Water Currents

Volume 2, Number 2

Summer 1983

Dear Reader:

Groundwater is very important to Texas. More than one-half the state is underlain by significant groundwater resources. Statewide, groundwater supplies 61 percent of all water used, and about 50 percent of all municipal water needs.

There is a problem, however, with use of groundwater in Texas. In some areas of the state, we are using the water faster than it is being replaced by natural processes. It is only through research and education that we can learn to use this water resource more efficiently. Through research, new and better methods of water production and use can be discovered and perfected. Through education, these new techniques can be explained to the users; the only ones who can convert ideas into meaningful action.

One goal of current water-related research is to foster water conservation. A water use that is amenable to water conservation practices is irrigation_ both for agricultural crops and for lawns. Seventy percent of all water used in Texas is for crop irrigation, and as much as one-half of the water used in the summer by an urban homeowner is used outside. Improved plant varieties, application methods, and farming techniques all have helped reduce water use. As has been shown in cities during times of rationing, changes in outside watering patterns effectively reduce water consumption rates.

One of the Texas Department of Water Resources' responsibilities is to continually plan for the orderly development of the State's water resources. One of the challenging aspects of this effort is the prediction of water requirements for 10, 20, 30, 40, and up to 50 years in the future. Research needs to continually address techniques that may change future water needs and to estimate the probable rate of implementation of such developments.

Most of the Department's work addresses fresh waters in Texas, but significant supplies of slightly to moderately saline groundwater exist in Texas. As fresh groundwater supplies are depleted, these saline supplies will become even more important. Research needs to be directed at salt-tolerant crops and methods of using this inferior quality water to meet some of our domestic needs.

Groundwater is a very important resource to Texans. We must continue to strive to use it intelligently. Research into ways of developing, using, and protecting it is one way of being good stewards for future generations.

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Water Currents reports quarterly on water research conducted by the Texas Water Resources Institute, J. R. Runkles, Director, and the Texas Agricultural Experiment Station, N. P. Clarke, Director.

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Good News: More Water With Less Energy

Agricultural engineer Bill Lyle has some good news for Texas farmers caught in an economic squeeze between declining groundwater levels and soaring energy costs.

Lyle, a researcher with The Texas Agricultural Experiment Station (TAES), has designed and installed wells which are much more efficient than conventional wells. He also studies ways to renovate old, inefficient wells.

Irrigators in the High Plains of Texas should benefit the most from Lyle's research. In addition to generally inefficient water wells, farmers there are hard hit by deeper groundwater levels and higher energy costs each year.

Most of the irrigation wells now in operation on the High Plains date back to years of abundant water and cheap energy. Some older irrigation wells are so inefficient that the current cost of pumping from them actually exceeds the benefit derived from the water produced.

The efficiency of a well affects the amount of energy required to pull water through the intake portion of the well. Even if the pump and the power plant are operating at peak efficiency, the overall system efficiency may be far from optimum if the well itself is not properly designed.

Even though it has been overlooked to a great extent in the past, Lyle feels that the well design itself is probably the single most important consideration in overall pumping system efficiency. Poorly designed wells can mean: less water yield, more energy required, sand pumping, air entrainment and encrustation on well screen. These problems, in turn, contribute to increased wear of the pump lowering efficiency even more.

Irrigators should also take a closer look at their water wells and pumps because of their increasingly sophisticated irrigation equipment. Their new, more efficient systems such as sprinkler or drip systems require a markedly higher quality water than has historically been delivered by High Plains wells.

"ENGINEERED" WELLS

Through research conducted at the TAES research centers in Lubbock and Halfway, Lyle demonstrated that proper design and development techniques can increase the efficiency of a well dramatically.

By improving four components of well design data gathering, well screen design, gravel pack size, and well development - Lyle has installed two exceptionally efficient, sand-free wells at the TAES center in Halfway. He calls these "engineered" wells.

He used information from a test hole drilled near the well site to analyze formation samples of strata in the saturated zone. He also used geophysical logging to verify the permeable sections within the saturated thickness. These tests provided, among other things, information on the need for and the size of a gravel pack and the type of well screen. The well screen is the porous section of the casing which allows water to move into the casing. A gravel pack is often placed outside the screen to hold sand and silt away from the screen while allowing water to move in freely .

Well development involves vigorous reversals of water flowing through the well to remove clay and material deposited during the drilling operation, to increase the permeability of the natural formation, and to stabilize the sand formation around the gravel pack.

An "engineered" well is test pumped following completion in order to install an efficient pump which will match the desired pumping rate and resulting pumping lift. Test pumping of a well at the research center produced a pump efficiency of about 78 percent, compared with the 52 percent average efficiency of most pumps in the area. This increased efficiency makes a big difference in the cost of water. Pumping cost is about $2.58 per acre-inch of water compared to approximately $5.10 per acre-inch of water from two Iess efficient wells at the center.

Even though such a well costs considerably more to install than a conventional well, the yield, efficiency, and low maintenance may make up the difference in a very few years.

A pump and electric motor operating at 70 percent overall efficiency rather than 45 percent efficiency, for example, could save approximately $4,400 per year. In the case of a natural gas well, increasing overall efficiency from 16 to 10 percent could mean a savings of $3,200 per year. These figures are based on pumping 221 acre-feet annually at a 300 foot lift, with electricity at $.08 per kilowatt hour and gas at $4.00 per thousand cubic feet.

The improved design will also greatly decrease or eliminate well plugging due to encrustation and will substantially increase the life of the pump by eliminating air and sand pumping. The elimination of sand will also mean lower maintenance and Iess frequent replacement of irrigation equipment.

Lyle says that none of the components of the well design are new. What is new is the realization that both proper well design and efficient pumping systems are necessary for overall pumping efficiency.

WELL RECLAMATION

Another TAES research project Lyle currently has underway at the Lubbock research center proposes to reclaim low-yielding, sand-pumping wells. The research is based on the idea that sand pumping can be eliminated and well efficiency improved by re-perforating existing casing, inserting a new well screen, and then placing uniform gravel between casing and screen.

Lyle cautions that the research results to date have not been all positive and that much testing is needed to determine a consistently successful well reclamation procedure. He hopes to design new perforating equipment and reclamation methods which will not deform the casing. Perforators now available tend to change the shape of the casing, sometimes severely enough to prevent the installation of a new well screen.

The TAES scientist believes, however, that through research, efficiency of existing wells can be increased or at least maintained. He estimates the average cost of reclaiming a well at only one-third to one-half that of a new well.

TEXAS GROUNDWATER FACTS

Fifty percent of all water used in cities comes from underground. Cities depending on groundwater are located in all areas of Texas and in practically every county.

The seven major aquifers and sixteen minor aquifers underlying the state collectively store 431 million acre-feet of recoverable water and receive an average annual natural recharge of about 5.3 million acre-feet.

The Value of Groundwater

Irrigation water is the single most expensive item in crop production on the High Plains. The over-riding question there is no longer whether a farmer has available water for irrigation, but whether he can afford to pump it.

TAES researchers use computer modeling to predict how much an irrigator can afford to pay for pumping groundwater to the surface and onto his crop.

Ronald Lacewell, a professor in the Texas A&M University Department of Agricultural Economics, and associate Duane Reneau are currently working on a model to determine how new, more efficient irrigation systems will change the value of groundwater to agricultural producers on the High Plains. A byproduct of their research is an estimate of how much a typical farmer could afford to pay for additional water if it were available.

The model takes into consideration several factors which determine the relative benefit of water to an irrigator:

- the type of irrigation system used,
- the depth and thickness of the aquifer,
- the crop choice and market prices,
- the price of natural gas and other production costs, and
- the soil type.

The graph above depicts estimated maximum value on the amounts a farmer could pay to pump and apply an additional acre-foot of water across a 1,000 acre farm. The figures are based on average crop prices in 1981 dollars for a 20-year period (1962-1981) and a natural gas price of $3.85 per thousand cubic feet.

The graph figures also assume the use of an improved irrigation method called LEPA in Terry and Lamb Counties. The LEPA (Low Energy Precision Application) system was designed by TAES researcher Bill Lyle at the research center in Halfway, Texas. Figures for Randall and Hale Counties are based on the use of an improved furrow irrigation method.

Differences between the curves for Terry and Randall Counties as well as for Hale and Lamb Counties represent the differences in irrigation technology used and in soil conditions. Varying groundwater conditions also contribute to the different dollar values for the pairs of counties.

Pumping and application costs vary with the irrigation technology used and the groundwater situation. These costs range from a low of $22 per acre-foot in Randall County to a high of approximately $44 per acre-foot in Lamb County.

If farmers could obtain all the water they desired every year, they would increase use until the value of the water in crop production just equaled the cost of pumping. The water source on the High Plains is, however, exhaustible. In order to save groundwater for future years, most farmers reduce their use of groundwater to a point short of where its value in crop production equals cost of pumping and application.

TAES research by Lacewell and associate John Ellis has calculated the average value of irrigation water to a major portion of the 42-county High Plains region for a period of 40 years. They used figures for economic returns under irrigated production and predominant groundwater situations compared to returns under dryland production. These values ranged from approximately $52 per acre-foot each year for the Northern High Plains and $96 per acre-foot for the Southern High Plains.

The TAES researchers made a distinction between the two subregions since cotton is generally not grown in the northern portion. Four of the southern region's major crops - cotton, grain sorghum, sunflowers, and wheat - can be grown either under irrigation or on dryland. Soybeans and corn, however, must have irrigation water to produce successfully most years anywhere in the High Plains.

Lacewell and Ellis found that the value of groundwater is very sensitive to market and input prices as well as the depth to water and the quantity of groundwater available.

Irrigators in the future can use information gained through computer models developed by this TAES research to help select crops as well as to determine how much water they can afford to apply to a specific crop. They can also learn whether it will pay to irrigate at all.

Computer Modeling to Protect Groundwater

The Texas Supreme Court ruled in 1904 that underground water belongs to the owner of the land surface:

". . . because the existence, origin, movement, and course of such waters, and the causes which govern and direct their movements, are so secret, occult, and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would, therefore, be practically impossible."

We've come a long way since then in our understanding of groundwater.

Groundwater existence and movement is no longer "secret" and "occult" to present day Texans. Current state law, though, does still recognize groundwater as the property of the surface owner.

Much of the mystery surrounding groundwater existence and movement has been removed through computer modeling. In the past several decades, tremendous strides have been made in understanding the occurrence and movement of underground water by simulating by computer what is known about aquifer characteristics, porosity of different soils, chemical reactions, and movement of water.

Knowledge of groundwater storage areas - called aquifers - steadily increases as scientists collect and analyze more and more detailed information. New techniques to study this information are continually discovered and refined.

With the aid of computers, scientists can now make accurate predictions on pumping effects in most locations for water levels and for well yields. They can also measure natural recharge and natural discharge of aquifers and can determine the inter-relationship of groundwater and surface water bodies. Computer modeling also aids in developing techniques for artificial recharge and in analyzing the effects of recharge on the availability of groundwater supplies.

Computer models developed by scientists with The Texas Agricultural Experiment Station (TAES) help present day groundwater managers

- to protect groundwater quality
- to determine and enhance effective recharge.
- to minimize water level decline and subsidence.

TAES scientist Donald L. Reddell designs models to predict and prevent groundwater pollution. He defines pollution as any alteration of water quality which makes the water unacceptable for reasonable uses. Reddell's models can simulate aquifer characteristics and water movement to determine impact of both natural and manmade pollution sources .

Reddell lists several groundwater pollution problems which can be analyzed and perhaps alleviated by groundwater modeling. Problems include chemical waste disposal; injection wells; agricultural chemical build-up; saltwater intrusion into freshwater aquifers; land application of industrial, municipal, or livestock wastes; and improperly installed septic tanks.

"Since water in Texas is a limited resource," says Reddell, "it is vitally important that Texans maintain the quality of their groundwater aquifers." Reddell, a professor in the Texas A&M University Department of Agricultural Engineering, conducts research and teaches graduate courses on groundwater modeling.

Perhaps his most important work so far is a numerical model which simulates the movement of pollutants underground. Reddell calls his model SUDS, for saturated-unsaturated dispersion simulator.

The SUDS model is unique because it includes the movement of air as well as water in analyzing the infiltration process. It can also describe the movement of a pollutant in the groundwater and determine potential impact on groundwater by different types of pollutants.

Answers to underground pollution problems are partially dependent, says Reddell, on knowing how groundwater moves under present conditions and in knowing how the groundwater can be made to move out of the system.

To use his mathematical simulation model, Reddell places in the computer a group of mathematical expressions to describe aquifer functions. He uses known physical characteristics of a specific site such as permeability and hydraulic characteristics of the aquifer, soil properties, position and number of wells, location of potential pollution sources, and groundwater recharge based on rainfall and evaporation.

Reddell says the applications of the SUDS model are numerous. He cites the following examples of pollution for which SUDS can predict the consequences:

- Saltwater intrusion. Because of heavy groundwater withdrawal along the upper Texas Gulf Coast, saltwater intrusion has become a major threat to freshwater aquifers.

- Underground injection. Texas leads the nation in underground injection wells with more than 40,000 wells associated with oil and gas recovery and with about six billion gallons of industrial wastes injected annually. Underground injection wells remove wastes from the earth's surface, enhance oil and gas recovery, recharge aquifers to maintain groundwater levels and to prevent subsidence, and provide barriers to prevent saltwater intrusion. But if not engineered, constructed, and maintained properly, underground injection wells can contaminate freshwater aquifers.
- Infiltration of surface pollutants. Surface mining and waste disposal as well as agricultural, municipal, and industrial activities can all impact groundwater sources.

The graph illustrated above shows how the SUDS computer model predicts the movement of pollution from a septic tank over time and space. Using his model Reddell can trace pollutants at far greater depths and distances from the pollution source.

TEXAS GROUNDWATER FACTS
Twelve percent of all the groundwater used in Texas goes for municipal purposes; almost 5 percent for manufacturing, steam electric generation, mining; and over 83 percent for agricultural production purposes.

Ripples & Waves

Land subsidence caused by over-pumping groundwater has meant enormous physical and economic damage to areas along the Texas Gulf Coast.

Research by The Texas Agricultural Experiment Station (TAES) can help regions affected by subsidence to determine an optimal mix between groundwater and alternate sources of water such as surface water or groundwater from another area. TAES scientists have developed computer models which can evaluate water pressure distribution in an aquifer system, predict land surface subsidence, and allocate surface and groundwater resources to minimize the region-wide cost of land surface subsidence.

Field experiments conducted by the High Plains Underground Water Conservation District and the Texas Department of Water Resources have shown increases in water yield when air pressure was increased underground.

TAES has initiated a new project this year to apply computer modeling techniques to help understand the effects of air pressure on groundwater in the High Plains (Ogallala) Aquifer.

As fuel costs rise, many technological possibilities previously considered uneconomical have attracted the attention of Texans. One of the most interesting is the concept of storing heat generated by summer sun or by electric generating plants in groundwater aquifers.

TAES researchers have looked at this possibility of using groundwater as a receptor for heat, then pumping the water back to the surface for space heating during the winter months. They have also tested in the field and in computer models a similar concept of chilling water in the winter, storing it underground, and using it to cool buildings during the summer.

Storing fresh surface water underground has been an appealing idea - and a research topic in the TAES research program - for decades. A current project at the TAES research center at Lubbock involves methods of clarifying and recharging surface waters.

Researchers there have built a physical model to design and test rapid sand filters, well sealers, and gravel pack grouts for clarifying and placing surface water into the unsaturated zone. They are also developing design criteria for recharge wells.