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FEATURE

Airborne Electromagnetic Surveys: One More Tool in California's Journey to Sustainable Groundwater Management

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THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT (SGMA) requires agencies across California to develop and carry out groundwater sustainability plans (GSPs). Plans depend on the sustainability thresholds of groundwater basins, but determining these thresholds is a complex undertaking. One new tool for collecting groundwater data—airborne electromagnetic (AEM) surveys—uses aerial surveying technology to see what's happening below ground. Widespread use of this technology is just getting underway, but it has the potential to produce a wealth of data that can help water managers balance inflows and outflows of groundwater.

AEM surveys are a geophysical method of measuring the electrical properties of subsurface materials from helicopter-mounted equipment. The State of California has just initiated a statewide program to use this technology to generate reconnaissance-level, coarse-grid subsurface maps of high-priority groundwater basins that will provide fundamental information about aquifer structures on a regional scale.

The surveying effort, sponsored by the Department of Water Resources (DWR), will also provide a standardized, statewide dataset that will help develop or refine a hydrogeologic conceptual model and aid in identifying possible recharge areas. The state anticipates that this initial collection of coarse-grid AEM data will serve as the basis for the additional collection of fine-grid AEM data by local stakeholders in the future.

AEM surveys have been used in other places, and particularly in Denmark. In California, efforts to advance its use have been led by the Stanford Groundwater Architecture Project (GAP) in collaboration with Max Halkjær (Ramboll), Niels-Peter Jensen (I-GIS), Esben Auken (Aarhus University), Jim Cannia (Aqua Geo Frameworks), the Kingdom of Denmark, and state and local project sponsors. GAP was the primary investigator in a two-year pilot project, ending in 2020, that generated critical information on how best to use the AEM method to support groundwater management in California. Under the guidance of Stanford geophysicist Rosemary Knight, GAP uses advanced geophysical and computational methods to develop the hydrogeologic conceptual models required by SGMA, which in turn help establish groundwater sustainability thresholds.

The SkyTEM AEM system during takeoff in Indian Wells Valley, California. SkyTEM is a geophysical survey company involved in implementing AEM surveys. Source: Ramboll Project File.

While in the end more data is better than less, the process used to collect and apply AEM data presents unique challenges. First, the information to be gathered in each survey depends on the geophysical location, management needs, and data requirements in each

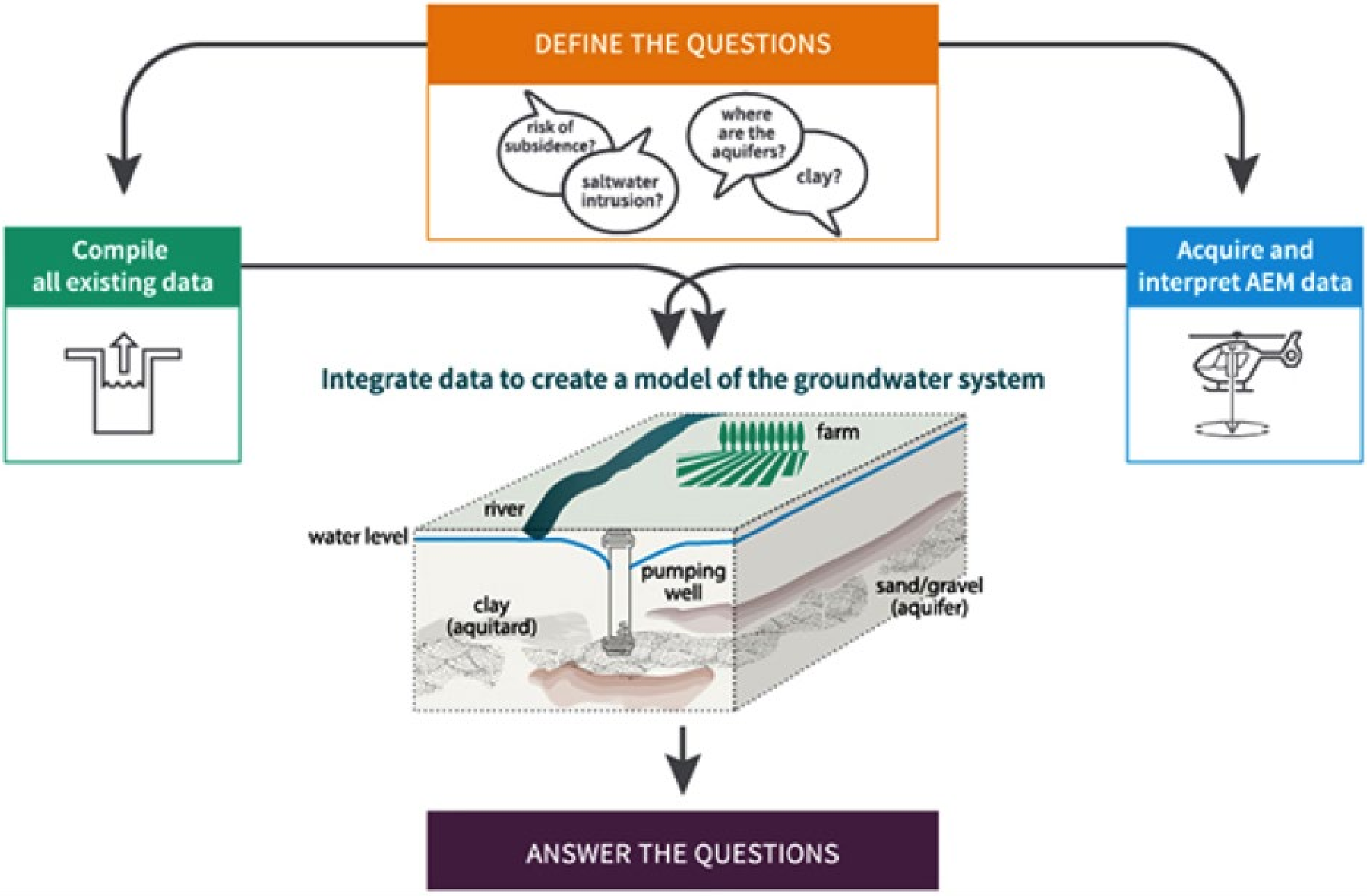

Figure 1. How AEM surveys contribute to modeling the groundwater system. Source: Stanford Groundwater Architecture Project (GAP).

context. Second, studies of groundwater resources do not commonly use data of this scale and nature, so local agencies may require technical assistance to fully realize the value of the data. Third, AEM surveys consist of a physical process involving very low flyovers and the use of electromagnetic current, both of which are likely to create public interest well beyond the typical groundwater management stakeholders.

Data Collection Goes Airborne

AEM equipment is housed in a large hoop frame that is hung from a helicopter flown by experienced pilots following all Federal Aviation Administration (FAA) regulations. The helicopter carries the equipment 100–150 feet (30–50 meters) above the ground and collects data along a defined flight path. Significant pre-planning is required, and special care is taken to create flight paths over open spaces and away from metallic infrastructure that creates interference and from residential areas and structures containing people or confined livestock.

To help interpret AEM data, it is important to gather local data and knowledge on the geologic structure, the hydrogeologic conceptual model, and the depth to the water table, and to have some lithologic, geophysical logs and water-quality data along the flight lines. Once collected, AEM data are interpreted to show the distribution of coarse-grained and fine-grained materials in the subsurface, structures such as faults, and fresh versus saline water. They are then used to characterize subsurface hydrogeology.

Can It Work in California?

Although the AEM technology has been used in other locations, it was important to determine the best way to execute the effort in the Golden State. Accordingly, a pilot study was conducted in three diverse locations: Indian Wells Valley, located at the southeastern corner of the Sierra Nevada; Butte County, in the northern Sacramento Valley; and San Luis Obispo County, along the central California coast.

The planning team developed a process to identify local groundwater management questions, develop data management approaches, and gather existing data (Figure 1). This information was used to design the AEM survey and acquire the AEM data. The team then analyzed these data to obtain the resistivity model, interpreted the resistivity model to extract the needed

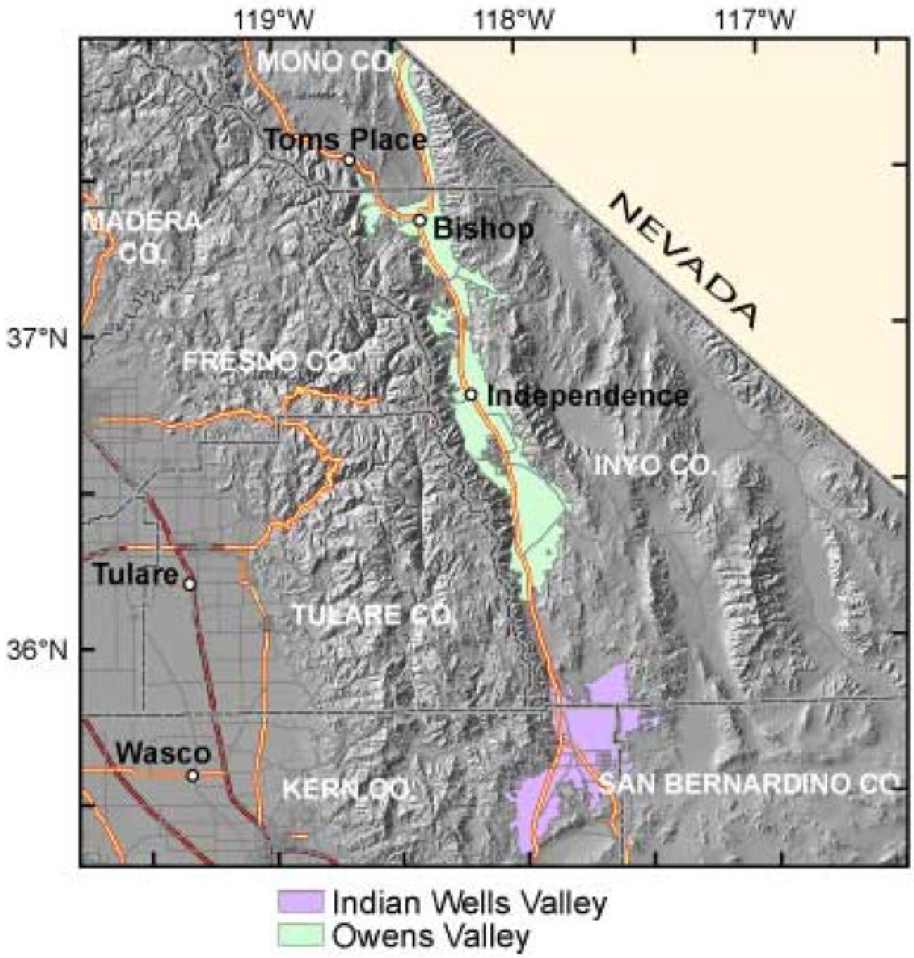

Figure 2. The Indian Wells Valley. Source: United State Geological Survey, Jim Nickles.

information, and integrated all data to generate the conceptual model of the groundwater basin. This approach allowed the team to answer the management questions while at the same time acknowledging uncertainty.

Case Study: Indian Wells Valley

The Indian Wells Valley area (Figure 2), home to the largest naval air station in the world, is considered essential to U.S. national security. The State of California considers groundwater in the Indian Wells Valley Groundwater Basin (IWVGB) to be unsustainably managed—a security issue in that context. Overdrafting was documented as far back as the 1970s and has had various undesirable results, including the chronic lowering of groundwater levels and the reduction of groundwater in storage throughout the basin. Nearly two decades ago, the Indian Wells Valley Water District (IWVWD) initiated work to evaluate the development of the basin's brackish water resources. The district needed information about the large-scale structure of the groundwater basin and the nature and distribution of brackish water. Based on the local need for information and on surface geophysics pilot studies conducted by Stanford researchers, the basin was incorporated into the GAP pilot project.

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Preparations for the survey included compiling and digitizing basin data, including more than 1,000 well logs, 60 geophysical logs, groundwater level measurements, water-quality samples showing total dissolved solids, documentation of 150 miles (240 kilometers) of seismic lines, and the Stanford surface geophysics pilot tests. This information was then used to create the AEM survey lines (Figure 3).

Community members expressed concern about whether the electromagnetic survey could affect health (it can't), whether the heavy equipment would pose safety problems, and whether the AEM data would be reliable. Public outreach, therefore, was essential. This effort included sending news releases to local newspapers, holding public meetings before and immediately after the helicopter-based surveys, and meeting with the public again after the AEM data had been interpreted and the hydrogeologic conceptual framework based on the AEM data had been developed. While there was some public concern, the presence of the NAS means that the community is accustomed to frequent aircraft overflights and may have had less interest in the AEM survey than other communities would. The IWVB pilot project produced some key lessons:

- Adequate data are essential to interpret the AEM data.

Legacy data in California (such as well completion reports and borehole geophysical logs) are often not digitized and are

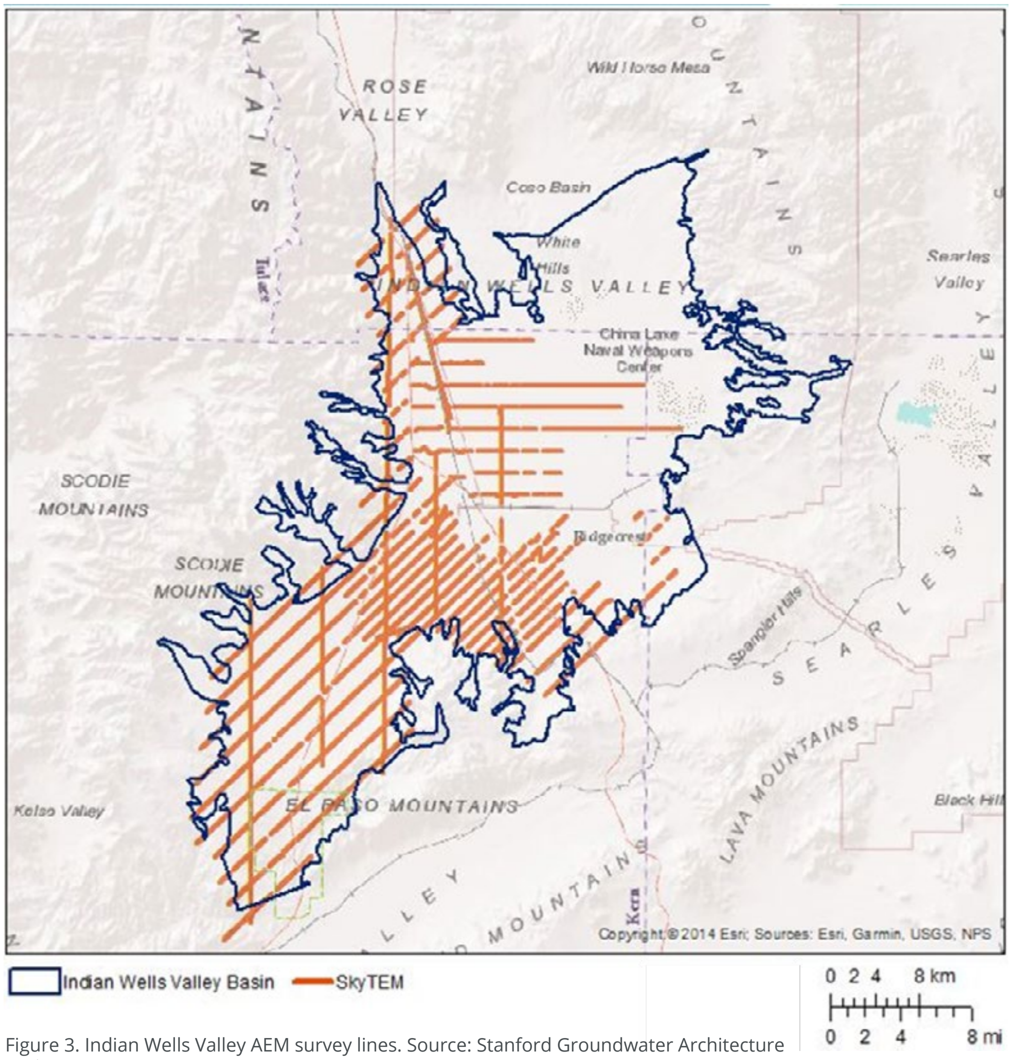

Figure 3. Indian Wells Valley AEM survey lines. Source: Stanford Groundwater Architecture Project (GAP).

challenging to use. Location information is only minimally useful, and improving accuracy requires significant time and resources.

- AEM surveys rapidly capture good data without disturbing sensitive habitat areas.
- Information gathered is from various depths, averaging 500–1000 feet (150–300 meters), with a maximum of about 1,500 feet (500 meters), depending on subsurface materials and water quality.
- Not everyone believes in or understands the value of AEM surveys. For example, the work was not incorporated in the GSP and has not yet been considered in ongoing efforts in the basin.

Next Steps

In the coming months DWR plans to convene a technical advisory committee to provide input on project activities, such as survey design, data management, guidance documents, and AEM data use. Before surveys are conducted, DWR will also coordinate with local governments in the survey areas to inform local communities about the safety of the AEM survey method and why surveys are being conducted. Then the statewide program will launch: the agency plans to initiate flyovers in 2021 and extend them into 2023 and beyond. ■

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