covering any aspect from the theoretical geophysical background, hardware and software utilized for data processing and inversion, and interpretation of the results. You can find their resumes in Appendix 2.

Budget

The table below provides cost estimates for the project, which will be invoiced as a lump sum. The cost estimates are provided according to the above-mentioned plan. Should the proposed plan require adjustments, we are happy to discuss it with the Client and modify the budget accordingly.

Tasks	**Price (USD)**
Mob/demob[1]	1,500
1 day of STEM survey ($9,000/day)[2]	9,000
Integration with AEM results and report[3]	5,000
Total (USD)	**15,500**

[1]Includes instrument preparation, hotels, car rental, gasoline for the car, insurance, time while traveling, software license (SPIA, Workbench), and per diem.

[2]Includes fieldwork, data processing and inversion.

[3]Includes presentation of the results to the Client, preparing standard data report and other project deliverables.

Appendix 1 – TEM Theory

For decades electromagnetic (EM) methods have been used worldwide for cost effective mapping of the subsurface materials for different applications. More recently, the accuracy of the instruments and their ability to obtain information about aquifers and hydrogeological properties has improved significantly. As a result, the TEM method is now one of the most efficient geophysical technologies for groundwater investigations.

Principles of TEM

The physical principle of the TEM is based on the electromagnetic induction phenomenon. The ground is first energized by a primary magnetic field generated by a direct current injected in a transmitter (Tx) loop. When the current stabilizes, the transmitter is turned off abruptly. During this rapid decay of the current an electromotive force results in short-duration eddy currents whose strength is largest in conductive parts of the ground. The EM induction phenomenon generates what is called the secondary magnetic field, which is measured just after the end of the turn-off using an induction receiver coil located in the center of the Tx loop (central loop configuration like STEM) or outside the Tx loop (off-set configuration like tTEM). The actual measurement is the time derivative of the magnetic flux passing through the receiver coil (dB/dt).

Just after the current in the Tx loop is turned off, the eddy currents in the ground will be close to the surface, and the measured signal primarily reflects the resistivity of the top layers. At later times the current will run deeper in the ground, and the measured signal contains information about the resistivity of the deeper layers. This is why the method is referred to as time-domain EM or TEM. Measuring the dB/dt in the receiver coil (also called a “sounding”) will therefore provide information about the resistivity as a function of depth.

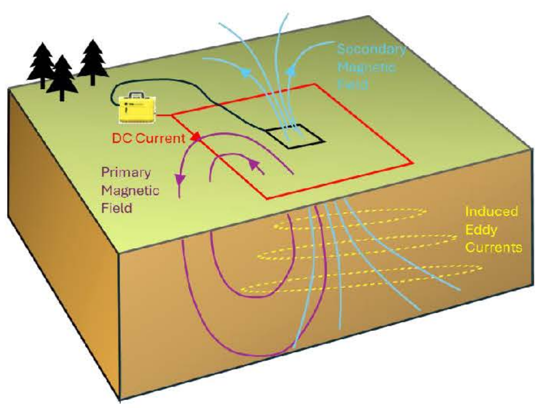

Figure 7 Basic principles of a TEM measurement.

The transmitter magnetic moment (Tx loop area x current x number of wire turns) and the signal-to-noise ratio (SNR) determine the depth of investigation (DOI). A stronger magnetic moment enables deeper penetration of the magnetic fields and thus greater DOI. The SNR depends on the ground electrical resistivity and ambient noise. The higher the SNR, the greater the DOI.

More information about the principles of the TEM method can be found in Ward and Hohmann (1988).

Noise in TEM data

TEM data are comprised of different type of noise components. Noise can cause bias signals and affect the depth of investigation and if not properly identified and removed, can result in incorrect geological and hydrological interpretations. The different sources of noise include: (1) Galvanic coupling caused by the electromagnetic signal induced in a metal object, such as a metal pipe, metal fence or the loop, following the ground-wire through the power-masts to the ground, (2) Capacitive coupling caused by the induced EM signal in an insulated installation such as a power cable, (3) Coherent noise from electrical powerlines, (4) Atmospheric noise, and (5) Instrument internal noise.

References

Ward SH, Hohmann GW (1988) Electromagnetic theory for geophysical applications. In: Nabighian MN (ed) Electromagnetic methods in applied geophysics, vol 1. SEG, Tulsa, pp 131–311.

Appendix 2 – Resumes

MAX HALKJAER

Mr. Halkjaer is a highly experienced geophysicist with multiple AEM, tTEM, FloaTEM, and other geophysical assignments successfully completed within California as well as globally. He holds a Master's degree in geology and geophysics from the University of Aarhus and has 28 years of experience in groundwater management, particularly with the application of geophysical methods.

Since 2016 he has served as a principal Hydro-geophysicist, focusing on projects in California.

In California, he has been the project director and principal geophysicist on the DWR state-wide Airborne Electromagnetic (AEM) survey project. Mr. Halkjaer also acted as the project manager on two of the three pilot projects under the Stanford Groundwater Architecture Project (GAP). The scope of these projects was to test the use of AEM and integrate the data with borehole information to create more solid Hydrogeologic Conceptual Models (HCM).

As a researcher at Aarhus University, he developed time domain electromagnetic (TEM) instrumentation and software for processing and inversion of TEM data. In 2004, he co-founded SkyTEM Surveys ApS and served as the managing director of the company until 2012. He has been responsible for a number of large AEM and ground-based projects with a focus on groundwater mapping across the world, including Australia, SE-Asia, Europe, and North America.

Mr. Halkjaer has extensive experience working with a variety of geophysical methods for groundwater investigations, geotechnical applications, environmental studies, and mineral exploration.

CERTIFICATES

First Aid, CPR, and AED Training certificate. Defensive Driving certificate. Firefighting certificate. Preventing Sexual Harassment and Discrimination. Maintain a drug-free work site.

PUBLICATIONS AND PRESENTATIONS

Mr. Halkjaer has co-authored numerous publications, and he has given numerous presentations at conferences.

SELECTED PROJECTS

California Statewide Airborne Electromagnetic (AEM) Surveys (2021-2022)
Client: CA Department of Water Resources
AEM surveys to map groundwater aquifers in all SGMA medium- and high-priority basins.
Role: Project Director and Principal Geophysicist | Technical expert and advisor | Data Quality Assurance - Quality Control

SPECIAL COMPETENCIES

- Hydro-geophysics
- Geophysics for geotechnic
- Geophysical methods: electromagnetic (EM), magnetics, gamma ray spectrometer (GRS)
- Innovation

PROJECT ASSIGNMENTS

- Project Director
- Principal geophysicist
- Member of technical advisory committees

TOTAL YEARS OF EXPERIENCE

28

EDUCATION

M.Sc/1995/Geology and Geophysics
University of Aarhus, Aarhus, Denmark

GAP: Airborne Electromagnetic Project pilot studies in California, Indian Wells Valley and Paso Robles, Stanford University (2017-2020)
Client: Stanford University, DWR, Indian Wells Valley Water District, San Luis Obispo County, the Danish EPA.
Digitization of well information. AEM geophysical survey for groundwater basin characterizations. Integrated interpretation.
Role: Project manager| AEM planning

Petaluma and Sonoma valleys groundwater investigations, Santa Rosa, CA (2021-2022)
Client: Sonoma County Water Agency
gTEM and ERT geophysical investigations for further characterization of the basin for refining the basin hydrogeologic conceptual model.
Role: Principal Geophysicist

Salinas Valley Deep Aquifer Study using AEM, Monterey, CA (2022-2023)
Client: Salinas Valley Basin Groundwater Sustainability Agency
AEM geophysical surveys in the Salinas Valley, CA, to investigate the deep aquifers in the region.
Role: Survey design and interpretation.

Geophysical investigations for siting production wells, Brenda, Arizona (2023)
Client: Private
Groundbased TEM geophysical survey for improved understanding of the groundwater basin to find optimal drilling locations.
Role: Project planning | data acquisition, analysis and interpretation

MAR site investigations along Cosumnes River, Sacramento, CA (2020-2022)
Client: Sacramento Area Flood Control Agency
tTEM and ERT geophysical investigation to map paleochannels and assess potential MAR sites.
Role: Principal Geophysicist and interpretation

Kern Fan Shallow Hydrogeological assessment, Bakersfield, CA (2021)
Client: Rosedale-Rio Bravo Water Storage District
tTEM geophysical investigation to assess potential MAR sites.
Role: Project manager | data acquisition, analysis and interpretation

Surface water Groundwater study, Silkeborg, Denmark (2021)
Client: The Danish EPA and Silkeborg Waterworks
FloaTEM geophysical investigation on lakes and rivers to map variations in the hydraulic connectivity as input to a numerical groundwater model.
Role: Project manager | Skipper, data acquisition, analysis, and interpretation

Yolo bypass shallow hydrogeological assessment, Yolo County, CA (2020-2021)
Client: CA Department of Water Resources
tTEM geophysical investigations to characterize the shallow subsurface on both sides of a levee structure.
Role: Project Manager, Project planning | data acquisition, analysis and interpretation.

Salton Sea Hydrogeological investigations, Salton Sea, CA – Two projects (2020-2021)
Clients: Department of Water Resources and Imperial Irrigation District
gTEM and tTEM geophysical surveys to investigate the geology and hydrology of three areas around the Salton Sea in California.
Role: Project planning |analysis and interpretation

MAR basin investigations, Orange County, CA (2020-2021)
Client: Orange County Water District
GCM geophysical surveys at existing infiltration basins to improve understanding of the shallow subsurface hydrogeology.
Role: Principal Geophysicist and interpretation

HCM development with support from AEM in Santa Ynez, Santa Barbara County, CA (2020-2021)
Client: Santa Barbara County, GSI, SYRWCD
AEM surveying and interpretation.
Role: Principal Geophysicist, Hydrogeological interpretations

AEM survey along the Pismo Beach to assess saltwater intrusion, Santa Maria County, CA (2020)
Client: WSI, City of Prismo Beach
AEM surveying and interpretation.
Role: Principal Geophysicist, Hydrogeological interpretations

AHMAD ALI BEHROOZMAND, PHD, PGP

Dr. Behroozmand is a Professional Geophysicist (#1106) in the State of California, holds a PhD degree in Geophysics and specializes in the field of Hydro-geophysics. Ahmad has more than 15 years of professional experience in the development and application of airborne, ground-based and logging geophysical methods for subsurface characterization. He has been involved in numerous groundwater-related projects worldwide and in California in compliance with the SGMA program, including the DWR State-wide Airborne Electromagnetics (AEM) Survey Project and the Stanford Groundwater Architecture Project (GAP).

Ahmad has a strong background in project management, as well as in the acquisition, processing and inversion, and interpretation of geophysical data.

As a research scientist at Stanford University and Aarhus University, Dr. Behroozmand conducted fundamental research in hydro-geophysics within the framework of different research projects. The results of his research have been published as peer-reviewed scientific journal articles and presented at numerous conferences. He has taught university courses at graduate and undergraduate levels, advised students and served as a scientific journal editor and reviewer.

Ahmad's work in California has focused on different applications, including large-scale groundwater basin characterizations, local-scale subsurface characterization, assessment of managed aquifer recharge sites, and levee projects, among others.

With a strong belief in teamworking, Dr. Behroozmand has, during his career, developed collaborations with governmental agencies, water stakeholders, and other private sectors to identify and develop solutions for improved groundwater management.

SPECIAL COMPETENCIES

- Hydro-geophysics
- Geophysical methods: airborne, ground-based, waterborne, logging
- Acquisition, Processing & inversion, and Interpretation of geophysical data
- GIS

PROJECT ASSIGNMENTS

- Project Manager
- Senior Geophysicist
- Project Planning
- Data Collection
- Data Interpretation and reporting

TOTAL YEARS OF EXPERIENCE

15

EDUCATION

PhD, Geophysics

PUBLICATIONS

22 Peer-Reviewed Journal Articles | 40+ Peer-Reviewed Conference Presentations | 1,072 ISI Citations | H-index: 12 | Google Scholar

SELECTED PROJECTS

California Statewide Airborne Electromagnetic (AEM) Surveys (2021-2022)
Client: CA Department of Water Resources
AEM surveys to map groundwater aquifers in all SGMA medium- and high-priority basins.

Role: Key project member | AEM data acquisition coordinator | Data acquisition, analysis and interpretation | Project planning

Petaluma and Sonoma valleys groundwater investigations, Santa Rosa, CA (2021-2022)
Client: Sonoma County Water Agency
gTEM and ERT geophysical investigations for further characterization of the basin for refining the basin hydrogeologic conceptual model.
Role: Project planning | data acquisition, analysis and interpretation

Salinas Valley Deep Aquifer Study using AEM, Monterey, CA (2022-2023)
Client: Salinas Valley Basin Groundwater Sustainability Agency
AEM geophysical surveys in the Salinas Valley, CA, to investigate the deep aquifers in the region.
Role: Data acquisition, analysis and interpretation.

Geophysical investigations for siting production wells, Brenda, Arizona (2023)
Client: Private
gTEM geophysical surveys for improved understanding of the groundwater basin to find optimal drilling locations.
Role: Project planning | data acquisition, analysis and interpretation

MAR site investigations along Cosumnes River, Sacramento, CA (2020-2022)
Client: Sacramento Area Flood Control Agency
tTEM and ERT geophysical investigation to map paleochannels and assess potential MAR sites.
Role: Project planning | data acquisition, analysis and interpretation

MAR site investigations in Kings County, CA – Two projects (2021-2022)
Client: Kings County Water District
tTEM geophysical investigation to investigate multiple potential MAR sites within the Kings County of California.
Role: Project manager | data acquisition, analysis, and interpretation

Kern Fan Shallow Hydrogeological assessment, Bakersfield, CA (2021)
Client: Rosedale-Rio Bravo Water Storage District
tTEM geophysical investigation to assess potential MAR sites.
Role: Project planning | data acquisition, analysis and interpretation

MAR site investigations in Santa Clarita, CA (2021)
Client: Santa Clarita Valley Water Agency
tTEM geophysical investigation to investigate recharge potential at a study site.
Role: Project manager | data acquisition, analysis, and interpretation

Yolo bypass shallow hydrogeological assessment, Yolo County, CA (2020-2021)
Client: CA Department of Water Resources
tTEM geophysical investigations to characterize the shallow subsurface on both sides of a levee structure.
Role: Project planning | data acquisition, analysis and interpretation.

Salton Sea Hydrogeological investigations, Salton Sea, CA – Two projects (2020-2021)
Clients: Department of Water Resources and Imperial Irrigation District
gTEM and tTEM geophysical surveys to investigate the geology and hydrology of three areas around the Salton Sea in California.
Role: Project planning | data acquisition, analysis and interpretation

MAR basin investigations, Orange County, CA (2020-2021)
Client: Orange County Water District
GCM geophysical surveys at existing infiltration basins to improve understanding of the shallow subsurface hydrogeology.
Role: Project planning | data acquisition

GAP: Airborne Electromagnetic Project Implementation, Indian Wells Valley, Stanford University (2015-2017)
Client: Indian Wells Valley Water District
Pilot testing of gTEM and NMR geophysical methods. AEM geophysical survey for groundwater basin characterizations.
Role: Project planning | acquisition, analysis and interpretation of NMR, TEM and AEM data.