LUCIA BARBATO AND KEVIN MULLIGAN HAVE INVESTIGATED THE OGALLALA AQUIFER THROUGH MAPPING DATA FROM THOUSANDS OF IRRIGATION WELLS.

BENEATH THE SURFACE:

Mapping the Ogallala

by Larissa K. True

PHOTO BY ARTIE LIMMER

For many years, students living on the Southern High Plains have learned about the Ogallala Aquifer, the region's main source of irrigation water. When these students learn that the Ogallala is declining in some areas, the first question they ask is undoubtedly, "How long will it last?" Although many generalized estimates have been made, Texas Tech University researchers say the question is difficult to answer because the volume of the underground water source depends upon where one lives.

For the past two years, a research team has been working to map the aquifer and to find an answer to this age-old question. The team is led by Lucia Barbato, senior research associate and associate director of the Center for Geospatial Technology (CGST), Kevin Mulligan, Ph.D., director of the center and associate professor of geography, and Kenneth Rainwater, Ph.D., director of the Water Resources Center.

The research project uses Geographic Information Systems (GIS) to analyze and map the data from thousands of irrigation wells that access the Ogallala.

"Twenty years ago, it would have been very difficult to take on a project like this," Barbato explains. "Within the last 10 years, however, GIS software has become more mainstream, and we have been able to develop programs to automate the analysis procedures." >

WITH THE GIS TECHNOLOGY, researchers have been working to determine how much water remains in the Ogallala as part of the Ogallala Aquifer Program, which is funded by the U.S. Department of Agriculture.

“Everyone wants to know how long the aquifer is going to last,” Mulligan says. “To figure that out, we need to answer two questions: First, how much water is there, and second, how fast we are we using the water?”

While Kansas State University, West Texas A&M University and the Agricultural Research Service tackle the northern portions of the Ogallala, Texas Tech has been working on the southern part of the aquifer in Texas, New Mexico and Oklahoma. The university’s contribution to the project involves analyzing more than 42,000 water-level measurements from 4,700 wells in the Texas Water Development Board Monitoring Network. Historically, water levels have been measured annually by the High Plains Underground Water Conservation District on the South Plains, other underground water conservation districts in the region, and the Texas Water Development Board—all agencies that track changes in the Ogallala Aquifer.

“Initially, we assembled, organized and processed the data from wells in a 42-county area of Texas encompassing about 21.4 million acres (33,400 square miles) overlying the Ogallala Aquifer,” Barbato says. “The water level measurements were used to create annual water level elevation maps for a 15-year study period from 1990 to 2004. The GIS was used to create these maps that depict continuous water level surfaces with contours showing water level elevation values. After we completed the first set of water elevation maps, we noticed some obvious errors in the data. In some cases, the maps showed the water elevation surface above the land surface. We started a long process of county-by-county data analysis using GIS to visualize the irrigation wells in three-dimensions.”

Researchers then could see the exact position of each well in relation to the land surface and look for data errors. When researchers did the visualization, they could see some wells located hundreds of feet above the land surface and other well heads starting thousands of feet below the surface. They found and corrected many of the errors, which they subsequently reported to the Texas Water Development Board. Some of the errors had existed since the 1960s, and the data had been used in other research projects. Texas Tech’s first quality control step in the process allowed staff at the board to incorporate the corrections into a pre-existing groundwater database that is distributed statewide.

“Once we had a clean dataset of wells, we could create water table elevation maps for each year in our study period,” Barbato explains. “Next, we developed a map of the base of the Ogallala Aquifer, which was needed so we could calculate the thickness of the aquifer. The thickness is calculated by subtracting the aquifer base elevation from the water table elevation maps for each of the 15 years in our study period. Our research team now has a reliable dataset of saturated thickness for the Texas portion of the Ogallala Aquifer.”

The next step in the process was to determine the amount of available water in storage in the aquifer. Not only is water in the aquifer, but the underground water source is mostly gravel and sand with an average of a little more than 16 percent being water. The percentage represents the specific yield of the aquifer, Barbato notes. Using the specific yield and saturated thickness information, the team has developed an understanding of the amount of the aquifer that is water.

The team has calculated the saturated thickness, the aquifer volume, and the amount of available water in storage for the entire Texas Ogallala Aquifer and for each of the 42 counties over the 15-year study period. After the research team tackled the well data for Texas, researchers began work on the New Mexico and Oklahoma well data.

“The challenge was to build a consistent database of water well measurements, base of aquifer, specific yield, and available water in storage from three disparate data sources. The goal was to compare and analyze the data for the southern Ogallala as a whole,” Barbato says. “However, the wells in Oklahoma, and especially in New Mexico, were not consistently measured. If we have only a few well measurements in one corner of a county, we cannot confidently interpolate the water table for the whole county. We found that the pre-existing data were generally good and consistent from about 1990 to the present for Texas and Oklahoma. The data were spottier in New Mexico, so we have to treat that state differently and can only report information on a county-by-county basis depending upon what year and in what county the water levels were measured.”

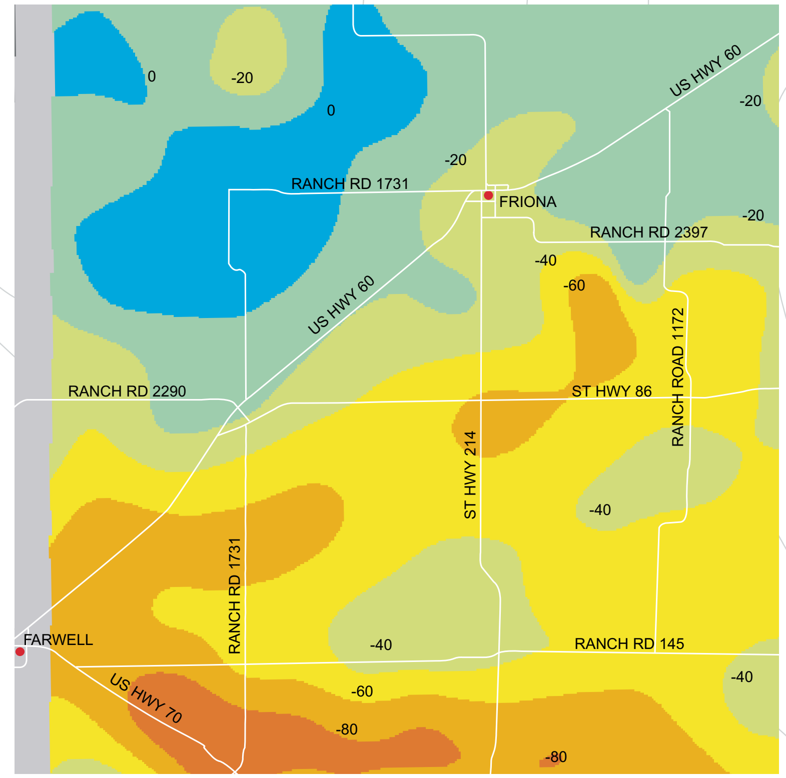
Finalizing the work and data has allowed the team to create maps that show areas of greater or lesser saturated thickness throughout the region.

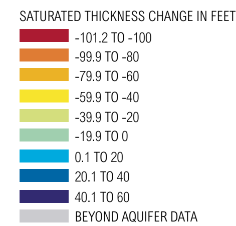
“As a final step, we developed maps to show what has changed from year to year in the aquifer. We took the available water results from one year and subtracted it from the next to determine the change in available water,” Mulligan says.

By analyzing results from the GIS data, the team found that the aquifer annually has gone up or down—typically down—for the region. Where the GIS can make a difference, according to Barbato, is that researchers are able to show the patterns of where these changes occur.

“We have created color-coded maps that show where the water is declining, where there is little or no change, and where the water is rising in the aquifer,” Barbato says. “For example, in the northern part of Parmer County in Texas, we saw little or no change in saturated thickness, while the southern part shows an 80 foot or more decline over the 15-year study period. The overall saturated thickness in Parmer County in 1990 was 109 feet and declined to 75 feet by 2004. This is a difference of 34 feet in 15 years, or about two feet per year, which is double the regional average. Keep in mind that most of the decline is occurring in the southern portion of the county. In another example, the maps of Lubbock County consistently show a small area in the southwest part of the county where the water level has been rising. Interestingly this is an area where the city of Lubbock has investigated pumping water to irrigate parks in that part of town. On average the aquifer declines about nine-tenths of a foot each year, but in some areas, the aquifer is going down as much as three feet per year.”

PARMER COUNTY SATURATED THICKNESS CHANGE 1990 TO 2004





Ogallala Aquifer Program 2006, Center for Geospatial Technology

With their maps, researchers are now able to pinpoint exactly where those declining areas are, Barbato says. “The average saturated thickness of the aquifer in the Texas study area is approximately 103 feet with a range from 28 feet in Oldham County to 282 feet in Roberts County. The total amount of water in storage for the 42 counties in 1990 was 403.5 million acre feet. In 2004, this amount was 354 million acre feet. Although the data vary significantly by county, overall the data show a decline of 49.5 million acre feet or about a 12 percent decline over the 15-year period. That’s slightly less than 1 percent decline per year,” Barbato says.

Not only will the team’s research benefit inquiring students, but mapping the Ogallala Aquifer is important to other researchers and producers throughout the region. By connecting the amount of water in the Ogallala with agricultural practices, researchers will have a better idea of how long the Ogallala will produce water in a specific area. Aquifer recharge studies being performed by Ken Rainwater and others associated with the Texas Tech Water Resources Center allows for the understanding of the amount of recharge that takes place each year, which ultimately affects the available water in storage.

“This research benefits numerous people and organizations,” says Barbato. “In the southern Ogallala, we’re at the raggedy edge of the aquifer, in which some parts have 20 feet or less of saturated thickness and some parts have much more. When you consider these figures with an average specific yield of about 16 percent, this translates to a range of about five feet to 46 column feet of available water in storage. Interestingly, our maps show that the areas where the aquifer is thickest are the areas where the aquifer is declining the fastest. These areas correlate with those that are the most intensely irrigated. In areas where the aquifer is thinnest, about 20 feet, are those areas that have changed the least or not at all.”

To share the results of their work, the research team also has developed an online atlas for other researchers and the public to use as a resource. (See http://gis.ttu.edu/ogallalaatlas.) The Atlas of the Ogallala Aquifer includes more than 500 maps and graphs showing the status and changes in the Ogallala Aquifer during the 15-year study period for the 42 Texas counties in the study area. The atlas also provides a series of maps that compare the agriculture, demographics and physical landscape of the Southern High Plains to the rest of the state. Barbato explains that the purpose of the atlas is to provide data and maps that will lead to informed decisions concerning the need for water conservation and continued management of the resource.

The southern Ogallala, which covers an area half the size of France, is in the heart of cotton country and the agricultural industry on the Southern High Plains. “When we look at our work with respect to the aquifer, combined with what other researchers are doing in terms of agricultural water usage and conservation, we can start to get an idea of how long our resource will last,” Mulligan emphasizes. “As some producers transition to dryland cotton, crops for biofuels or animal feed, we can start to quantify how these changes will affect the aquifer. As new conservation measures are developed, we can evaluate the aquifers’ ability to sustain irrigated agriculture on the Southern High Plains.”

Because the Ogallala Aquifer is one of the region’s most precious resources, the research is important to Texas Tech University, the U.S. Department of Agriculture, the Texas Water Development Board and the underground water management districts, Barbato says. “Water is a key element to sustaining the region’s economy.”