Our Underground Water Supplies: the Sometimes Dry Facts

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"Meditation and water are wedded forever." When Herman Melville wrote these words, he was not thinking about ground water—the invisible water source which not so long ago was still considered an occult and secret substance emanating from the bowels of the earth.

Now we know, of course, that ground water simply is rainwater which has seeped underground and is stored in geologic formations. If the formations are permeable enough so they yield adequate flows to wells, they are called aquifers.

Most aquifers consist of sand and gravel deposits. Cavernous limestones, sandstone, and fractured basalt or other rock also are good aquifer materials. Aquifers can be quite extensive and underlie several States, like the Ogallala Aquifer in the central and southern Plains of the United States.

Some aquifers are sandwiched between impermeable formations and the ground water is under pressure. Water in wells in such artesian aquifers rises above the aquifer itself, so that pumping lifts are less than depths to ground water. There also are artesian aquifers where the ground water has enough pressure to flow all the way to the surface, yielding free-flowing wells.

Some aquifers are hundreds of feet underground and require deep wells for ground-water pumping. Others are near the surface.

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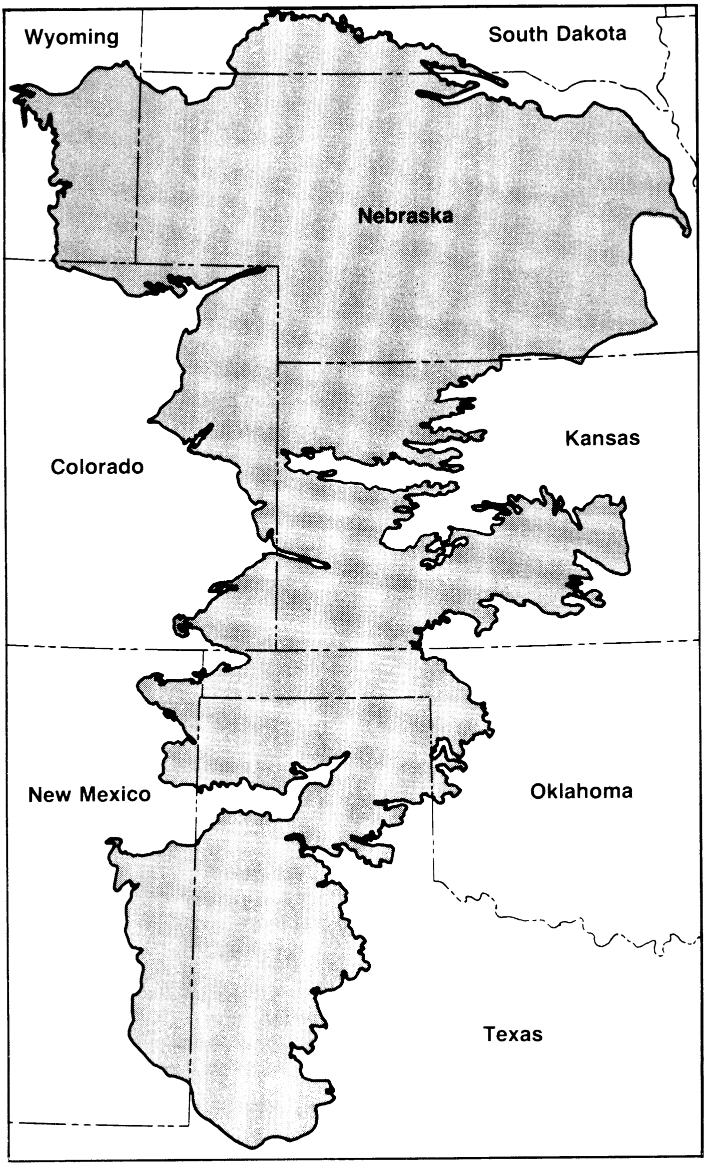
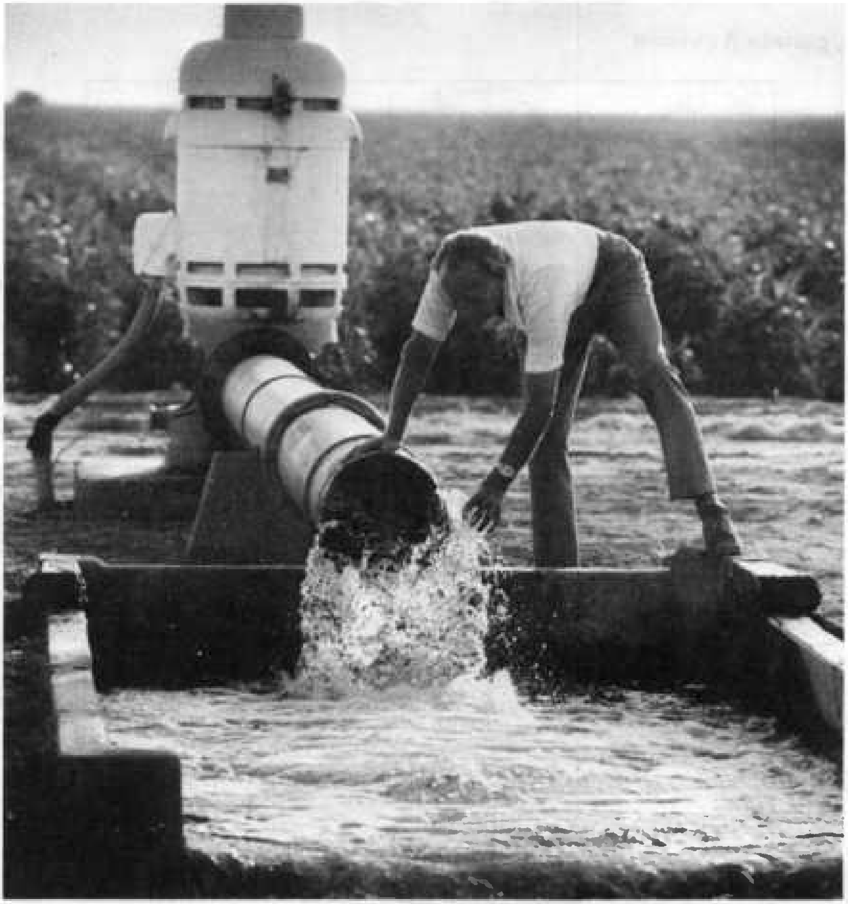
Ogallala Aquifers



Aquifers can be quite extensive and underlie several States. The Ogallala aquifer covers parts of eight States in the central and southern plains of the U.S.


Pete Mortimer

Average Age 150 Years

Average time the water has been underground, or average "age" of the ground water, in the United States is about 150 years. Some ground water is much younger, and some is older than 20,000 years. Most ground waters move horizontally but their velocities are small, often between 10 and 100 feet a year.

Some aquifers are hundreds of feet deep and require deep wells for ground-water pumping. In contrast, there are artesian aquifers where the ground-water has enough pressure to flow all the way to the surface, yielding free-flowing wells.

About half the population in the United States depends on ground water for drinking. In rural areas, the figure is close to 100 percent. Ground water supplies 25 percent of all water used in the United States and about 40 percent of all irrigation water.

Worldwide, about 30 times as much freshwater is stored within drillable distance underground as there is freshwater in all the lakes and streams. Ground water and springs have provided water for people throughout history and have made deserts bloom.

In arid and semiarid areas and in industrial or densely populated regions there is a tendency to overexploit the ground-water resource, pumping it out faster than the natural recharge or replenishment rate. This results in a decline of ground-water levels, which in turn increases pumping costs, requires deeper wells, causes some wells to go dry, and produces land subsidence.

A case in point is the Ogallala Aquifer, which underlies about 220,000 square miles in the Great Plains and is used extensively for irrigation.

Agriculture in the Great Plains originally was based on dryland production. The soils are among the world's most fertile, with inadequate moisture the principal factor limiting plant production. Rainfall ranges from 10 inches a year in the driest parts to more than 30 inches in the wettest areas. The variations from year to year can be very great. It is not unusual for annual precipitation to vary between 50 and 200 percent of the average.

Irrigation Pushed in 1950's

Irrigation in the Ogallala region began in the early 1900's, but did not accelerate until the late 1930's following the major drought responsible for the Dust Bowl era. After World War II, and particularly during the drought of 1951-1956, irrigated acreage expanded rapidly. The rapid conversion to irrigation provided much more consistent production for the farmer and reduced the extreme variation in production due to normal climatic variability.

The first irrigation developments took place in Texas and in the southern High Plains, followed by Colorado, Kansas, and Nebraska. Currently the Great Plains States account for about 48 percent of irrigated land in the United States. Over 80 percent of the water used for irrigation in this area comes from ground water, with the Ogallala the principal source.

The combination of a seemingly unlimited supply of excellent quality water, highly fertile soils, newly developed hybrid grain sorghum and other improved crops, a favorable climate, and readily available capital resulted in a tremendous expansion of agricultural production and associated agribusiness.

Feedlot development based on the abundant supply of feedgrains and the availability of feeder cattle followed, so that now more than 60 percent of all fed cattle produced in the United States are fed in the Great Plains.

Transformed by Ogallala

The Ogallala Aquifer thus transformed a region that had been used for dryland farming and ranching to a major irrigated area of profound importance to the region, the Nation, and the world.

It was in the 1960's, when the center pivot irrigation systems became quite popular, that significant well-drilling activity in Colorado and Nebraska was undertaken. The center pivot system provided a way of irrigating the undulating and sandy soil areas in the High Plains.

This system consists of a pipe supported about 10 feet above the ground on A-shaped towers with sprinklers mounted on the pipeline. The typical system is about a fourth of a mile long and irrigates about 130 acres. Supporting towers usually are spaced 100 to 180 feet apart and move in a circular pattern about a pivot point.

One can get an excellent view of this irrigation development while flying over the Great Plains. There are systems in use which irrigate a circle inscribed in one square mile. These systems are very adaptable to irrigating soils of low water-holding capacity, such as sandy soils. The light, frequent application of water possible with these systems can keep the water balance favorable, and very high yields are readily obtained.

Water Level Drops

As irrigation expanded, it became all too apparent that the aquifer's water level was dropping significantly and the once seemingly unlimited supply of ground water was rapidly being depleted.

The first adjustment by many farmers to maintain irrigated acreage was to add additional wells. While this was a suitable solution for the short term, it only accelerated decline of the ground-water level. These declines were most significant in the southern High Plains of Texas and Oklahoma and in southeastern Colorado.

Water stored in the Ogallala Aquifer is not uniformly distributed. Estimated water storage in 1977 was 3.04 billion acre-feet, underlying about 113 million acres. Nebraska has 36 percent of the land above the aquifer but more than 75 percent of the water in storage. Texas has 20 percent of the land area above the aquifer with only 9 percent of the water. Consequently the future of irrigation in the Great Plains States will vary greatly.

Even with more efficient irrigation systems, some irrigated land—particularly in the southern High Plains—will have to revert to dryland. The conversion of irrigated land to dryland will result from a declining supply of water and/or the inability to realize enough profit from irrigated farming to pay for energy costs associated with pumping from greater depths.

If water availability is a primary constraint, conversion of irrigated land to dryland will be gradual and will generally move from fully irrigated to limited irrigated dryland. Limited irrigation will involve only one or two irrigations during the crop growing season, or perhaps applying a preplant irrigation during winter.

Dryland Yields

These cropland areas can generally be returned to dryland farming without serious environmental impacts, and with modern technology will maintain a fair level of production. In fact, yields from dryland today will be higher generally than before irrigation, because improved farming systems better utilize rainfall.

Conservation tillage systems in the Great Plains can in many cases increase the soil water storage when crops are not grown. Conservation tillage also reduces wind and water erosion. These and other improved practices greatly minimize the likelihood of widespread duststorms as occurred during the "Dirty Thirties."

Continued use of some limited irrigation, however, will still contribute real benefits to agriculture in the Great Plains because of the stabilizing effect it has on crop production and the region's economy. The extreme variability in climatic conditions in the Great Plains would see yields under dryland farming range from fairly high in above average rainfall years, to very low—or even crop failure—in drought years.

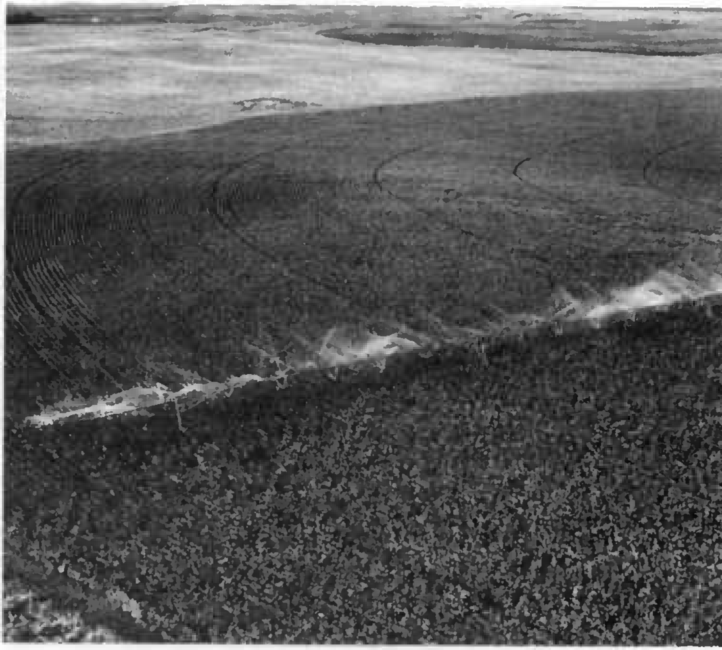
In contrast, the Northern Plains region, particularly in Nebraska, has significant new areas which will be brought under irrigation. Recent studies have projected that total irrigation in the Great Plains will increase during the next 50 years.

Pollution Threat

Much of the area to be developed is on very sandy soils which will see even larger use of center pivot sprinkler irrigation. The latest in technology must be used in managing these systems to maintain economical operations. If proper management is not used, environmental degradation of ground-water resources with nitrogen, insecticides, and herbicides as pollutants presents a real threat.

The latest deterrent at the present time to increased irrigation from the Ogallala Aquifer is the increasing cost of energy. In early years of development, irrigation wells were shallow, energy resources cheap, and total pumping costs often considered insignificant. These factors changed dramatically during the 1970's, and some farmers have ceased irrigation simply because of rising pumping costs, rather than lack of available water.

What is happening to the Ogallala is happening to many irrigated areas of the West, and for that matter to the rest of the country. Some States advocate letting economics and the free market determine how much farmers can draw down their ground-water levels before it becomes uneconomical to pump.



Even larger developments of center pivot sprinkler irrigation are expected in the years ahead on sandy soils in the Great Plains.

In other States, like New Mexico and Arizona, the solution is sought in increased State control over ground-water pumping.

The strictest ground-water law was adopted in Arizona in 1980. This law will set water duties to farmers using ground water for irrigation and will force increased water conservation and abandonment of irrigated land to reduce ground-water pumping to safe yield levels by the year 2025. Safe yield is the natural replenishment rate of the ground water. Pumping ground water at or below safe yield rates thus will not produce any decline in ground-water levels.

Land Subsides

Declining ground-water levels often cause subsidence of the overlying land. This is because material in the dewatered ground water zone has lost its buoyancy and thus exerts a greater pressure on the underlying formations which will then become more compressed. As the deeper layers compress, the entire overburden moves down.

For water table aquifers, the land surface typically goes down about 0.01 to 0.5 feet for every 10-foot drop in ground-water level, depending on the thickness and compressibility of the deeper materials. Many irrigated areas have subsided several feet to about 10 feet. The record subsidence is 30 feet and occurred in the San Joaquin Valley west of Fresno, Calif.

Land subsidence increases the flood danger of already low areas

(for example, Venice in Italy and the Houston-Baytown area in Texas), and has caused water wells to collapse. Subsidence is not uniform and varies from place to place in a given area. It has damaged roads, railroads, bridges, and buildings, and changed the gradients of irrigation channels and drainage and sewer lines.

Fissures Formed

Differential subsidence can also cause long cracks in the earth. Geologically, the irrigated valleys in the Basin and Range Province of the Southwest are particularly vulnerable to this kind of cracking. The cracks appear mostly along the periphery of the basins and valleys, parallel to the surrounding mountain ranges. Cracks also develop above underground bedrock ridges in alluvial fills.

Initially the cracks are only an inch or so wide, but since they tend to run parallel to mountain ranges, they intercept surface runoff and become eroded and enlarged. Mature fissures may be several yards wide and more than 10 yards deep, and may become several miles long. Fortunately, they have mostly developed in sparsely populated areas, but they could also form in cities like Phoenix where they can do considerable damage.

Land subsidence is essentially irreversible. It can be stopped by halting ground-water depletion, but the land surface will never revert to its original elevation—even when ground-water levels are restored to predepletion levels.

Artificial Recharge

In some areas, ground-water supplies are successfully augmented by artificial recharge. This calls for pumping water directly into aquifers through wells (like pumped wells in reverse), or by spreading water over the surface and letting it infiltrate into the soil and percolate down to the ground water. Both systems require a source of water (such as stored surface water, surface runoff, or treated wastewater). The spreading system also requires permeable surface soils and unrestricted flow of the water down to the ground water.

Artificial recharge is success-

Herman Bouwer

Subsidence due to lowered ground-water levels can cause deep cracks in the earth, and mature fissures may become several miles long. Land subsidence is essentially irreversible.

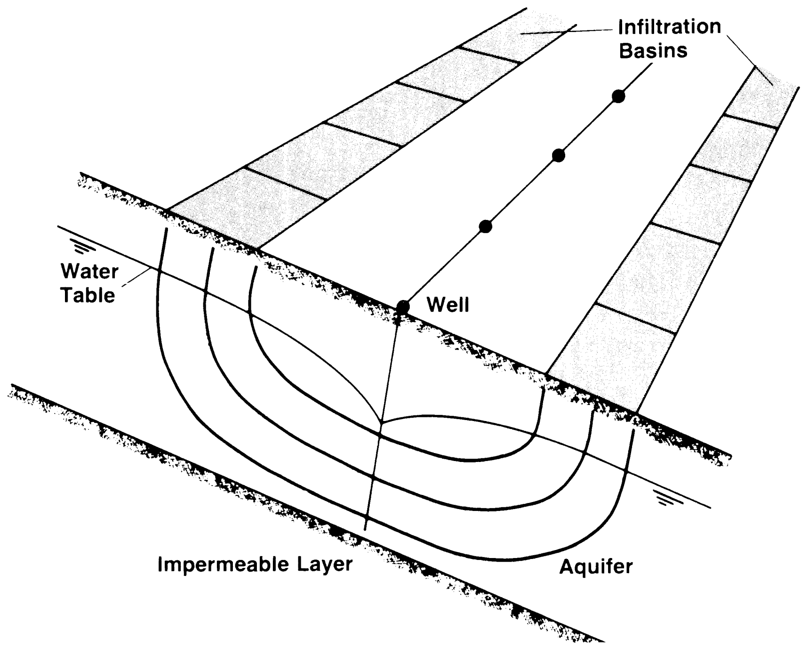
fully practiced in a number of places, particularly where there is an adequate supply of surface water during certain times of the year. Yet it cannot be considered a general solution to the problem of ground-water overdraft. Sound water conservation practices on the farm—and in water resource management generally—offer the best approach.

Filtering Wastes

Under the right soil and geological conditions, aquifers can be used as natural filter systems to treat sewage effluent or other wastewater so it can be used for unrestricted irrigation, recreational lakes, and other purposes. With such systems, partially treated effluent is infiltrated into the soil through basins arranged in two parallel strips.

After the sewage water has reached the ground water, it travels some distance through the aquifer before it is pumped as "renovated" water from wells located on a line midway be-

Infiltration Basins for Partially Treated Sewage Effluent, and Wells for Pumping Renovated Water After Soil-Aquifer Filtration.



tween the infiltration areas. The systems can be managed so no native ground water will move in from outside the system, and no sewage water will move into the aquifer outside the system.

Such systems generally give complete removal of suspended material, biodegradable organic matter, bacteria, and viruses from the wastewater. Phosphorus and heavy metals are greatly reduced. The systems can be operated to either leave the nitrogen in the renovated water where it has fertilizer value, or to remove about two-thirds of it by denitrification.

The renovated water thus is sufficiently pure for unrestricted irrigation and recreation, and with further treatment can even be recycled for drinking. This use of the aquifer could be valuable in municipal water reuse programs because "soil-aquifer treatment systems" are inexpensive to operate and provide a lot of purification for the money.

Ground-water resources are not infinite. When properly protected and managed, however, they can provide water "forever." This is the challenge of the future.