WATER REUSE IN SELECTED STATES

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ABSTRACT

This paper is a summary of nonpotable water reuse practices of several arid states in the west and southwest United States and also in Florida, Georgia and North Carolina. The states that are examined provide examples of various regulatory requirements for treatment of reclaimed water, for uses of reclaimed water, and for incentives to encourage water reuse.

Water reuse is practiced for a variety of reasons, including the need for additional water sources as well as the high treatment costs faced by wastewater dischargers. Many examples of nonpotable reuse are generally acceptable to the public.

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SUMMARY AND CONCLUSIONS

This review of several states' water reuse practices shows that nonpotable reuse is widely practiced and accepted. A city faced with finding an affordable way to meet its water demand may find that turning to nonpotable reuse is economical when compared to building another reservoir. Health concerns have been addressed through regulations, and reuse has been encouraged through various incentives.

INTRODUCTION

Water is reused in a variety of ways--sometimes planned, sometimes unplanned, sometimes to augment the supply, sometimes to dispose of wastewater. In days gone by, reuse may have occurred predominantly through indirect pathways limited to a few locations, but in recent years the practice has become more common, especially in arid states in the west and southwest. As the practice has grown, so have public concerns about its health and environmental implications. Of particular concern has been the use of effluent from wastewater treatment plants for agricultural purposes and other uses that have even more direct implications for human health.

Many water-rich states, however, do not view effluent as a resource. Instead, reusing water sometimes happens as an added benefit of attempting to avoid high wastewater treatment costs for effluent that would be discharged into surface waters. Rather than treating wastewater to remove nutrients that would add to eutrophication in surface waters, effluent may be used for urban or agricultural irrigation where the nutrients act as a fertilizer. Land application systems reuse water while simultaneously treating it, though in this case the reuse is a by-product of a treatment process.

Water reuse is not a new idea. Not only have European countries reused water for centuries through sewage farms documented in the mid-1800's, unplanned reuse has occurred any time the treated water discharged from a town upstream becomes part of the water supply for a town downstream (Blanton, 1989).

Planned water reuse happens in a variety of ways, some of which are more acceptable to the public than others:

-- Nonpotable reuse occurs when effluent is used for agricultural irrigation or industrial purposes. A dual distribution system ensures its separation from a potable water supply. Uses range from irrigation of feed crops, orchards, ornamentals and recreational areas to industrial cooling water.

-- Indirect potable reuse provides another option for some areas. Treated effluent is either discharged to streams that are used for public water supply or used for aquifer recharge through infiltration or direct injection.

-- An experiment with direct potable reuse had been underway in Denver, Colorado. But the general public does not seem receptive to drinking reclaimed wastewater, and there is still disagreement throughout the scientific community regarding its safety and necessity (Goff and Busch, 1985).

This paper focuses on planned reuse of municipal wastewater for nonpotable purposes, including discussions of potential benefits and problems from reuse. Reuse practices and regulations in arid states in the west and southwest United States and in Florida, North Carolina and Georgia are discussed.

REASONS FOR WASTEWATER REUSE

Wastewater has proven to be a viable additional water source for several reasons. Water-short areas need to develop new sources of water to meet needs of growing populations. For some arid areas, turning to water reuse has proven more economical than developing another water source. In Texas, for example, agriculture accounts for 54 percent of the state's surface water use (Keith and King, 1989). Using treated effluent for agricultural irrigation leaves more potable water available for other uses.

Another economic aspect of water reuse comes from the strict federal and state standards that dischargers must now meet, regulations that apply to water-scarce and water-surplus areas alike. Wastewater must be treated to such high levels, it is a true "waste" to dump it into a river where it will mix with untreated water that may be contaminated with urban runoff or fertilizers and pesticides (Smith and Ritter, 1983). Furthermore, treatment for non-potable reuse is less costly than for discharge when nutrient removal is required (Daniel A. Okun, Kenan Professor of Environmental Engineering, Emeritus, University of North Carolina at Chapel Hill and consultant for Camp, Dresser and McKee, Inc., personal communication September 1990). Nutrients in the wastewater encourage crop growth, saving money in treatment and fertilizer costs. Water reuse saves high quality water for high quality uses (Smith and Ritter, 1983).

Additionally, the 1972 Federal Water Pollution Control Act set "zero discharge" of pollutants as a national goal, which further strengthens the incentive for using a land application system (Massey, 1983). Land application policy does not view wastewater as a resource per se but recognizes its beneficial qualities as an additional water source and, in some cases, its high nutrient content, which can reduce the need for fertilizers.

These incentives have spurred several arid areas to turn to reuse. Though North Carolina may feel no urgent need to pursue reuse due to the state's abundant water supply, it would be wise to consider some widely accepted aspects of reuse in long-term planning for water supplies. For instance, reuse for agricultural purposes is a possibility. North Carolina reported 5.7 million acres of cropland in 1987, and it irrigated about 2 percent (137,858 acres) of that land (Census of Agriculture, 1987).

The U.S. Geological Survey reported that in 1985 North Carolina used spray irrigation on 222,000 acres of land, with 123 MGD from surface water and 9.8 MGD from groundwater. No irrigation by reclaimed sewage was reported, and consumptive use of freshwater totalled 126 MGD (Solley, 1988).

REUSE IN CALIFORNIA

One state in the arid west where reuse has become popular is California. That state has been in the reuse business since 1896, when state officials regulated the use of wastewater for irrigation of specific crops. Golden Gate Park lands were irrigated with untreated sewage in 1889, and a reclamation plant was built in 1932. In 1929, the City of Ponoma began irrigating landscapes with treated wastewater from its municipal treatment plant (Blanton, 1989).

The Department of Water Resources estimates that now 350,000 acre-feet per year (114,000 MG) of municipal wastewater (5 percent of urban deliveries) are being reclaimed annually, and that could increase to 625,000 acre-feet (204,000 MG) by 2010. The expected increase would be largely due to major metropolitan areas in southern California (Blanton, 1989).

Most water reused in the state irrigates golf courses, highway medians and parks. The state also is investigating its potential for groundwater recharge, industrial cooling, and possibly, industrial processing. Reclaimed wastewater is an important component of meeting the rising demand of California (Charles W. Pike, Program Manager for Industrial Water Conservation of California Department of Water Resources, phone interview June 1990).

The California Association of Reclamation Entities of Water (CAREW) completed a survey in 1989 that showed 117 reclamation projects with a yield of 686,000 acre-feet a year (224,000 MG) were either under construction, designed, planned or in a conceptual phase. The survey was given to all wastewater treatment plant operators to learn what they were doing in reclamation and what they would like to do. The respondents were not limited to municipals disposing of wastewater. In some cases, the projects were designed to reclaim a groundwater supply that was not currently useable, if, for example, its nitrate levels were too high (Pike, personal communication 1990).

Among other findings were the following:

-- Seven reclamation projects were under construction that would provide 23,000 acre-feet a year (7,500 MG) at a capital cost of $55 million ($2,400/AFY or $2.68/GPD).

-- Twenty projects that would provide 89,700 acre-feet annually (29,200 MG) were in the design phase at a capital cost of $181 million ($2,000/AFY or $2.23/GPD).

These first two categories are likely to be completed within the next 10 years. In addition, the survey found the following:

-- 48 projects in the planning stage with an estimated yield of 363,100 acre-feet a year (118,300 MG) at a capital cost of $982 million.

-- 42 projects in the conceptual phase with an estimated yield of 209,000 acre-feet (68,100 MG) at a total capital cost of $748 million.

California law specifies treatment requirements according to the type of reuse: the greater the possibility of human contact, the stricter are the standards (Blanton, 1989). For example, effluent from secondary treatment is adequate for surface irrigation of food crops. Effluent must be treated to tertiary levels with oxidation and disinfection if it is to be used for irrigation of parks and playgrounds. (See Appendix, Table 1A.) Regulations have recently been drafted for groundwater recharge (Pike, personal communication 1990).

California's criteria for reclamation for urban nonpotable reuse specifies a treatment strategy. High quality secondary effluent must be subjected to a train of processes that includes coagulation, filtration, and chlorination. More specific requirements are listed in Table 1.

Table 1: California Criteria for Reclamation for Urban Nonpotable Reuse.*

Coagulant (e.g. alum, polymer)	Required unless effluent turbidity <5 NTU
Rapid mix	High-energy
Filter media	Anthracite -- sand
Media, effective size	Anthracite 1.0-1.2 mm Sand 0.55-0.6 mm
Filter bed depth	0.92 m (3 ft.)
Filter loading rate	12 m/hr (5 gpm/sf)
Chlorine residual	Minimum of 5 mg/L after 2 hrs
Chlorine contact time	2 hrs.
Chlorine chamber	40:1 length to width or depth
Coliform bacteria, MPN	
7-day median	2.2/100 ml
maximum	23/100 ml
Filter effluent turbidity	
24-hr average	2 NTU

*Adapted from "Policy Statement for Wastewater Reclamation Plants with Direct Filtration," California Department of Health Services, Berkeley (June 10, 1988).

Where reuse is for agriculture, criteria may be relaxed depending on the crop. Also, sand alone can be used of somewhat larger size but with greater bed depth. Coagulant choice and dosages and filtration rates are best determined by pilot studies.

Source: Okun, October 1990.

To encourage reuse, California offers a variety of incentives (see Table 2). Average costs for conventional treatment of reclaimed water by local districts within the Metropolitan Water District (MWD) of Southern California range from $300 to $400 per acre-foot ($0.92 to $1.23 per 1,000 gallons). The wholesale price for water meant for municipal or industrial use averages about $230 ($0.71 per 1,000 gallons). Reclaimed water is often sold for 20 to 25 percent less than potable water to encourage reuse. Treatment with nonconventional technology for groundwater recharge costs $65 to $120 an acre-foot ($0.20 to $0.36 per 1,000 gallons) (Blanton, 1989).

Subsidizing reclaimed water users may be relatively cost effective when other water supply options, such as finding a new reservoir site, are considered. If a new water supply is feasible and lower in cost, there is no need to subsidize. (Okun, personal communication 1990) However, when it is not possible to find a new reservoir site at a reasonable cost, subsidizing reclaimed water uses is the most feasible alternative.

The Local Projects program of MWD has a goal of developing "any facility or process within MWD's service area which produces new water that replaces an imported supply." MWD gives credit to projects for the "avoided energy cost" of pumping the equivalent amount of potable water from the State Water Project (SWP) water supplies. The practice relies on energy cost savings rather than grants to encourage reuse (Blanton, 1989).

Table 2: California Water Reuse Incentives

*** Sell reclaimed water at prices less than potable water.**

*** Credit facilities using reclaimed water with "avoided energy costs" of pumping potable water.**

*** Provide low interest loans for reclamation.**

*** Provide 50/50 cost sharing for reclamation studies.**

*** Provide local workshops on reclamation.**

*** Lobbying is underway for $200 million in funding for reclamation facility construction.**

Source: Layperson's Guide to Water Reclamation (1989)

Several other incentives have been approved in recent years to increase reuse. Since 1984, three separate bond issues have been approved authorizing low interest loans for reclamation. A financial assistance program of the San Diego Water Authority provides 50:50 cost sharing--up to $50,000 per study--for planning and preliminary engineering of water reuse projects. California's Department of Water Resources and the California Association of Reclamation Entities of Water have agreed to develop a program of local workshops on reclamation (Blanton, 1989). In addition, there is active lobbying for $200 million in funding for reclamation facility construction to be administered by the State Water Resources Control Board. Applicants must have about 50 percent of the water pre-sold before construction (Pike, personal communication 1990).

Future opportunities for reuse in California include continuing existing use of dual distribution systems that provide reclaimed water for landscape irrigation for homeowners associations, developers and institutions (such as cities and schools); dual water systems in high-rise buildings; increased industrial reuse; reuse of agricultural wastewater by desalting or diluting; and additional desalting and stream enhancement (Blanton, 1989).

REUSE IN FLORIDA

Florida is a leader in water reuse, but it differs from dry states in the Southwest that have turned to effluent as an additional water supply. Initiation of reuse in Florida was motivated by the need to dispose of nutrient-rich effluents from wastewater treatment plants. By 1985, there were more than 100 reuse projects, including St. Petersburg's dual distribution system and Tallahassee's spray irrigation system (York and Crook, 1989).

With the burgeoning population growth in Florida, water reuse is now viewed also as a means of reducing demands on water. The population is growing by 6,000 people each week, and officials expect about 82 percent of the growth to occur in coastal counties. Shallow aquifers, the primary water supply sources in coastal areas, are susceptible to overdraft and saltwater intrusion (York and Crook, 1989).

St. Petersburg's limited dual distribution system has reduced potable water demands considerably and was responsible for a potable water savings of 14,700 acre-feet (4,790 MG) in 1983. The distribution network is 92 miles long and its peak capacity is 68.4 MGD. Residential user fees are $6 per month and industrial user fees are $6 per month for the first acre-foot and $1.20 for each .5 acre-foot increment or $0.25/1,000 gallons. Nonpotable water in the dual system irrigates public and private properties, including golf courses, parks, school grounds, street medians and commercial and residential sites (Miller, 1990).

In June 1990, a study team from the University of South Florida, under contract with the Department of Environmental Regulation, completed an inventory of reuse activity in the state. The inventory found about 322 MGD of reclaimed water is used in Florida, with about 31 percent irrigating public access areas and 28 percent irrigating agricultural lands. The total capacity of the reuse facilities is about 586 MGD (Florida Department of Environmental Regulation (FDER), 1990). Other types of reuse consisted of commercial and industrial reuse, groundwater recharge, environmental enhancement and other uses that were not specified. Most of the public access systems were used on golf courses. The largest portion of acreage (14,650 acres) irrigated with reclaimed water was in agricultural crops other than citrus crops. However, 8,700 acres of citrus crops were irrigated by reclaimed water (FDER, 1990).

There were 211 full-treatment facilities, one partial-treatment facility providing high-level disinfection only, and two reclaimed water distribution networks reported. Most of the facilities (119) used secondary treatment with filtration. All facilities used chlorine as the primary disinfectant, and 117 reported high-level disinfection (FDER, 1990).

Legislation in Florida establishes reuse of reclaimed water and water conservation as a formal state objective (FDER, 1990). In 1987, FDER began a rulemaking program that would encourage reuse of reclaimed water. Three existing rules were changed.

An October 1988 amendment to Rule 17-40, Florida Administrative Code (F.A.C.), outlining the state's policy for the use and regulation of water created a program for mandatory reuse of reclaimed water. Through the consumptive use permitting process, the five water management districts have primary responsibility for the implementation of the program. By November 1991, reuse will be required in critical water supply areas that exist now and that are projected by the water management districts to develop over the next 20 years. Water management districts can also require reuse outside water critical areas if reclaimed water is readily available to the applicant for a consumptive use permit (York and Crook, 1989).

Amendments to the Wastewater Facilities Rule (Rule 17-6, F.A.C.) changed high level disinfection requirements for treatment to reflect existing technology, including details on fecal coliform counts, suspended solids and turbidity. In addition, guidelines for wet weather discharge were added with required dilution ratios based on the quality of reclaimed water and the anticipated frequency of discharge (York and Crook, 1989). More details are given in Appendix Table 2A.

The original land application rule was expanded to include detailed requirements for design and operation of reuse projects irrigating public access areas as well as edible food crops (Rule 17-610, F.A.C.). The rule prohibited contact of reclaimed water on edible food crops that will not be skinned, cooked, peeled or thermally processed before human consumption. FDER has set a goal for 1992 of increasing reuse by 40 percent above 1987 levels.

REUSE IN COLORADO

Information about reuse in Colorado was provided by Ron Schuyler, Chief of the Field Support Section for the Colorado Department of Health, Water Quality Control Division, in a phone interview in June 1990. In Colorado, which has about 17 inches of rain a year, there is a saying that every drop of water that leaves the state (other than by evapotranspiration) has been used seven times. Water availability--or lack of it--contributes to reuse. With low rainfalls, water reuse becomes an attractive, economical option.

By Colorado water rights, water may be used one time; then it must be given to the person downstream or to whoever has the next rights to the water. Spray irrigation is allowed only if the drainage will occur in the same watershed from which the water is withdrawn. But there is an exception to that right: if the water from the western slope is brought to the eastern slope, it can be reused. The cities of Aurora, Northglenn and Westminster benefit from this provision.

Colorado uses most reclaimed water for agricultural irrigation, but the state prohibits the use of wastewater on edible crops. The other main use is for landscape irrigation along roadways, in parks or on golf courses.

Colorado reuse treatment standards are generally patterned after California standards. If there is a chance of public contact, wastewater must be treated to tertiary levels. There are no limits on biochemical oxygen demand (BOD) and total suspended solids (TSS); instead, the total coliform count (TCC) must be quite low, less than 2.3 per 100 ml. To meet this TCC level, BOD and fecal coliform levels must be extremely low. If the area where wastewater is applied is fenced, the limits are evaluated on an individual basis, and the state may allow a TCC as high as 23 per 100 ml. All permitting is on an individual basis.

There are not many state incentives to use reclaimed water, but the water shortage is a powerful impetus. One of the state's only other alternatives is to build more dams and reservoirs, but the Denver Water Board recently had its most likely site for a reservoir rejected, an action that does not bode well for the reservoir-building option. As a result, nonpotable reuse is more likely to be adopted.

REUSE IN ARIZONA

If potable water is not available for nonpotable purposes--golf course irrigation, for example--a market for reclaimed water is bound to develop. That is the approach several Arizona cities have taken: banning the use of potable water for golf course irrigation and other non-potable uses as a means of encouraging reuse (Arizona Water Resources Research Center, 1990). Projections for reclaimed water use projects for all four of Arizona's active management areas (AMA's) suggest that by 2025, more than 500,000 acre-feet (163,000 MG) will be available for reuse annually (Gelt, 1988). The largest reuse project in the United States is the Palo Verde Nuclear Generating Station (Okun, personal communication 1990).

Arizona uses reclaimed water primarily for irrigation, with some filling of artificial lakes. The state encourages reuse through rules, regulations and incentives.

Arizona rules address both quality and quantity. To protect the quality of water supplies, Article 7 of the Water Pollution Control Article specifies that there must be a minimum of five days storage for reclaimed wastewater when the available treatment is surface irrigation. The storage capacity ensures that there is time for the soil to dry if it is saturated and provides a holding space for reclaimed water that does not meet surface irrigation standards.

Reclaimed water must be treated to secondary treatment levels, but as long as it meets the pollutant discharge standards, Arizona officials do not specify a treatment method. Reuse permits are now issued for each reuser, regardless of the source, but officials are attempting to develop procedures for issuing permits for irrigation districts where, for example, one treatment plant can serve a number of different farms. Arizona is rewriting its reuse rules, patterning the regulations after those in California and Florida. The reuse rules pertain to sites where the effluent is being applied. The new rules vary according to a number of categories with specific criteria applied to each category: orchards, fiber, seed and forage, pastures, livestock feed, processed food, landscaping food consumed raw, incidental contact, and full body human contact (Michael Kruse, Reuse Coordinator for the Arizona Department of Environmental Quality, phone interview June 1990). See Appendix, Table 3A.

The Aquifer Protection Permit Program also regulates the quality of effluent used to artificially recharge groundwater. Reuse rules the Arizona Department of Environmental Quality is developing will include new categories for use of reclaimed effluent, such as for potable supplies. The Department will decide on what it will base reclaimed effluent standards: treatment processes, product quality or some combination of both (Arizona Water Resources Research Center, 1990).

Arizona also encourages reuse through its 1980 Groundwater Management Act (GMA), which contains a variety of mandates and incentives. The Act's Second Management Plan (SMP) 1990-2000, under which the state's population center's now operate (Kruse, personal communication 1990), provides the following:

For municipalities, the reclaimed water supplied to their customers is not counted as part of their gallons per day per capita (GPCD) rate. SMP requires that the water providers meet conservation goals either based solely on the GPCD rate or the GPCD rate in conjunction with Arizona Department Water Resources (ADWR)-prescribed programs. Reclaimed water is not used to compute the GPCD rate, so it is in effect a bonus.

Some people have expressed concern that this incentive will actually increase water use. Conservation should replace water pumped from the ground, but this incentive could increase commercial and residential indoor water use that was previously used on turf, a practice that could increase water demand.

To boost turf-related reuse, the SMP increases water allocations for turf-related facilities that use substantial amounts of reclaimed water.

The SMP also requires facilities that come on line after 1990 to use 75 percent reclaimed water by 1995. The SMP commits ADWR to providing technical and administrative assistance to aid in developing recharge projects that use reclaimed water.

Through the SMP's augmentation grant program, ADWR agrees to provide funds for certain reclaimed water projects, such as the recharge of reclaimed water.

As another incentive for reuse, in April 1989 the Arizona Supreme Court ruled that existing laws regulating groundwater and surface water use do not apply to effluent. The ruling--removing effluent from those laws' quantity restrictions--gave holders of effluent rights a potential wealth of water (Arizona Water Resources Research Center, 1990). A further incentive for reuse in Arizona is the 1987 Lakes Bill, which mandates that reclaimed water, rather than potable supplies, fill artificial lakes.

Phoenix, Tucson and Mesa plan for reuse to increase dramatically, and they are encouraging the practice in several ways, as Gelt, 1988, shows:

Phoenix: Phoenix anticipates that its effluent supply available for reuse will increase from 78,000 acre-feet (25,400 MG) in 1985 to 246,000 acre-feet (80,200 MG) in 2000 and 398,000 acre-feet (129,700 MG) in 2025.

The city has made individual agreements with developers to reward use of reclaimed water. In addition, the city sells reclaimed water to the Palo Verde Nuclear Generating Station, and it exchanges reclaimed water for potable water with agricultural users. Plans call for regional treatment plants that would deliver reclaimed water through separate distribution systems.

The Phoenix Active Management Area Second Management Plan establishes a goal of increasing direct use of effluent, especially on agricultural and turf applications. It also encourages increasing controlled recharge for effluent that cannot be used directly. Recharge addresses one of the problems of direct reuse: that people demand more water in the summer but generate about the same amount of wastewater year-round.

Recharge allows effluent to be stored during lower demand periods and also allows for indirect potable reuse. Advanced wastewater systems produce effluent close to drinking water standards, and percolation to an aquifer additionally cleanses and filters the water. When it reaches the groundwater, it blends and dilutes.

Tucson: The Tucson AMA anticipates that its supply of effluent available for reuse will increase from 7,000 acre-feet (2,300 MG) in 1985 to 62,000 acre-feet (20,200 MG) in 2000 and 105,000 acre-feet (34,200 MG) in 2025.

The city uses both incentives and mandates to increase reuse. Reclaimed water prices are set at about 80 percent of the cost of potable water. The city requires new areas with turf to irrigate with reclaimed water and supports conversion of current areas to use of reclaimed water supplies for irrigation. The city plans to use reclaimed water on all public turf areas.

To further encourage conservation and reuse, Tucson established a demonstration home. Since September 1985, Tucson's **Casa Del Agua** ("House of Water") has displayed water conservation ideas, including water reuse. A University of Arizona brochure reports that the three bedroom, two-bath private house has been used to monitor water savings from using efficient water fixtures and reusing water.

The house has a graywater recycling system that provides water for outdoor irrigation and some toilet flushing. Graywater in this case is defined as wastewater from a household, excluding wastewater from the kitchen sink and toilets, but including water from washing machines, lavatories, bathroom sinks, one side of the kitchen sink and the shower. It flows by gravity through the various treatment systems back to the storage tank, where it is pumped back for irrigation or toilet flushing. The tanks can store as much as 7,000 gallons of graywater, reducing the house's peak summer demand for municipal water.

Mesa: A 1986 ordinance in Mesa requires use of reclaimed water in all artificial lakes and new turf areas over 10 acres. It allows the city to negotiate with individual water users and convince them to convert to reclaimed water. Plans call for a total reclamation system, with four plants looping the city and a distribution system that will meet all major turf areas in Mesa. The city's three-phase reclaimed water use plan calls for

1. using reclaimed water to substitute for potable water in nonpotable uses

2. recharging reclaimed water for future withdrawal as potable water

3. pumping reclaimed water directly into the city system with intermediate recharge (Gelt, 1988).

REUSE IN TEXAS

Many areas of Texas are water-short due to climate and growth, and reusing wastewater is often more economical than developing new water supplies. Texas generates about 1.5 billion gallons of wastewater each day and up to 70 million gallons, or a little less than 5 percent, is reused (Jensen, 1989).

The Texas Water Commission has issued more than 800 "no discharge" permits, including systems for municipalities, industries, livestock and state agencies (Keith and King, 1989).

In May 1990, Texas adopted the "Use of Reclaimed Water Rule" Chapter 310, which allows the use of reclaimed water under specified circumstances, rather than on an individual permitting basis as before (Ann McGinley, Chief of Wastewater Permits for the Texas Water Commission, Phone interview June 1990). The categories for reuse each have their own standards. The categories are unrestricted and restricted uses, food chain crops, other crops, pastures used for milking, industrial reuse, toilet flushing/graywater, fountains and ornamental parks, and restricted recreation uses (See Appendix, Table 4A).

About 12 percent (or 220) of the 1,800 municipal and industrial wastewater treatment permit holders have wastewater reuse programs. West Texas cities irrigate grasses, small grains, sorghum, cotton and golf courses with wastewater, which lowers costs for wastewater treatment and provides plants with water and nutrients. Irrigation of restricted access areas, such as golf courses and cemeteries, also occurs in west and central Texas (Jensen, 1989).

Several cities have begun advanced uses of reclaimed water.

In Irving, the Las Colinas development uses about 7 mgd of effluent combined with stormwater and water from the Trinity River to irrigate four golf courses, highway medians and open spaces and for 158 aesthetic man-made lakes.

In San Antonio, the Alamo Conservation and Reuse District is proposing that streams be used as the distribution system for wastewater from treatment plants to golf courses and other landscaped users. The District plans to convert the resulting unused "surplus" waters to drinking water. Its goal is to make 83,000 acre-feet (27,000 MG) of effluent available by the year 2000.

A Texas Water Commission ban on new wastewater discharges into lakes has spurred the Lower Colorado River Authority to study dual distribution systems. The systems appear to be a feasible alternative for developers who are forced under the new regulations to either dedicate a portion of their land to disposal of effluents or to develop low density subdivisions (Jensen, 1989).

REUSE IN GEORGIA

Although like North Carolina in having a fairly abundant water supply, Georgia has adopted water reuse guidelines based on research and case studies in California, Florida and other states with a history of water reuse projects. In June 1990, Georgia had five land application systems that spray treated wastewater onto golf courses, and six more had been proposed (Georgia DNR, N.D.).

In the guidelines for systems using reclaimed water for irrigation of golf courses or landscaped areas, the state distinguishes between areas classified as having either non-restricted or restricted access, where access is restricted to certain times. Restricted areas--a fenced golf course, for example--also have adequate buffer zones adjacent to property lines and buildings. Non-restricted access includes areas where access cannot be controlled and adequate buffer zones cannot be maintained, such as in a residential golf course community (See Appendix, Table 5A).

Standards are much stricter for areas with non-restricted access than for those with restricted access. In restricted areas, secondary treatment is acceptable. But areas with non-restricted access must use advanced treatment with disinfection, including oxidation, clarification, coagulation, flocculation and filtration (See Appendix, Table 5A).

Storage requirements must be based on actual irrigation needs. Golf course water hazards can be used as storage areas, but they cannot have any outlet other than the irrigation system. Georgia has explicit reliability requirements of backup equipment. It also requires that there be adequate notification of the public that reclaimed water is being used (Georgia DNR, N.D.).

REUSE IN NORTH CAROLINA

North Carolina is in the water-rich section of the southeast, but, as described above, reasons other than water shortage justify examining the potential for water reclamation in the state. With about 50 inches of rainfall in an average year, North Carolina has seen little need to develop effluent as an additional water supply, and using effluent for irrigation is still viewed as a treatment method rather than water supply augmentation.

North Carolina has permitted 328 spray irrigation systems. Twenty are small municipal systems; about 200 are single family homes and about 42 are convenience stores or small industries. Some of the other systems are used by mobile home parks and subdivisions. The state has permitted about seven golf courses, which tend to treat wastewater from subdivisions. Most of the other systems irrigate agriculture. Spray irrigation is a very expensive way of discharging waste in North Carolina. North Carolina requires large buffers, and as a result, single family homes must have a minimum of six acres in order to discharge 360 gallons per day (Carolyn D. McCaskill, Environmental Supervisor, N.C. Division of Environmental Management, Water Quality Section-Permits and Engineering, personal communication June 1990).

Some facilities spray wastewater on forests, utilizing effluent that may be rich in nutrients. Many poultry facilities use spray irrigation of their wastewater (Donald L. Safrit, Supervisor of the Permits and Engineering Unit of N.C. Division of Environmental Management, Water Quality Section, personal interview June 1990). In addition, some industries also apply their wastewater to land.

Applicants for discharging permits must consider alternative non-discharging systems before they can be considered for a NPDES permit (Safrit, personal communication 1990). The Permits and

Engineering Unit has developed an economic and engineering analysis for people to use as they consider alternative systems. Potential dischargers must look at adjacent lands and determine if they can purchase available land before applying for a permit to discharge.

The state requires secondary treatment for effluent that is to be used for irrigation. Like other states, North Carolina has restrictions on when, where and what can be sprayed with effluent. North Carolina would not approve any potential spraying on food crops for direct human consumption (Safrit, personal communication 1990). In addition, lactating cattle cannot graze on land irrigated with wastewater, and there must be an 18-month rotation between spraying and grazing. Most permits do not indicate treatment levels specific to agricultural uses because land application is not seen as reuse but as waste disposal. Water released from a spray irrigation facility may need as much treatment as that from a discharge facility (McCaskill, personal communication 1990).

Spray irrigation on land with public access is a relatively new phenomenon in North Carolina, only approved as recently as 1988. When the irrigation is planned for public access land, such as a golf course, the state requires tertiary treatment and allows no fecal coliforms. Golf course systems spray at night and often follow wastewater application with an application of potable water (Safrit, personal communication 1990).

In February, the N.C. Environmental Management Commission is expected to consider amendments to the regulations that affect land application of domestic wastewater on golf courses and other public access areas. The changes include requiring that over a 30-day average, 75 percent of the fecal coliform samples must fall below the detection limits and any one sample shall not exceed 25 per 100/ml of the sample prior to discharge to a 5-day detention pond. The changes also propose reducing the vegetative buffer zone between the edge of the spray influence and the nearest dwelling from 100 to 50 feet (Proposed changes to 15A NCAC 2H .0219 (k)).

North Carolina has no cumulative data available about total acreage of spraying.

Reuse in Raleigh: Raleigh is the first municipality in North Carolina to view wastewater as a resource. In 1984, Raleigh received its permit to discharge up to 5 MGD of tertiary treated effluent onto 168 acres of agricultural lands intended for livestock consumption, including corn, fescue, rye and sorghum (Dale Crisp, Assistant Director of Raleigh Public Utilities, phone interview June 1990).

The volume of effluent Raleigh uses for irrigation depends on the rainfall and is a function of the weather (Crisp, personal communication 1990). Raleigh estimated they used about 1 MGD of reclaimed wastewater during the droughts (Billy Ray Creech, Raleigh Plant Superintendent, phone interview June 1990). The treatment includes a waste-activated biological filter and filtering through sand and anthracite coal.

Most of the land Raleigh irrigates lies within a quarter of a mile of the administration building and is the same land on which Raleigh applies its sludge. The city has two wastewater holding basins of about 50,000 gallons each (Creech personal communication 1990).

In addition to its capability for using effluent for irrigation, the distribution system within Raleigh's waste treatment plant is designed to use non-potable water to backwash filters and to dissolve chemicals that are used in treatment processes. Buildings also use reclaimed water for hydrants, air conditioner chillers and outside spigots (Creech, personal communication 1990).

CONCERNS ABOUT REUSING WASTEWATER

Although nonpotable wastewater reuse clearly provides many benefits, particularly to water-short areas, it also causes concerns over potential soil and water contamination, odor problems, health effects and water supply (Keith and King, 1989). Nonpotable water reuse is widely accepted and is considered by many to be economical, since it reduces treatment costs. In addition, it is generally accepted that for nonpotable uses, adequate technology exists for treatment, and public health concerns can be addressed. Reclaimed water provides a ready supply of water at generally lower costs and is acceptable where it is practiced carefully (Crook and Okun, 1987).

Concerns remain over effects of water reuse for drinking and the fact that since each city's wastewater contains different pollutants, studies on direct potable reuse cannot be generalized and must be conducted for effluent from each city that would potentially become a potable source (Crook and Okun, 1987).

Groundwater could become contaminated by deep seepage if wastewater were applied repeatedly without proper design and regard for the ecology of the site. The metal content of wastewater could be a problem in systems where industry flows are large (Keith and King, 1989).

Potential disease from exposure to pathogens in wastewater is another concern (Keith and King, 1989). Although wastewater treatment systems do not aim to remove all pathogens, reclamation for unrestricted nonpotable use is designed to remove all pathogens (Okun, personal communication 1990).

Direct contact presents the highest risk of infection. Most all wastewater reuse studies showed no disease outbreaks in surrounding populations unless raw crops were eaten or cattle grazed shortly after raw waste was applied. Land-based systems have the advantage of having air, sun and heat that kill pathogens (Keith and King, 1989), but this approach to pathogen removal is less certain than treatment and chlorine disinfection (Okun, personal communication 1990).

With proper enforcement, regulatory policies can minimize health risks. For example, Texas has more than 800 land application sites. The Texas Department of Health prohibits use of effluent on crops for direct human consumption and limits application rates to prevent water pollution. California has more than 240 plants that supply reclaimed water for reuse and allows primary effluent sprayed on fodder, fiber and seed crops and surface irrigation of vineyards and orchards. Effluent for landscape irrigation must be treated to secondary levels, and crops that will be eaten or sold raw must have effluent treated to tertiary levels, as must irrigation of root crops and areas where children may play (Keith and King, 1989).

Some scientists express opposing views on the minimum levels of pollutants that must be removed to protect public health. While many cities are adopting strict standards as a precautionary measure to ensure protection of public health, some scientists say the standards are unnecessarily restrictive (Keith and King, 1989).

Another concern resulting from reuse is the potential for reduction of downstream flows. Diverting wastewater through land application potentially reduces downstream flows, posing a concern for those communities that depend on that quantity for their water supply. Stream flows below metropolitan areas are often effluent dominated (Keith and King, 1989).

Some scientists argue that potential reuse suffers from the lack of federal standards. The absence of standards is viewed by some as prohibiting reuse or allowing regulatory agencies to make ad hoc decisions on specific projects. Without clearly stated regulations, requirements could change over time into more rigid standards, raising the price tag on project estimates. Economic incentives for reuse are limited at the state and federal levels (Crook and Okun, 1987).

Although reuse is not cheap, it may be less expensive than other alternatives. The following should be considered to determine whether reuse is an economical alternative for any given area:

- -- additional treatment costs to meet quality criteria
- -- costs of distribution and storage facilities and monitoring
- -- costs to users of reclaimed water, including on-site hookup, monitoring facilities, treatment, repiping, worker safety measures, changes in procedures, such as restricted access

The economic benefits come largely from eliminating the need to fund costly treatment facilities and alternative water supplies. Other constraints to developing reuse include legal issues and institutional structures. In addition to questions of diversion arising from water rights, requirements for regulatory authority are specific to each state. Product liability is shifted to the manufacturer, supplier or seller of the product--in this case, reclaimed water (Miller, 1984).

PUBLIC PERCEPTIONS ON WATER REUSE

A study by Bruvold published in 1985 found that although people generally oppose direct potable reuse of effluent, there are nonpotable uses that can be and have been implemented without public opposition. Stated opposition to reuse dropped off when questions about potable use were stopped in the survey, and the reduction in opposition followed the pattern of the reduction in the extent of human contact.

The study suggested that many uses could be started without public opposition, such as residential lawn irrigation, toilet flushing, irrigation of freeway greenbelts and parks, and irrigation of golf courses and filling golf course hazard lakes, as well as lakes for boating and fishing. Commercial and industrial uses such as air conditioning and process water and agricultural irrigation of dairy pastures vineyards, orchards and hay and alfalfa crops were also generally acceptable.

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Table 1A: California Wastewater Treatment Requirements for Reuse (By Type of Use)

Type of Use	Requirements
Irrigation of Food Crops: Spray irrigation	-- adequately disinfected, oxidized, coagulated, clarified, filtered wastewater -- median number of coliform organisms < or = 2.2 per 100 milliliters (over 7 days' sampling) -- number of coliforms does not exceed 23 per 100 milliliters in more than one sample in 30-day period
Irrigation of Food Crops: Surface Irrigation	-- adequately disinfected, oxidized wastewater -- median number of coliforms < or = 2.2 per 100 milliliters (over 7 days' sampling) -- orchards and vineyards may be surface irrigated with reclaimed wastewater provided that no fruit is harvested that has come in contact with irrigating water or the ground

Note: Exceptions to quality requirements for reclaimed water used for irrigation of food crops may be considered by the State Department of Health on a case-by-case basis if the crop is to go through substantial physical and chemical processing that would destroy pathogenic agents before it is suitable for human consumption.

Type of Use	Requirements
Fodder, fiber and seed crops	-- minimum quality of primary effluent
Pasture for milking animals	-- adequately disinfected, oxidized wastewater -- median number of coliform organisms < or = 23 per 100 milliliters (over 7 days' sampling)
Landscape irrigation (i.e. golf courses, freeway landscapes, cemeteries)	-- adequately disinfected, oxidized wastewater -- median number of coliform organisms < 23 per 100 milliliters (over 7 days' sampling) -- number of coliform organisms does not exceed 240 per 100

	milliliters in any two consecutive samples
(i.e. parks, playgrounds, schoolyards)	-- adequately disinfected, oxidized, coagulated, clarified, filtered wastewater or equivalent level of treatment -- median number of coliform organisms < or = 2.2 per 100 milliliters (over 7 days' sampling) -- number of coliform organisms < or = 23 per 100 milliliters in any sample
<u>Recreational Impoundments</u>	
Nonrestricted	-- adequately disinfected, oxidized, coagulated, clarified, filtered wastewater -- median number of coliform organisms < or = 2.2 per 100 milliliters (over 7 days' sampling) -- number of coliform organisms does not exceed 23 per 100 milliliters in more than 1 sample in 30-day period
Restricted	-- adequately disinfected, oxidized wastewater -- median number of coliform organisms < or = 2.2 per 100 milliliters (over 7 days' sampling)
Landscape Impoundment	-- adequately disinfected, oxidized wastewater -- median number of coliform organisms < or = 23 per 100 milliliters (over 7 days' sampling)

Source: Excerpt from California Department of Health Services Wastewater Reclamation Criteria Containing Wastewater Treatment Requirements [4] (California State Water Resources Control Board Office of Water Recycling, 1990).

Table 2A: Disinfection Levels Defined by Florida Rules.

Disinfection Level	Fecal Coliform Limit*	Application
High-level	No detectable fecal coliforms** Maximum TSS 5 mg/l	Public access irrigation and irrigation of edible crops For discharge to Class I surface waters (potable water supplies).
Intermediate	14/100 mL maximum	For discharge to waters tributary to Class II surface waters (shellfish propagation or harvesting).
Basic	200/100 mL monthly arithmetic mean	For most land application systems For most discharges to surface waters
Low-level	2400/100 mL maximum	For overland flow systems and some underdrained irrigation systems

* Disinfection requirements were originally contained in Rule 17-6, F.A.C. These requirements now appear in Rule 17-600, F.A.C.

** The original rule requirements specified no detectable fecal coliforms at all times. The 1989 rule revisions specify that 75 percent of all fecal coliform observations must be below detectable limits and that no observation may exceed 25/100 mL.

Contents of Rule 17-610. F.A.C., and Preapplication Treatment Requirements.

Part	Title	Minimum Treatment Requirements	Minimum Disinfection Requirements
I	General	----	----
II	Reuse; Slow-Rate Land Application Systems; Restricted Public Access	Secondary	Basic
III	Reuse; Slow-Rate Land Application Systems; Public Access Areas, Residential Irrigation, and Edible Crops	Secondary + Filtration	High-level
IV	Reuse; Rapid-Rate Land Application Systems*	Secondary	Basic
V	Reuse; Absorption Field Systems**	Secondary	Basic
VI	Effluent Disposal; Overland Flow Systems	Lower Degree of Secondary***	Low-Level
VII	Other Land Application Systems		
	Additional Levels of Treatment	Secondary + Filtration	High-Level
	Lower Levels of Treatment****	Lower Degree of Secondary***	Low-Level

* Typically rapid infiltration basins featuring multiple cells and alternating wetting/drying cycles.

** Systems are similar to rapid-rate land application systems except that a soil/plant overburden is provided. Alternating wetting/drying cycles are required.

*** BOD and TSS limited to 40-60 mg/L.

**** Apply to underdrained irrigation systems having a continuous aquitard such that effluent percolating through the soil system above the aquitard is under operational control.

Requirements for Reuse in Public Access Areas, Residential Lawn Irrigation and Irrigation of Edible Crops

Parameter	Requirements[17]
Minimum treatment level	Secondary with filtration and chemical feed. Maximum TSS of 5 mg/L.
Disinfection	High-level.
Minimum system size	378.5m^3/d (0.1 mgd) for any public access irrigation system 1983 m^3/d (0.5 mgd) for residential lawn irrigation or edible crop irrigation.
Reliability	Class I.[18]
Staffing	24 hours/day-7 days/week. May be reduced to 6 hours/day-7 days/week if additional reliability measures are included.
Continuous monitoring	Required for turbidity and disinfectant residual.
Operating protocol	Required. A formal statement of how the treatment facility will be operated to ensure compliance with treatment and disinfection requirements.
Storage requirements	System storage (minimum 3 days, may be unlined), or back-up system required. Golf course lakes may be used for system storage.

Parameter	Requirements[17]
Reject storage	Minimum 1 day, lined. To hold unacceptable quality product water for return for additional treatment.
Limits on reuse	Only product water meeting the criteria of the operating protocol shall be released to the reuse system. Reclaimed water shall not be used to fill swimming pools, hot tubs or wading pools.
Cross-connection control	Prohibit cross-connections to potable water systems. Reclaimed water shall not enter a dwelling unit. Minimum standards for separation of reclaimed water lines from water lines and sewers. Color-coding or marking required. Back-flow prevention devices required on potable water sources entering property served by reclaimed water systems. Dual check valves are acceptable.
Buffer zones	22.9 m (75 feet) to shallow potable water supply wells. Otherwise, none.
Other O&M requirements	Approved operating protocol. Approved cross-connection control program. Documentation of controls on individual users (agreements or ordinance). Assess need for industrial pretreatment program.

Table 3A:

ALLOWABLE PERMIT LIMITS FOR SPECIFIC REUSES

	Orchards	Fiber Seed & Forage	Pastures	Livestock Watering	Processsed Food	Landscaped areas Restricted Access	Open Access	Food Consumed Raw	Incidental Human Contact	Full Body Contact
pH	4.5-9	4.5-9	4.5-9	6.5-9	4.5-9	4.5-9	4.5-9	4.5-9	6.5-9	6.5-9
Fecal coliforms (CFU/100 ml)										
geometric mean (5 sample minimum)	1,000	1,000	1,000	1,000	1,000	200	25	2.2	1,000	200
single sample not to exceed	4,000	4,000	4,000	4,000	2,500	1,000	75	25	4,000	800
Turbidity (NTU)	---	---	---	---	---	---	5	1	5	1
Enteric virus (c)	---	---	---	---	---	---	125 per 40 liters	1 per 40 liters	125 per 40 liters	1 per 40 liters
Entamoeba Histolytica	---	---	---	---	---	---	---	none detectable	---	none detectable
Giardia I Amblia	---	---	---	---	---	---	---	none detectable	---	none detectable
Ascaris Lumbricoides	---	---	---	---	---	---	none detectable	none detectable	none detectable	none detectable
Common large Tapeworm	---	---	none detectable	none detectable	---	---	---	---	---	---

Notes: CFU = Colony forming units
NTU = nephlometric turbidity units
(c) expressed as PFU, plaque forming units; MPN, most probable numbers; or immunofluorescent foci per liter
"None detectable" means no pathogenic microorganisms observed during examination

Source: Arizona Statutes Section R18-9-703

Table 4A: Texas Quality Standards for Use of Reclaimed Wastewater

Irrigation of Food Crops: Sampling required once per week.		
30-day average:		
-- BOD5 (system other than pond system)		10 mg/l
-- Turbidity		3 NTU
-- Fecal coliform	(not to exceed)	75 CFU/100 ml
-- BOD5 (pond system)		30 mg/l
--Fecal Coliform	(not to exceed)	75 CFU/100 ml
Irrigation of Fodder, Fiber and seed crops: Sampling required once per month		
30-day average:		
-- BOD5		30 mg/l
Irrigation of pastures for animals milked for human consumption: Sampling required once per two weeks.		
30-day average:		
-- BOD5 (other than pond system)		20 mg/l
(pond system)		30 mg/l
-- Fecal coliform	(not to exceed)	800 CFU/100 ml
Irrigation of landscaped areas:.		
30-day average:		
Unrestricted: Sampling required once per week		
-- BOD5		5 mg/l
-- Turbidity		3 NTU
-- Fecal coliform	(not to exceed)	75 CFU/100 ml
Restricted: Sampling required once per month		
-- BOD5 (other than pond system)		20 mg/l
(pond system)		30 mg/l
-- Fecal Coliform	(not to exceed)	800 CFU/100 ml
Landscape Impoundment, Restricted Recreational Impoundments or Ornamental Fountains: Sampling required once per week		
-- BOD5		10 mg/l
-- Turbidity		3 NTU
-- Fecal Coliform	(not to exceed)	75 CFU/100 ml
Commercial and Industrial: Sampling required once per month		
-- BOD5 (other than pond system)		20 mg/l
(pond system)		30 mg/l
-- Fecal Coliform	(not to exceed)	200 CFU/100 ml
Toilet Flush Water: Sampling required once per week		
-- BOD5		5 mg/l
-- Fecal Coliform		75 CFU/100 ml

Source: Texas Water Code, Chapter 310 Use of Reclaimed Water.

Table 5A: Treatment standards for urban water reuse in Georgia

	Restricted access	Non-restricted access
BOD5	30 mg/l	10 mg/l
TSS	30 mg/l	
Turbidity		< 5 NTU
Fecal coliforms	< 200/100 ml	< 20/100 ml
Buffers	150 ft. wetted area to property lines 300 ft. wetted area to habitable structure	Not normally required but may be warranted in certain circumstances

Source: Environmental Protection Division of the Georgia Department of Natural Resources