15. M. R. Henzen, "Die Herwinning, Opberging en Onttrekking van Gesuiwerde Rioolwater in die Kaapse Skiereiland" (D.Sc. thesis).
16. Van Vuuren and Henzen, "Process Selection."
17. O. O. Hart, "Process Refinement in the Development of a Water Reclamation System" (Paper presented at the workshop, International Association on Water Pollution Research, Vienna, Austria, September 8–12, 1975).

CHAPTER 7

# Water Reuse in Agriculture, Industry and Recreation

James E. Bertram

The multiple reuse of water in Lubbock, Texas, is evolving as one solution to a growing demand for a depleting resource. Many cities in arid or semi-arid regions of the United States have considered, or will probably consider, similar courses of action in the near future.

The city of Lubbock is situated on the southern portion of the high plains of West Texas. The only noticeable variations in topography are numerous playa lakes, which are shallow depressions, varying in size from 10 to 1 square mile, and small canyons eroded by occasional surface runoff. Average annual rainfall is approximately 18 inches. Most rainfall runoff is trapped in playa lakes, where considerable surface water is lost through evaporation, averaging 73 in./yr.[1]

The high plains area of Texas has a rich agricultural economy. It has an underlying, large aquifer referred to as the Ogallala formation. Many cities, using water from the aquifer for domestic water supplies and numerous irrigated farms, are lowering the watertable from 1 to 3 ft/yr, while recharge averages only 1 in./yr or less.[2] The city of Lubbock, until 1968, took its entire water supply from the Ogallala. Recent engineering studies indicate that, based on Lubbock's estimated growth rate, peak daily domestic water demands will reach 141.3 mg/d by 1995, while maximum development of existing water sources will produce only 137.3 mg/d by 1995.[3]

## RECLAIMED WATER AS A PROBLEM AND RESOURCE

Like most cities, the early history of sewage effluent disposal in Lubbock reflected a growing "problem" of what to do with the "wastewater." Early solutions in Lubbock involved large, man-made tanks near the reclamation plant.[4] By 1974, Lubbock's average daily use of potable water was 31.3 mg/d, of which an average of 16.3 mg/d, or 52 percent of the water used, flowed into the sewage treatment plants. It is estimated that the amount

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of effluent could increase to 22 mg/d by 1990. Currently, most of the effluent is received by the southeast treatment plant (activated sludge process), which has a design capacity of 25 mg/d.

## HISTORICAL REUSE APPLICATIONS

### Crop Irrigation

The first change in attitude in Lubbock from effluent being "wastewater" to being a "resource" came with the decision in 1937 to irrigate cropland near the southeast reclamation plant. Frank Gray, a farmer, through a series of long-term contracts with the city, began spreading 1 to 1.5 mg/d on 200 ac.[5] By 1974, he had applied 14 to 15 mg/d to 5,000 ac (figure 7-1). Occasionally, Gray supplies water to an additional 200 ac adjacent to his farm.[6] During many times of the year, effluent ponds are formed in lower areas of the farm, where grazing cattle drink from them. In addition, Mr. Gray's domestic water supply comes from wells in the groundwater table beneath the farm. No adverse effects are known to have occurred from such ranching and domestic use.

In addition to the profits derived by Mr. Gray from his farming operation, several benefits have accrued to the city of Lubbock: (1) Nearby crop irrigation is a convenient method of disposing of the effluent while avoiding releasing water into the adjacent Yellowhouse Canyon streambed; (2) Crops remove much of the nitrogen that cannot be totally removed by percolation through the soil; and (3) The constant percolation of water through the soil has created an "artificially" recharged watertable, which has been raised to within a few feet of the surface under the Gray farm.

It is estimated that annual withdrawals of as much as 6 mg/d could be sustained for twenty years from this watertable.[7] This groundwater is reduced in biochemical oxygen demand (BOD), organic carbon, phosphorus, ammonia, virus, and bacteria and is available for reclamation as either industrial or recreational water after having undergone the equivalent of tertiary treatment.

Gray's farm consistently produces high yields of cotton, wheat, and grain sorghum and requires no additional fertilization. Production comparisons of typical crops on the Gray farm are shown in table 7-1.[8] In a long-term contract between Gray and the city of Lubbock, this water can be reclaimed and purchased for 1.5 cents/1,000 gal.

In terms of the priority of use or recommended sequence of multiple reuse, a recent research report by the Water Resource Center at Texas Technological University (Texas Tech) has recommended that "in most cases, irrigation be employed as mandatory first use."[9]



*Figure 7-1.* Applications of Water Reuse in Lubbock County, Texas

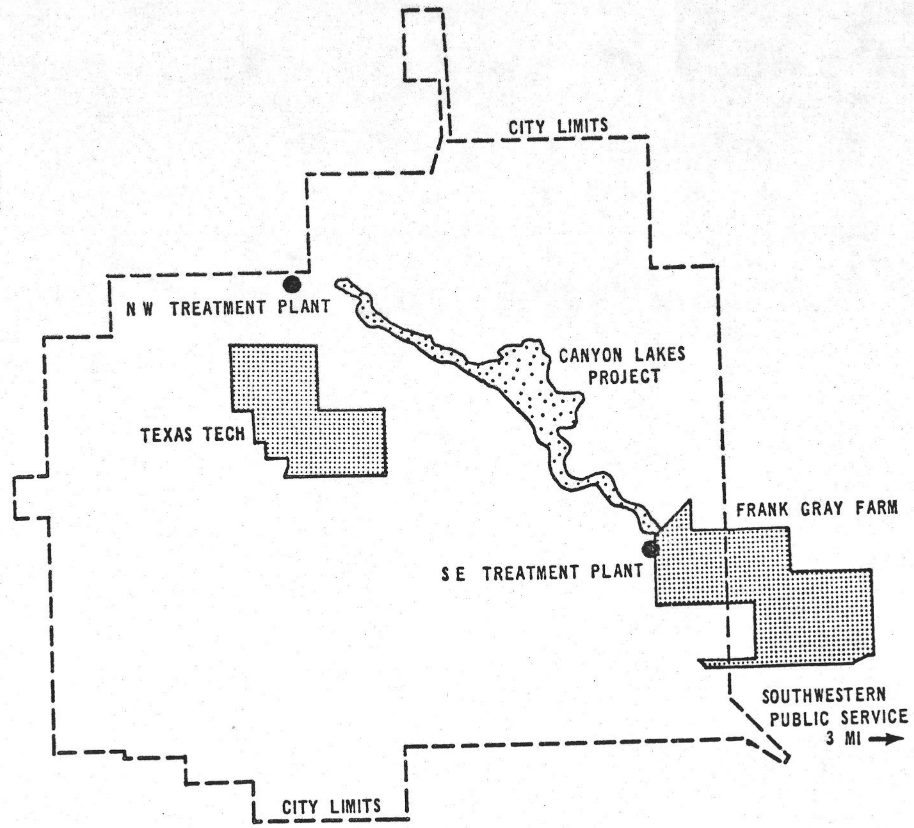


*Table 7-1.* Production Comparisons of Typical Crops

| | Dry Land | Irrigation with Water from Ogallala | Irrigation with Effluent Without Fertilizing |
|---|---|---|---|
| Grain sorghum* | 800–1,000 | 4,000–5,000 | 6,500 |
| Wheat+ | 10–12 | 30–40 | 80 |
| Lint cotton* | 150–225 | 600–800 | 1,250 |

*lb.
+bu.

### Texas Tech

In terms of historical sequence, Texas Tech was the second user and began receiving all of the effluent from Lubbock's northwest treatment plant in 1965. Currently, this water (1 mg/d) is used exclusively to irrigate farm-land on the Tech campus. Long-range planning is under way to consider recharge of the watertable under the Tech campus for future domestic reuse and also to water turf areas of the campus entirely with reclaimed water (figure 7-1).

**Southwestern Public Service Company**

In May 1968, the city of Lubbock contracted with Southwestern Public Service Company (an electric utility) to provide treated effluent to be used as cooling water at the generating plant, southeast of the city. Southwestern Public Service could initially take 3.5 mg/d with two options to increase to 7.7 mg/d in June 1977, and ultimately to 12.35 mg/d by June 1986.[10] The water is piped directly to the electric production plant after secondary treatment at the southeast treatment plant. The water is purchased from Mr. Gray at 1 cent/1,000 gal.

**Canyon Lakes Project**

The most distinctive topographic feature in Lubbock is the Yellowhouse Canyon, extending approximately eight miles from northwest to southeast Lubbock (figure 7-1). It ranges in depth from 40 feet at the northern end to approximately 75 feet at the southern end; and in width from a few hundred feet to approximately one-half mile.[11]

Historically the canyon had become an eyesore, being used for dumping building debris, junk yards, caliche mining, wrecking yards, and even a sanitary landfill for the city of Lubbock. In 1967, during the City Planning Department's update of the Lubbock Land Use Plan, it was recommended that the Yellowhouse Canyon be reclaimed as an open space greenbelt and used to store reclaimed water in a series of recreational lakes. The Santee, California, project was used as an example of recreational applications of reclaimed water. Through a series of reports and a color slide presentation, numerous civic clubs and interested citizens were exposed to the proposal. Widespread acceptance of the proposal resulted in the project becoming the primary recreational goal in "Lubbock's Goals for the Seventies." Numerous citizens and civic clubs requested that the city council pursue an investigation of the project.

In 1968, the engineering firm of Freese, Nichols, and Endress was commissioned to complete a feasibility study on the project. In November 1969, the feasibility report concluded that "there is enough water available to support the proposed lakes and that, with proper monitoring and control, they can be kept safe and attractive for public use."[12] Conclusions of the report, relating to the first six lakes, include the following: (1) make-up water should be obtained from wells beneath the Frank Gray farm; (2) lakes 1 through 6 would be suitable for secondary contact activities; (3) concentrations of plant nutrients in the lakes would be substantial, and while algae and aquatic weeds could be expected, they could be adequately controlled; (4) all surface drainage from cattle feed lots would have to be abated; (5) induced aeration of the water should be employed: and (6) a continual water quality monitoring program should be established. The estimated capital cost of the first six lakes was set at $6,063,100.



Following a massive tornado on May 11, 1970, that damaged over seven square miles in the central and northeastern sectors of the city, a tornado-recovery bond election was held. It included $2.8 million for the Canyon Lakes project, which was approved by an approximate margin of 2 to 1. Subsequently, in 1971, $3.4 million from the State Parks and Wildlife Department and the BOR and $832,828 from the Department of Housing and Urban Development were tentatively committed to the project. BOR funding was conditional upon the water meeting state water quality standards. This requirement initiated a second report on make-up water by the firm of Freese and Nichols.[13] After investigating three alternatives—well water from beneath the Gray farm, effluent from the activated sludge plant, and in-plant, tertiary treatment of effluent—the report concluded that groundwater from the Gray farm should be used. By cost comparison, it was estimated that annual operations costs for 5 mg/d would be $229,000 (12.55 cents/1,000 gal.) for groundwater, $425,900 (23.33 cents/1,000 gal.) for activated sludge effluent, and $854,400 (46.81 cents/1,000 gal.) for in-plant tertiary treatment. The report concluded that groundwater is superior to other alternatives and that it is relatively free of virus and bacteria. A subsequent report by the Water Resource Center at Texas Tech supported the conclusions about virus and bacteria control; however, it raised concern over urban storm runoff that would be "considerably poorer in quality than treated domestic sewage."[14] The Water Resource Center is currently under contract to the city as the project's "water quality monitoring agent." Water quality monitoring equipment is being constructed with the Canyon Lakes dams, and an active program is under way to clean up the urban watershed. In the initial phase of the project, four lakes of an eventual eight-lake system will be constructed. Rainfall will fill the lakes and approximately 4 mg/d of reclaimed water will be used to offset evaporation and percolation.

To date, all of the necessary land for the project (555.29 acres) has been purchased, and when combined with existing local and state parks along the canyon, creates a 1,350-acre continuous greenbelt through the city. In 1973, the City Parks Department acquired a bulldozer, front-end loader, maintainer, and three dump trucks with general revenue-sharing funds and initiated a concentrated cleanup of the canyon. Clark Equipment Company, a local manufacturing firm, has donated large earth scrapers to be tested in excavation of lake areas. The transformation in the canyon has been remarkable. Four dams have been built and approximately nineteen acres of park development have been completed. Future plans include over twelve miles of bicycle trails, picnicking areas, and various forms of water recreation. Initially all water sports in the four lakes will be limited to secondary contact; however, future monitoring and testing of the water may allow primary contact.

## FUTURE WATER REUSE APPLICATIONS

Future application are uncertain. In all probability they will consist of variations of existing agricultural, public use, industrial, or recreational applications. Because of Lubbock's limited sources of new domestic water, multiple reuse of water will continue to be a necessity, rather than a discretionary alternative.

The Lubbock experience seems to be a fulfillment of a forward-looking prediction in an early publication on water reuse of 1965: "Re-use of water through many cycles will be routine practice in fifty years."[15]

## NOTES


1. Freese, Nichols, and Endress, Consulting Engineers, *Feasibility Report on the Canyon Lakes Project* (Lubbock, Tex., 1969).
2. R. M. Sweazy and G. A. Whetstone, "Case History of Effluent Reuse at Lubbock, Texas" (Paper presented at Spray Irrigation Seminar, Harrison Hot Springs, British Columbia, April 1975).
3. Freese, Nichols, and Endress, Consulting Engineers, *Report on Makeup Water for the Upper Canyon Lakes* (Lubbock, Tex., 1971).
4. City of Lubbock Planning Department, "Methods of Storing and Using Renovated Waste Water for Lubbock, Texas," *An Expanding Lubbock... Reclaimed Water for a Growing City* (Lubbock, Tex.: April 1968).
5. Sweazy and Whetstone, "Lubbock, Texas."
6. R. M. Sweazy, "Multiple Reuse of Municipal Wastewater" (Paper presented to An Interna-tional Symposium—Frontiers of the Semi-Arid World, International Center for Arid and Semi-Arid Land Studies, October 1974).
7. Freese, Nichols, and Endress, Consulting Engineers *Canyon Lakes Project.*
8. Sweazy and Whetstone, "Lubbock, Texas."
9. Sweazy, "Multiple Reuse of Municipal Wastewater."
10. Freese, Nichols, and Endress, Consulting Engineers, *Canyon Lakes Project.*
11. Marcia Headstream et al., "The Canyon Lakes Project," *Journal of the American Water Works Association* 67, no. 3 (March 1975): 125–27.
12. Freese, Nichols, and Endress, Consulting Engineers, *Canyon Lakes Project.*
13. Freese and Nichols, Consulting Engineers, *Recommended Plan of Action for Development of Additional Surface Water Supply for Lubbock, Texas* (Fort Worth, Tex., 1975).
14. G. B. Thompson, et al., *Variation of Urban Runoff Quality and Quantity with Duration and Intensity of Storms—Phase III*, Office of Water Resources Research, Department of the Interior, Washington, D.C., August 1974.
15. G. A. Whetstone, *Re-use of Effluent in the Future with an Annotated Bibliography*, Texas Water Development Board Report 8, Austin, Tex., 1965.


CHAPTER 8

# The Experience/Evaluation of Water Reuse in Orange County, California

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Orange County, California, is a growing metropolitan area of about 1.7 million persons, situated in the near-desert area along the Southern California coastline. Twenty-five years ago the county was devoted to citrus and row-crop farming; however, since the end of World War II there has been a steady displacement of agriculture by urban development. This transformation has taken place at a rapid rate, with population increases averaging 8 percent per year.

The county receives about thirteen inches of rainfall annually. Natural flows of the Santa Ana River and its tributary creeks combine with local precipitation to provide about 25 percent of current water demand.

Orange County's greatest natural resource, the underground water supply, was used by early settlers to supplement surface flows of the Santa Ana River. As the area gradually became an important agricultural center, the increased demand upon subsurface water by the county's many wells resulted in gradual lowering of the watertable. To supplement local supplies, in 1928 the cities of Santa Ana, Anaheim, and Fullerton joined ten other communities from neighboring counties to form the MWD to import Colorado River water. The Colorado River aqueduct, built by MWD in the 1930s, is 242 miles long and sized to provide over a million acre-feet annually to the arid coastal region of Southern California. In the late 1940s it was apparent to water planners in Southern California that additional water supplies would be required, resulting in a cooperative program with the State of California Department of Water Resources to develop the most ambitious water system devised in the West to transport high-quality surplus Northern California water to the south, a distance of over 450 miles. The system, sized to supply over 2 million acre-feet, was completed in the early 1970s, and initial water deliveries from Northern California arrived in Orange County in 1973.

As the economic boom of the late 1940s got under way, it became necessary to use groundwater reserves to meet the rapidly growing water requirements in quantities that exceeded the natural recharge. The over-

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