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Storing Water Underground

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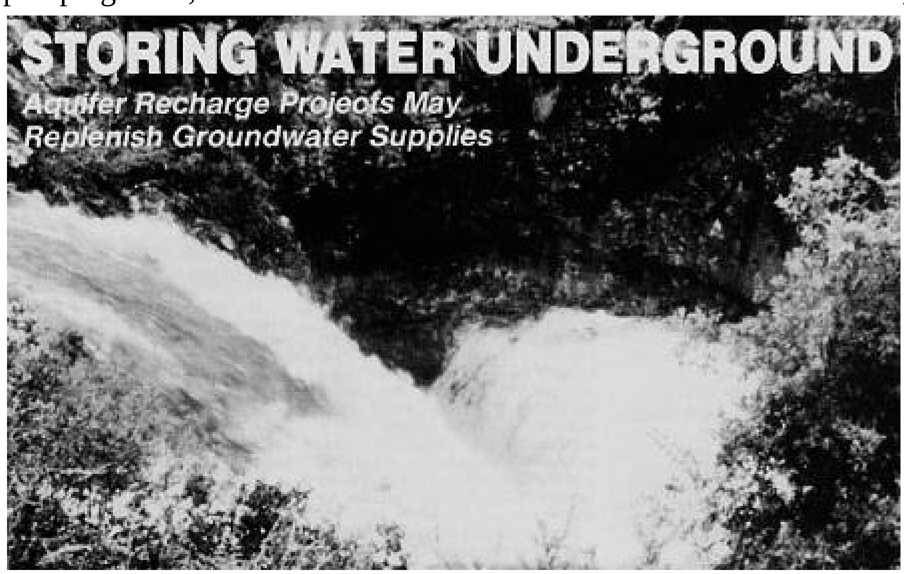
We've all heard of saving money for a rainy day.

Well, many areas of Texas are adding a slightly different twist to that well-used saying. They're saving excess water for dry days ahead by storing it underground.

The concept is usually referred to as "artificial groundwater recharge." In simple terms, it involves increasing the flow of water into underground aquifers.

Enhancing groundwater recharge makes sense for many reasons.



For example, where groundwater levels are declining, recharge can stabilize or raise them. This lowers pumping costs, lessens the risks of salt water intrusion and subsidence, and increases the useful life of groundwater systems. Storing water underground also minimizes the amount of water lost to evaporation, which is a major problem in many Texas reservoirs. Stormwaters can also be diverted and stored in aquifers, lessening flood damages.

In Texas, there are numerous examples of artificial groundwater recharge projects that have been proposed or are operating.

El Paso injects highly treated drinking water to replenish the Hueco Bolson aquifer. Nearby in Dell City, wells have been installed downstream of flood control dams to divert stormwaters into groundwater supplies. Texas Tech researchers are examining strategies to manage High Plains playa lakes to increase groundwater supplies. Near the Texas-Oklahoma border in Collingsworth and Hardeman counties, the Blaine Gypsum Aquifer is being replenished by drilling recharge wells and diverting runoff to sinkholes.

Throughout the Edwards Aquifer, dams have been built to direct rainfall into caverns and sinkholes and into groundwater supplies. A plan is also being discussed that could utilize Medina Lake to recharge the aquifer. Recharge dams have also been proposed for the Barton Springs segment of the Edwards Aquifer near Austin. In Kerrville, a pilot project is being tested to determine if supplementing surface water supplies with groundwater recharge could help meet peak demands and delay expanding existing water supply plants.

Water quality and water supply issues will need to be addressed before artificial recharge is widely adopted.

For example, El Paso treats wastewaters to drinking water standards and then uses them for recharge. Although there is no evidence that significant water quality changes have occurred yet, there are concerns that bacteria and other contaminants may pollute groundwater supplies. More data need to be collected on the time it takes recharged waters to reach recoverable portions of aquifers, the ability of the soil to filter pollutants, and whether levels of contaminants build up as a result of long term recharge efforts. Water quality may also be an issue in projects where largely untreated rainfall and runoff are diverted into playa lakes and sinkholes to recharge aquifers. Increasing the amount of runoff may provide a greater opportunity for nonpoint source pollutants including urban, industrial, and agricultural chemicals to enter and pollute sensitive groundwater systems.

Increasing groundwater recharge also raises some critical water rights issues, particularly in water-short areas.

In the Edwards Aquifer, for example, there are concerns that increasing groundwater recharge may reduce downstream flows of surface water. Studies are under way to determine the amount of surface water that could be available for recharge in the region.

Another key water rights issue will be to make sure that those who initiate groundwater recharge activities will be able to capture and benefit from the increased water supplies. In areas like the Edwards Aquifer groundwater flows rapidly and is hard to recover on-site. This means that others may be free to use and benefit from the groundwater supplies that others have paid to develop.

In summary, groundwater recharge has the potential to extend Texas' water supplies by capturing rainfall and runoff. However, water quality and legal issues need to be resolved before groundwater recharge is implemented on a wide scale.

BASIC CONCEPTS

Groundwater recharge can be natural or artificial. Natural recharge refers to rainfall and runoff that flows into aquifers when conditions have not been altered. Texas' aquifers receive an average of 5.3 million acre feet (AF) of natural recharge annually. Artificial recharge refers to physical adjustments and management strategies to increase the amount of recharge.

There are two broad types of recharge projects - aquifer storage and recovery (ASR) and conventional recharge projects. ASR projects in Texas are in El Paso and Kerrville. ASR systems treat water to drinking water standards and inject and store it underground for later use. Often, water is injected when rainfall is plentiful and is recovered when water supplies diminish and water use is high. In an ASR system, the water that is injected is intended to be recovered on-site. These projects typically do not deal with enhancing groundwater supplies over a wide region.

Conventional recharge projects utilize a variety of techniques to increase the amount of water entering aquifers. These include wells, dams and levees, excavation of impermeable soils, filters to remove pollutants, and systems to convey floodwaters to recharge points.

Not all sites are suitable for recharge projects. Aquifers must have adequate transmissivity - the ability to accept and yield large volumes of water.

It's also important to compare the chemistry of the water being recharged to the native groundwater. For example, if the recharge water contains excess calcium and the native groundwater is too hard then the aquifer can become clogged and will produce less water.

The geology and chemistry of the groundwater formation can also influence contaminant removal. Fractured limestone formations, for example, are not as able to adsorb pollutants as are aquifers comprised of sandstones, clays and organic matter.

Successful recharge projects have been carried out for many years in California, Florida and Arizona and other areas. California has been enhancing groundwater recharge since the late 1800s. Now, an average of more than 1.8 million acre feet per year is recharged annually, depending on climate conditions. Three sites in Florida are now using ASR techniques to recharge more than 6.5 million gallons per day.

Two California studies suggest that recharge programs will not typically degrade groundwater quality. One project focused on whether recharging urban stormwater could pollute aquifers. The results showed some increases in levels of pollutants at shallow soil depths, but no evidence that those contaminants were reaching aquifers (Nightingale, 1990). A five-year study investigated the health effects of using treated wastewater to replenish aquifers. Findings suggest that recharge had no impact on groundwater quality or on the health of persons who drank the recharged water (Nellor and others. 1990).

TEXAS REGULATIONS ON RECHARGE

In Texas, projects that will inject recharge water by using wells require permits from the Texas Water Commission (TWC). If recharge water will be treated to drinking water standards before being injected, approval is required from the Texas Department of Health. Recharge dams may be subject to Corps of Engineers' rules concerning man-made obstructions of streamflows.

Water rights and water supply questions concerning groundwater recharge are resolved by the TWC. Section 1 1.023 of the Texas Water Code contains specific regulations governing groundwater recharge only for the Edwards Aquifer. However, many of the same principles are used by the TWC to evaluate projects in other regions on a case by case basis.

Applications must be made to TWC for rights to unappropriated water if a project involves diverting and recharging surface water and runoff that would normally contribute to streamflows. In the High Plains, however, rainfall is captured in playa lakes and would not normally increase surface water flows. In that case, TWC permission is not required.

In the Edwards Aquifer, it also has to be proven that only waters in excess of the "normal" and "ordinary" flow of surface waters will be used for groundwater recharge. Long-term streamflow records can be used to identify normal and excess amounts on a site-specific basis. When flows exceed the normal rate, those waters can be used for recharge. An easier way of distinguishing between normal and excess flows is to divert water from streams that are normally dry. When those streams have water in them, the flows are greater than normal levels. Seco Creek in the Edwards Aquifer, for example, is normally dry but during storms waters are diverted into a sinkhole. It also has to be shown that unreasonable losses of State water will not occur and that the water can be withdrawn at a later time and can then be put to a beneficial use.

The TWC can then issue permits authorizing the amount of water that can be impounded for recharge. However, as a practical matter, it may be nearly impossible to limit the amount of runoff entering a sinkhole or fracture. For example, the Seco Creek project is authorized to recharge only 1,185 AF annually but recharged nearly 13,000 AF in 1987.

Many of the water rights questions about groundwater recharge center around Texas' different standards for surface water (state regulated) and groundwater (unregulated). One proposed solution is the creation of an agency to coordinate the conjunctive use of surface and groundwater in the Edwards Aquifer region.

EL PASO'S EXPERIENCE - CONVERTING WASTEWATER INTO DRINKING WATER

In El Paso, groundwater recharge made sense for a number of reasons. The Hueco Bolson aquifer was being depleted by overpumping, groundwater levels were dropping, and there were fears that the region could run out of groundwater early in the 21st century. El Paso investigated various ways to increase its water supplies including groundwater pumping in New Mexico, importing water from the Trans Pecos region, and wastewater reuse. Meanwhile, El Paso needed to expand and improve its sewage treatment facilities. Large amounts of water would have been lost to evaporation if traditional lagoons were utilized.

El Paso decided to treat the wastewater to drinking water standards and then inject it underground in a series of 10 wells. The recharge project also allowed El Paso to recapture and reuse its water supply. If El Paso chose to discharge wastewaters into the Rio Grande, those flows would have been unrecoverable.

The recharge system has been operational since 1985. The recharge water eventually flows to a series of production wells which supply drinking water for the City. It is estimated that recharge water is diluted by a ratio of 20-to-1 as it passes through the aquifer. The time it takes the recharged water to f low to the drinking water wells is estimated at 2 to 7 years. The U.S. Geological Survey is now studying whether boron isotopes and computer models could be used to track flow travel times and patterns, and whether levels of trihalomethanes could increase as a result of the program.

Theoretically, the water could be safe enough to be recycled directly into El Paso's water system once it's been subjected to such high levels of treatment. However, State regulations now ban such direct reuse programs. Also, having the water flow through the soil before it's recaptured adds another measure of protection against bacteria, chemicals and other contaminants that may remain after the treatment process. No significant changes in water quality have been reported in the aquifer since the program began.

Roughly 7,850 AF were recharged into the aquifer in 1986. City officials predict that the system will probably be doubled in size within the next 10 years to supply 25% of El Paso's water needs (19,000 AF annually). Costs for the treatment and recharge system totaled roughly $1.55 per 1,000 gallons of finished water in 1988.

The project seems to have helped stabilize groundwater levels in the area. Before the ASR program was begun, water levels were dropping an average of 2 feet per year. Since that time, water level declines at the injection site have averaged only 0.6 feet per year.

DELL CITY: MERGING FLOODWATERS WITH GROUNDWATER RECHARGE

In Dell City, an unusual flooding problem led to studies to determine if stormwaters could be trapped and utilized for groundwater recharge. Dell City is located 90 miles east of El Paso in a valley that is occasionally victimized by disastrous floods. The lack of natural drainage prevents runoff into rivers and streams and results in extremely swift flows and heavy flood losses. At the same time, groundwater levels were falling because of heavy agricultural usage.

To solve the problem, the U.S. Department of Agriculture/ Soil Conservation Service proposed building four flood control dams. Because there are no rivers in the area it was difficult to drain the reservoirs without causing f food damage. The solution was to develop a series of wells immediately downstream of each dam. Floodwaters would flow into the reservoirs during storms and would then flow to the wells, providing much needed recharge and preventing flood damages.

So far, 11 recharge wells have been constructed (Logan, 1990). Designs are now being developed for a conveyance system that will transport the floodwaters from the dams to the wells. When the system is operational in 1991, it could add as much as 6,000 AF of fresh water to regional aquifers each year, depending on the amount of rainfall. This could help stabilize groundwater levels and decrease the salinity of groundwater supplies.

HIGH PLAINS: PUTTING PLAYA LAKES TO WORK FOR THE OGALLALA

The Texas High Plains are covered with more than 17,000 shallow, naturally occurring, depressions called playa lakes. The lakes capture an average of 1.8 to 5.7 million AF of water annually.

The characteristics of individual playas vary tremendously. Some cover only a small area while others can be as large as 200 acres. Most of the playas are 2 to 10 feet deep when full of water. There are an average of one to two playas per square mile in the Southern High Plains.

In the spring and fall, intense thunderstorms frequently fill the playas. However, little infiltration occurs, 50% to 80% of the water is lost to evaporation and winds, and minimal groundwater recharge occurs.

Researchers at the Texas Tech University Water Resources Center have been investigating the amount of water playas naturally recharge and whether recharge could be increased by modifying the playas.

Almost all playa lakes have a clay bottom. However, the clay layer thins out and is often replaced by sandy soils in upper portions of the lakebed. When enough rain falls to raise the water level above the clay bottom and into the sandy areas, significant natural recharge can take place. After the lake levels fall back into the clay zone, little recharge occurs.

The clay layer also presents water quality problems. When clays shrink they crack and briefly provide a direct conduit for contaminants to enter shallow soils. When plants grow in playa lakebeds, their roots can also create openings and cracks.

The Texas Water Resources Institute sponsored studies by Texas Tech scientists to quantify the amount of water available for recharge. Many of the studies involved evaluating the effectiveness of filters to reduce clogging of wells and aquifers, and removing clay from the bottom of the lakes (Urban and others, 1990).

The amount of water lost to evaporation can be as much or more than the amount recharged to the Ogallala in many playa lakes. However, studies at Texas Tech suggest that 60 to 80% of the water now lost to evaporation can be recharged when playas are modified.

The modifications involve installing a textile filter in the lake bottom that is covered with a thin layer of clay and sand to improve the quality and the amount of water being recharged to the aquifer. The thin clay layer is needed to trap suspended solids and filter out other contaminants. The water flows through the filters into pipelines connected to recharge wells and then into the aquifer.

In a demonstration project near Shallowater, the quality of the recharge water was better than native groundwater for all parameters except total suspended solids and chemical oxygen demand (Urban and others, 1988).

Texas Tech scientists have also proposed a large scale project to demonstrate the feasibility of playa lake recharge. The effort would involve assessing the costs and benefits of modifying 8 playas with highly variable characteristics. Hopefully, filters and recharge wells could be developed that would last 7 to 8 years - long enough to make the modifications pay for themselves.

Researchers with the U.S. Department of Agriculture/Agricultural Research Station at Bushland have also found that basins excavated in playa lakes can produce significantly more recharge than unmodified lakes. Work is also going on to divert stormwater runoff into sinkholes and wells d rifled into the Blaine Gypsum aquifer which straddles the Texas-Oklahoma border in Hardeman and Collingsworth counties (Runkle and Johnson, 1989).

The implications of widespread recharge projects could be significant. Individual playa lake recharge projects could save enough water to sustain irrigation on 20 to 50 acres without depleting the aquifer.

PLAYA LAKE MODIFICATIONS RAISE WTER TABLES

Although it may not seem likely, one of the main water problems facing Lubbock is an overabundance of groundwater. The problem seems to be that some urban playa lakes have been altered to allow for increased development. In the process, they began generating too much recharge.

For example, many playa lakes have been deepened and the clay layer has been excavated. This allows more adjoining land to be developed and, in theory, provides for the same volume of storage space. When the clay liner is removed the potential volume of additional recharge that can occur increases dramatically and the ability to filter pollutants is reduced.

Groundwater levels beneath Lubbock have been rising an average of 2 feet per year since 1965. Since 1981,watertables in some parts of Lubbock have risen by more than 40 feet or an average of more than 9 million gallons per day (mgd). A number of playas are now are often full and overflow when rainfall occurs. Officials are concerned that foundations and basements of many buildings at Texas Tech (including Jones Stadium) may be threatened by the high water tables (Chen and other, 1988).

Numerous alternatives have been suggested to deal with the excess water. Pumping of an average of 10 mgd could stabilize groundwater levels. Potential solutions include treating the water to remove fluoride and selenium and then using it for potable purposes, irrigating parks and medians, and pumping it to area lakes for recreational use.

EDWARDS AQUIFER: RECHARGE DAMS AND MEDINA LAKE

The Edwards Aquifer recharge zone is characterized by sinkholes, fractures and fissures that provide ideal opportunities for groundwater recharge projects. As a result, the Edwards Underground Water District (EUWD) constructed four recharge dams that hold back floodwaters long enough to allow the water to seep down into the Edwards Aquifer.

Parker Dam is the largest and has a capacity of 2,661 acre feet. Seco Dam is perhaps the most unique- it diverts water to a 200-foot deep sinkhole.

The amount of recharge generated by the dams varies greatly from year to year (see Figure 1). In 1987 Seco Dam alone produced nearly 13,000 AF of recharge and all four dams combined to produce more than 20,000 AF. Long-term average recharge is roughly 5,000 AF per year. However, no recharge was reported in 1988 and 1989.

The dams also provide an economical way to add to the area's groundwater supplies. The EUWD estimates that the cost of producing an acre foot of water using a recharge dam is only $15, while the current market value for an acre foot is as much as $45 (Bader and Masters, 1990).

In addition to the recharge projects, the EUWD has also helped develop flood control dams in the region. These dams contribute an extra 13,000 AF of "accidentals recharge as waters seep through porous rock formations into the aquifer. The EUWD is now determining if any additional water is available in the Nueces, San Antonio, and Guadalupe river basins that could be used in recharge projects.

Brush control programs might be able to increase flows to the aquifer by lessening the amount of water consumed by mesquite and other brush species. Research into the amount of water that can be saved through brush control is now underway by Texas

A&M University scientists (McCarl and others, 1987). Extension agents and others are now determining whether increasing recharge may impact water quality.

Another way to increase the amount of water entering the Edwards involves using Medina Lake as a recharge project. The lake is now being used for irrigation. Even though it's not designed to be a recharge project, the lake contributes an average of 40,000 to 59,000 AF of recharge to the aquifer each year. Plans now being proposed involve pumping water from the lake to a series of injection wells. As much as an additional 40,000 AF could be recharged to the aquifer annually. To protect water quality, monitoring wells could be installed. EUWD is now debating whether rights to Medina Lake water should be purchased or leased.

In the Barton Springs portion of the Edwards AquIfer near Austin, groundwater recharge can also be increased. For example, some estimates suggest as much as 45,000 AF per year could be available for groundwater recharge in the region. Much of that runoff now contributes to streamflows in the Guadalupe and Blanco rivers.

Many potential solutions have been investigated. In the early 1980s, Driftwood Dam (a 55,000 AF dam on Onion Creek) was proposed that could have added an average of 18,000 AF per year of groundwater recharge. During droughts, the dam could have still increased average recharge by 9,300 AF per year (Ruiz, 1985).

Recently, many smaller recharge dams have been proposed that would slow and capture floodwaters to increase groundwater recharge. The dams would only hold waters during storms and would be emptied shortly afterwards to make sure that runoff into streams would not be impaired. Six channel dams with a combined storage capacity of 815 AF could be constructed along Onion Creek. During an average year, 12 storms would produce enough rainfall and runoff to fill each of the 20-foot deep lakes. This could produce 5,000 to 9,800 AF of groundwater recharge, according to the Barton Springs Edwards Aquifer Conservation District (1990).

Other recharge options include diverting waters from Lake Travis and floodwaters from the Blanco River to Onion Creek, utilizing sinkholes and other natural features, and building the Dripping Springs Dam.

Groundwater recharge in the Edwards also raises some interesting water rights questions. Because water flows so rapidly in the aquifer, the water that's being recharged will probably end up benefiting someone else. This could discourage potential sponsors from becoming involved who may need direct benefits to compensate for the costs of initiating such a project. While recharge benefits the aquifer, it may also reduce surface water flows. Many studies are now underway to determine the impact of groundwater recharge projects on surface water supplies.

It is not yet clear whether groundwater recharge programs could make aquifers like the Edwards more vulnerable to contamination. Diverting rainfall and runoff into recharge dams and openings that are directly connected to the aquifer could increase the chance that pollutants would enter the system. Some contaminants would still enter the aquifer even under natural recharge conditions.

Fortunately, most of the recharge dams are in largely undeveloped areas that are unaffected by man-made pollution. North of San Antonio, urban sprawl is beginning to encroach upon the recharge zone. The EUWD is now working with citizens' groups to determine whether lands on the recharge zone can be purchased as a public trust and left undeveloped to protect water quality.

KERRVILLE: USING RECHARGE TO MEET PEAK DEMANDS

In Kerrville, the maximum daily demand can be twice as much as average demands.

Typically, the only solution would be to construct a water treatment plant large enough to meet those maximum demands, even though the facility would be underutilized much of the year.

The Upper Guadalupe River Authority (UGRA) is determining whether excess river water (treated to drinking water standards) could be stored underground during rainy, low demand, periods in an ASR system. That water could be recovered during summer months to meet maximum demands. The recharge project would raise groundwater levels by 40 to 60 feet during wet months. No major long-term changes of aquifer levels are expected (UGRA, 1988).

UGRA is hoping to be able to store 2 mgd in the project by as early as 1992. This amount of recharge would probably produce enough water to postpone the expansion of a water supply plant by 10 years. The cost of the ASR system will save 25% compared to conventional costs of increasing water supplies.

So far, one monitoring well has been installed. A pilot well will be drilled shortly to conduct field tests to determine the performance of the system.

This case also raises some water rights questions. If the increased groundwater supplies left the ASR site, neighboring landowners could pump the additional water. To make su re they can capture the water being recharged, the UGRA is working with City of Kerrville to determine if an ordinance could be passed to prohibit the drilling of water wells within Kerrville's city limits where the project is located.

SUMMARY

Texas is a water-short state and must look for ways to increase water use efficiency and eliminate waste.

Artificially enhancing groundwater recharge seems to be a way to accomplish many of these objectives. Groundwater recharge has the benefit of avoiding high losses to evaporation. Recharging groundwater supplies can even reduce flooding problems in some instances.

Some issues still need to be addressed. Rainfall and runoff can tee put to a variety of uses such as improving water quality by diluting contaminants, maintaining in-stream habitat for aquatic species, and supplying fresh water to bays and estuaries. Policy makers must decide what priority to give to groundwater recharge projects, in relation to these other potential uses, and then must reflect those choices in State regulations.

The implications of recharge on downstream surface water supplies also needs to be studied, especially in water-short areas. Recharge structures may have to be monitored to ensure that the amount of
water captured and recharged doesn't exceed permitted amounts at the expense of downstream surface water flows. Physical modifications may be able to limit the amount that's recharged to match per conditions, or the permits can be rewritten to reflect actual amounts of recharge.

Ways to encourage groundwater recharge need to be developed. If the State determines that recharging the Ogallala (or any other aquifer) is beneficial, grants or other incentives could be provided to motivate individuals and agencies to initiate recharge projects to conserve water. Measures need to be taken to ensure that those who pay to increase groundwater recharge are rewarded.

Directing runoff into sinkholes and open wells may increase the possibility that nonpoint source pollutants will contaminate water supplies. Studies need to be undertaken to investigate whether such processes are actually lessening groundwater quality. Perhaps some form of pretreatment or detention needs to be required before runoff waters enter aquifers. When treated sewage is recharged into aquifers, special attention must be given to ensure that contaminants do not enter the aquifer.

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