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Researcher discovers groundwater modeling breakthrough 84 years in the making

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University of Wyoming Professor Fred Ogden anticipates his discovery will greatly improve the reliability and functionality for hundreds of important water models used around the country and the world. Credit: University of Wyoming

A University of Wyoming professor has made a discovery that answers a nearly 100-year-old question about water movement, with implications for agriculture, hydrology, climate science and other fields.

After decades of effort, Fred Ogden, UW's Cline Chair of Engineering, Environment and Natural Resources in the Department of Civil and Architectural Engineering and Haub School of Environment and Natural Resources, and a team of collaborators published their findings in the journal *Water Resources Research* this spring. The paper, titled "A new general 1-D vadose zone flow solution method," presents an equation to replace a difficult and unreliable formula that's stymied hydrologic modelers since 1931.

"I honestly never thought I would be involved in a discovery in my field," Ogden says.

He anticipates this finding will greatly improve the reliability and functionality for hundreds of important water models used by everyone from irrigators and city planners to climate scientists and botanists around the country and the world, as well as trigger a new surge in data collection.

In 1931, Lorenzo Richards developed a beautiful, if numerically complex, equation to calculate how much water makes it into soil over time as rainfall hits the ground surface and filters down toward the water table. That equation, known as the Richards equation and often shortened to RE, has been the only rigorous way to calculate the movement of water in the vadose zone—that is, the unsaturated soil between the water table and the ground surface where most plant roots grow.

Calculating the movement of water in the vadose zone is critical to everything from estimating return flows and aquifer recharge to better managing irrigation and predicting floods. But RE is extremely difficult to solve, and occasionally unsolvable. So, while some high-powered computer models can handle it over small geographic areas, simpler models or those covering large regions must use approximations that compromise accuracy.

For decades, hydrologists and other scientists have pursued a better way to estimate vadose zone water. Cornell University Environment and Ecology Professor Jean-Yves Parlange and Australian soil physicist John Robert Philip battled one another in the literature, proposing new equations and disproving each other—from the 1950s until Philip's untimely death in a traffic accident in 1999. Princeton Environmental Engineering and Water Resources Director Michael Celia published a partial solution in 1990 that is not reliable in all circumstances.

Ogden first worked on the problem in 1994 as a postdoctoral researcher. He teamed with Iranian hydrology engineer Bahram Saghafian, who was finishing a Ph.D. at Colorado State University, to publish an equation that estimates water "suction" in the vadose zone. In the early 2000s, Ogden advised a Ph.D. candidate named Cary Talbot, a researcher with the U.S. Army Corps of Engineers, on a project seeking a solution to the RE. The two developed a new way to represent vadose zone water.

In more recent years, the search continued, and a major National Science Foundation research grant in 2011 enabled Ogden to bring additional experts to the quest and use UW's supercomputing power to test prospective solutions.

Then, late last fall, just before the large American Geophysical Union annual meeting, Ogden and his research team discovered a novel solution, an elegant new equation that he thought would equal the RE in accuracy while greatly reducing the computing power needed to run it. He tested this solution with precipitation data from his field site in Panama.

"We ran eight months of Panama data with 263 centimeters of rain through our equation and Hydrus," Ogden says.

Hydrus is an existing supercomputer model that uses RE. The results his model generated had only 7 millimeters, or two tenths of 1 percent, difference from the results of the Hydrus model that employs Celia's solution of the RE.

"They were almost identical. That's when I knew," he says. "I felt like the guy who discovered the gold nugget in the American River in California."

What's next for the new equation? First, it is the centerpiece of Ogden's ADHydro model, a massive, supercomputer-powered model that's first simulating the water supply effects of different climate and management scenarios throughout the entire upper Colorado River Basin. From there, Ogden hopes other models will incorporate it, too.

"I think, for rigorous models, it's going to become the standard," he says. "With help from mathematicians and computer scientists, it will just get faster and better."

Furthermore, new pushes for data collection often follow technological advances, Ogden explains. He hopes this discovery will bring soil science back into relevance for water managers and lead to new soil data collection.

"We now have a reliable way to couple groundwater to surface through the soil that people have been looking for since 1931," Ogden says, almost in awe of the moment.

Provided by University of Wyoming