

California's Statewide AEM Surveys: Project Implementation and Next Steps

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SUMMARY

Passage of the Sustainable Groundwater Management Act (SGMA) in California has resulted in the need for improving the understanding of groundwater aquifers to support groundwater managers in developing and implementing groundwater management plans and actions. The California Department of Water Resources (DWR) has supported this effort by implementing the Statewide AEM Survey Project, where data are collected in a reconnaissance grid across California's priority basins. Raw, processed, inverted, and interpreted AEM data as well as digitized lithology and e-logs are made publicly available and novel tools have been developed to support data accessibility.

With the Statewide AEM Surveys nearing completion, DWR is undertaking an effort to utilize the Statewide AEM Survey dataset along with other existing data (surface geophysics, lithology logs, e-logs, geologic cross sections) to provide an improved understanding of basin characteristics. To support this task, new tools are being developed that will analyse all data available to produce refined, texture and hydrogeologic models. Results will be archived in DWR's California Groundwater publication and Basin Reports and models will be available to visualize through new and innovative 3D, GIS-based tools.

To support this effort, DWR will also be conducting Pilot Studies that will include the collection of additional data with the goal of filling data gaps and addressing specific SGMA implementation questions. The first Pilot Study will be conducted on the eastern side of the San Joaquin Valley in California's Central Valley and will include the collection of infill AEM data, as well as other ground-based geophysical surveys.

Key words: AEM, California, Sustainable, Groundwater, Statewide,

The historic passage of California's Sustainable Groundwater Management Act (SGMA) in 2014 set forth a statewide framework to help protect groundwater resources over the long-term (California Assembly Bill 1739, Senate Bill 1319, and Senate Bill 1168, 2014). SGMA requires local agencies to form groundwater sustainability agencies (GSAs) for groundwater basin's defined as high- and medium-priority. GSAs develop and implement groundwater sustainability plans (GSPs) to avoid undesirable results and mitigate overdraft within 20 years.

DWR serves two roles to support local SGMA implementation: 1) regulatory oversight through the evaluation and assessment of GSPs and 2) providing ongoing assistance to locals through the development of best management practice guidance, financial assistance, and technical assistance.

DWR has a long history of characterizing California's groundwater basins and providing technical assistance through DWR's Basin Characterization efforts under California's Groundwater, Bulletin 118 (California Code of Regulations, California Department of Water Resources 2020b). California's Groundwater archives and documents groundwater basin characteristics, available data within the basin, and groundwater management activities through the 5-Year Update, Basin Reports, and CalGW Live.

As a part of DWR's Basin Characterization effort, DWR supports locals in improving their basin's hydrogeologic conceptual model through the collection and compilation of relevant data. Data and information that DWR collects or catalogues includes lithology and geophysical logs, location of dry wells, groundwater elevation levels, interferometric synthetic aperture radar data, extensometers, crop mapping and drilling new wells.

In 2021, DWR's Basin Characterization data collection effort expanded to include the Statewide AEM Survey Project. The goal of the project is to improve the understanding of large-scale aquifer structures across groundwater basins and support refinement of texture models, hydrogeologic conceptual models, and groundwater flow models. As a part of the project, AEM data are collected in all high- and medium-priority groundwater basins, where data collection is feasible and all data and reports are made publicly available (California Assembly Bill 1755, 2016). To support data accessibility, DWR has developed novel tools to allow the data to be viewed online by the general public.

INTRODUCTION

As the Statewide AEM Survey Project nears its completion, DWR is starting the next phase of the Basin Characterization effort where all new and existing data will be compiled and analysed to provide an improved understanding of basin characteristics.

METHOD AND RESULTS

In 2018, California Proposition 68 was passed, which provided DWR with \$12 million to collect AEM data in California to support the implementation of SGMA (California Department of Water Resources, 2020). From 2018 through 2020, a set of AEM Pilot Studies was undertaken by Stanford University, the Kingdom of Denmark, local groundwater agencies, and private consulting firms to determine the optimal workflow of AEM data collection in California. Knowledge gained from the AEM Pilot Studies was used to support the development of DWR's Statewide AEM Surveys.

As a part of the Statewide Survey Project, DWR and their consultants (Ramboll, SkyTEM, Sinton Helicopters, GEI, Eclogite Consulting, and Aarhus University) are collecting AEM data in a coarse, reconnaissance grid with a line spacing of approximately 3 by 13 km. The grid was defined to allow the maximum amount of data to be collected within the defined groundwater basins while capturing the geologic heterogeneity unique to California. The survey grid was oriented to capture local geologic features and to lines were modified to cover areas of interest defined by local, state, and federal agencies. Survey lines were further modified to avoid safety and electromagnetic noise sources, like buildings and structures containing people or confined livestock, heavily trafficked highways, powerlines, vineyards, etc.

Prior to the start of the surveys, DWR undertakes a robust outreach effort to ensure the public are aware of the project and that a low-flying helicopter will be in their area. This includes meetings with local GSAs, sending notification letters to parcel owners within the vicinity of the flight path, social media announcements, and media advisories. DWR also keeps the public aware of the survey schedule through an online Survey Schedule StoryMap.

After data collection, the data are processed and inverted by the consultant. Data at all stages (raw, processed, and inverted) are provided to DWR and published on the California Natural Resources Agency Open Data Portal. Inverted AEM data can be viewed on DWR's AEM Data Viewer, an online, GIS-based tool that displays electrical resistivity values as Point Clouds, which points located within the centre of the AEM data interval. The tool allows users to zoom and view the data from various angles without the data being downloaded or the use of specialised software (Figure 1). DWR also makes the formatted Point Cloud files publicly available so that technical users can download and view the data along with other relevant datasets in a GIS-based platform.

AEM data are interpreted for coarse fraction (texture) and for an initial hydrostratigraphic cluster model through the integration of other supporting datasets, including lithology logs, e-logs, water quality, and water levels. Two lithology logs and e-logs per Public Land Survey Square Mile along a survey flight line are quality controlled (for location accuracy and lithology description) and digitized. Water quality and water level data were utilized in the interpretation only when the

density and quality of data were appropriate. All digitized supporting data are made publicly available and locations and metadata can be viewed on DWR's Supporting Data Viewer.

With the Statewide AEM Surveys nearing completion, DWR is undertaking the next phase of the Basin Characterisation effort where all AEM coarse fraction data will be incorporated with other existing data (surface geophysics, lithology logs, e-logs, geologic cross sections) and analysed to provide an improved understanding of basin characteristics. To support this task, new tools are being developed that will analyse all data available within a basin to develop refined, 3D hydrogeologic and texture models. The results of these analyses will be available to visualise through new and innovative 3D, GIS-based tools, which will be updated on a regular basis as new data and tools become available.

To support Basin Characterization and the implementation of SGMA, DWR will also be conducting Pilot Studies to address SGMA implementation initiatives and fill data gaps. The Pilot Studies will include the collection of additional data based on review of the reconnaissance AEM data and local SGMA implementation initiatives, like groundwater recharge, surface water groundwater interaction, subsidence, vulnerable domestic wells, disadvantaged communities, seawater intrusion, base of fresh water, etc. Additional data collection methods may include infill AEM, t-TEM, floatEM, NMR logging, e-logging, installing new wells or reactivating existing wells, CPT, etc.

The first Pilot Study will focus on providing information to support floodplain rehabilitation, groundwater recharge, and domestic well assistance activities. The study area is located within the Kings and Madera subbasins and concentrated on the eastern side of the San Joaquin Valley, between the Upper San Joaquin and Fresno Rivers. The Pilot Study will include AEM infill data collection followed by ground-based surveys. The results from the Pilot Study are expected to be available by Winter 2023/2024 and available to support local and state groundwater management decisions in the event of another wet water year.

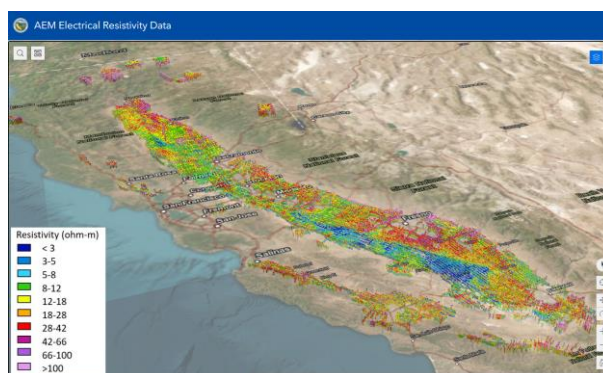


Figure 1. DWR's AEM Data Viewer displaying AEM data as a Point Cloud in an online, GIS-based platform.

CONCLUSIONS

DWR's Statewide AEM Survey Project has provided high-quality AEM data across the medium- and high-priority

groundwater basins and has provided local GSAs with a unique dataset that improves the development and implementation of their GSPs and project and management actions. DWR's commitment to open access to data has resulted in the development of novel tools which has made viewing data accessible to the general public and increased the public's understanding of geophysics. The success of this project has allowed DWR to continue with the next steps of Basin Characterization and the collection of additional geophysical data and the development of new tools to improve the understanding of groundwater basins.

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