Stanford project maps underground water -- aimed at taking the guesswork out of well drilling

Lisa M. Krieger, Bay Area News Group, 10-30-15

TULARE -- In the drought-ravaged Central Valley, scientists are using a new imaging technology to find ancient worlds of trapped water, hidden hundreds of feet underground.

The Stanford University-led project, the first of its type in California, is aimed at taking the guesswork out of well drilling -- and guiding restoration of precious groundwater supplies once winter rains start soaking the state.

"Medical imaging has revolutionized our approach to human health. This lets us do the same thing for groundwater, probing very deep," said Stanford geophysicist Rosemary Knight, who is leading the effort.

This week, a helicopter swept 60 linear miles of parched fields in the Tulare Irrigation District in one of the most arid regions of California.

By suspending a large hexagonal array of electrical equipment, the technology located patches of underground sand, gravel, clay and water by measuring the differences in their conductivity. The low-flying helicopter system sent an electromagnetic pulse, about the same strength as that emitted by a cellphone, which then traveled into the Earth's subsurface and returned to be measured by instruments on the helicopter. The data will be used to build a colorful three-dimensional map of the ground that identifies the regions of differing soils and water.

While the technology, owned by a Danish company called SkyTEM, has been widely used in oil, gas and mineral exploration in California, it has never been used to survey the state's other huge natural resource: groundwater.

Scientists hope the tool can build a picture of what's underneath not only Tulare County's dusty soils, but also California's 20 other stressed water basins.

As deep as the Empire State Building is tall, these aquifers and surrounding geology are poorly understood.

"The basin isn't just a big pothole -- it's a bunch of lots of little holes and very porous," trapped in complex patterns of pocketed soils that accumulated as the mighty Sierra Nevada eroded over thousands of years, said John Austin, retired National Park Service scientist and author of the book "Floods and Droughts in the Tulare Lake Basin."

There's a new urgency to understanding this geology: Aquifers are under profound stress. With little rain falling from the sky or snow melting into reservoirs, thirsty Californians are racing to drill new wells, pitting neighbor against neighbor in a perverse race to the bottom.

Last year, Gov. Jerry Brown signed a bill establishing -- for the first time in state history -- a framework for statewide regulation of California's underground water. Under the Sustainable Groundwater Management Act, water agencies need to develop plans that demonstrate over time that long-term overdraft will end.

It's tough, however, to manage what you can't see. But once you have a map of sand, gravel, clay and water -- turned into a 3-D model -- you understand where to most effectively drill as well as where water is needed to best replenish the aquifer.

While other tools, such as underground water pressure-measuring devices and orbiting satellites, are studying underground reservoirs and related subsidence, this offers the most detailed and accurate view, Knight said.

With this information, drilling is more accurate and less damaging, scientists say. Some soils hold water far better than others; it's futile to drill into a thick layer of clay. Moreover, water extraction causes clay particles to permanently collapse, like pancakes, leading to dangerous subsidence. Other soils, like gravel, are more resilient, Austin said.

"Our growers ask me: 'Hey, I'm putting in a well. How deep should I go?' " said Aaron Fukuda, of the Tulare Irrigation District, located between Fresno and Bakersfield. He shows them the only map he has of the region's soils: a 2007 U.S. Geological Survey report that is too general to be of specific help.

"Why drill when you're not connected to water? You're buying yourself a $200,000 dry well," said Fukuda, whose district of 238 farms has not received a drop of its federal water allotment for the past two years. "With this, we won't be guessing every time."

This new information will be equally important for replenishment of these aquifers, Fukuda said. They hope to lease acreage so they can flood fields with coming winter rains-- letting water slowly soak back into the basin. But they need to know where it is best applied.

"We want it to go where there is a nice sandy soil profile, with a connection to the aquifer below," he said. If the water is poured atop clay, it just pools and evaporates.

Denmark has used this same tool, developed at its Aarhus University and commercialized by SkyTEM (the acronym stands for "transient electromagnetism"), to map and monitor the nation's entire groundwater supply, Knight said. It was also used recently to build information about eastern Nebraska's aquifers.

Ten private landowners in the Central Valley have hired the helicopter and its array, flown by Native American Helicopters of Fort Smith, Arkansas -- at a price tag starting at $250,000. But their findings are private.

If used by the state, "this tool could be used to map groundwater districts all over California," said Knight, of Stanford's School of Earth, Energy and Environmental Sciences, who with geophysics graduate student Ryan Smith hopes to expand their study.

The system is an 80-foot diameter electrical loop, connected by cables inside long fiberglass tubes and towed by the helicopter.

Directed by an airborne computer, its transmitter sends electrical current into the ground. Then its receiver coil measures the returning voltage, said North American Helicopters' geophysicist Todd Meglich.

The team correlates this voltage -- as small as one billionth of a volt -- to the electrical conductivity of what's underground. For instance, clay is electrically conductive; sand is not.

Then the Colorado company Aqua Geo Frameworks translates this data into a 30-layer colorful cube, each layer representing 15 to 30 feet of soil.

Sierra Nevada environmentalist Steve Haze called the flyover "a good first step for a specific irrigation district or water agency. ... They're moving forward in a forthright fashion," said Haze, executive director for the Yosemite/Sequoia Resource Conservation and Development Council.

"However, it is almost like rearranging the chairs on the Titanic," as long as water is over-consumed and water districts don't coordinate their efforts. "There are thousands of straws in essentially one large container" -- and as water is drained, it moves laterally, he said.

The real challenge, he said, will be implementing water and land-use reforms once the new technology reveals the true nature of the beleaguered aquifers.

"How does the state of California and the people put this into a proper context to take meaningful action?" he asked. "Sooner, rather than later?"