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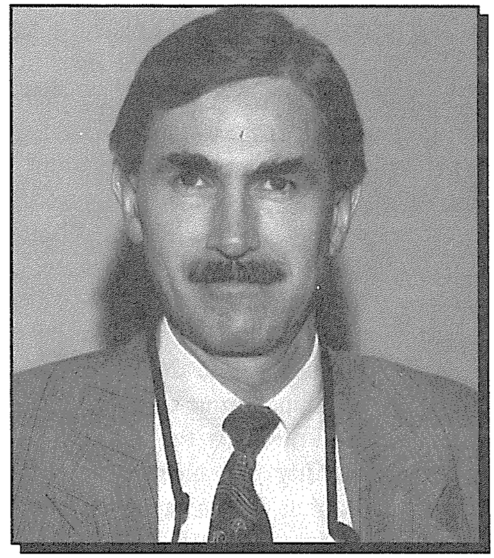

WASTEWATER RECLAMATION AND RECHARGE: A WATER MANAGEMENT STRATEGY FOR ALBUQUERQUE

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BACKGROUND

The City of Albuquerque, New Mexico is characterized by an arid climate with an annual rainfall of about 8 inches. Like most growing southwestern cities, Albuquerque consumes more water than is naturally replenished to its supply. The City relies exclusively on groundwater, currently pumping about 120,000 acre-feet per year (a-f/y) from the Albuquerque Basin aquifer (Santa Fe Formation), which is accomplished with more than 140 wells (about 90 of which are currently active), located throughout the metropolitan area. Albuquerque's groundwater allocation is 132,000 a-f/y, and at present there is no movement toward increasing this allocation. The City also owns a total of 48,200 a-f/y of surface water in the San Juan-Chama diversion system, most of which is currently leased or kept available to maintain minimum streamflows in conjunction with wastewater discharge requirements. Yearly recharge of the groundwater aquifer by natural means is only about 30,000 acre-feet.

Albuquerque's groundwater withdrawals have a depletion effect on flow in the Rio Grande, although the precise impact is presently under study. The City is allowed to deplete flow in the Rio Grande by no more than 20,000 a-f annually, as a result of its groundwater pumpage. Indications are that current depletions far exceed this amount, but the difference is roughly offset by the amount of treated wastewater returned to the river. This relationship is expected to change in the future, with depletions becoming greater.

Approximately 61,000 a-f of the pumped water is annually discharged to the Rio Grande as treated wastewater. Albuquerque's Southside Water Reclamation Plant (SWRP) is the primary wastewater treatment facility for most of the Albuquerque area. Its current design capacity is 76 million gallons per day (mgd), which is expected to be adequate until about 2004. A master plan currently is being prepared (discussed in Wastewater Master Planning and the Zero Discharge Concept section below) to provide guidelines for future expansions of the plant and wastewater infrastructure. Construction documents presently are being prepared to add ammonia and nitrogen removal capability to the plant, as required by its new discharge permit.

WATER MANAGEMENT STRATEGIES

Options for Water Resource Management

Recognizing that its water supply is a scarce and finite resource, the City is implementing voluntary conservation measures as well as commencing a planning program to identify potential sources and strategies for meeting future demands. An aggressive annual conservation goal has been set for 30 percent reduction of per capita use in the next six to ten years. Even if accomplished, annual groundwater withdrawal still will be nearly triple the natural recharge rate. Therefore, further programs will be needed for optimization of existing supplies and development of new sources.

Some of Albuquerque's potential future water management options include:

- Continued use of groundwater, although the City's groundwater diversion permit will provide for a future additional annual pumpage of only about 10 percent, beyond which the allocation would need to be increased. While the use of this resource can be extended through conservation, it is nonetheless limited, as groundwater mining will continue to decrease depth and volume of this resource. Continued pumping also will require the use of surface water rights for river flow augmentation, in order to offset depletions to the Rio Grande caused by the pumping.
- Development, treatment and distribution of surface water supplies. Conversion to a surface water system would be complex and expensive, as extensive repiping of much of the City would be required to deliver treated surface water to customers from one or two centralized treatment locations.
- Reclamation, distribution and reuse of wastewater effluent for non-potable applications via a separate distribution system, thereby reducing the demand on the City's groundwater resources. This concept is further discussed in the section on Recommended Approach - Indirect Potable Reuse Options.
- Treatment of surface water and injection into the groundwater aquifer, with continued reliance on groundwater as the primary supply source. This approach would directly recharge the supply aquifer, reducing the mining impact, and therefore extend the life of that resource. It offers little benefit over direct use of surface water, however, except possibly in terms of cost savings (see discussion in following section).
- Reclamation and treatment of wastewater effluent to a very high quality, and direct recharge of the City's groundwater supply. This concept, called "indirect potable reuse," is similar to the above recharge concept using treated surface water, but also offers direct benefits to the City's wastewater management program, by reducing or eliminating wastewater discharge to the Rio Grande. Further, this concept provides the greatest opportunity for maximum utilization of the City's current water resources, by continuously recycling all or a portion of the wastewater flow, thereby placing the least amount of strain on groundwater or surface water resources.

Water Rights Aspects of a Recharge Program

Constructing and operating a surface water system, in addition to the high costs for implementation, would expand the City's available supply only by the amount of surface water that it owns or can purchase. If surface water is treated and injected into the ground, the potential exists both for reductions in groundwater mining as well as in the depletion effect on the Rio Grande. However, the amount injected also would be limited to the amount of owned surface water, and as water demands continue to grow, groundwater pumpage will continue to increase river depletions, and additional surface water also would then be needed to offset these depletions. One possible advantage of this scheme over direct usage of the surface water would be potentially lower costs, since less new distribution infrastructure would be needed with continued use of a groundwater-based system, although significant additional piping would be required to get the surface water to injection sites. Other than these potential cost savings, injection of treated surface flow offers little advantage over the direct use of surface water.

Greater benefits are realized with a system that reclaims and recharges treated wastewater, because the available amount for recharge is the actual wastewater flow, rather than a limiting amount of San Juan-Chama water the City owns. This flow, which represents the non-consumed portion of the City's water usage, would be continually recycled (injected and then repumped into the system), and the river depletion (caused by long-term groundwater pumping effects and a reduced effluent discharge to the river) would be offset with direct releases of San Juan-Chama surface water. Wastewater recycling in this manner proportionally reduces the amount of groundwater which must be pumped from the aquifer resource, subsequentially lowering the depletion effect on the Rio Grande caused by such pumping. With the depletion effect on the river reduced, a smaller amount of surface water augmentation is needed to keep the river at the allowed depletion level of 20,000 a-f/y, than would be needed without a recycling/recharge program. Therefore, a wastewater reclamation and recharge program would provide for a more optimal use of the City's existing water resources, extending considerably the point in time that additional supplies would need to be obtained.

It must be pointed out that this concept assumes Albuquerque will receive credit for and be able to reuse the water injected back into the aquifer (without losing the right to also pump up to its current allocated amount), and that return flow credits will be recognized by the State Engineer Office as a result of reduced river depletion rates attributable to reduced aquifer pumping.

The influence of Albuquerque's groundwater pumpage on river flow has been the subject of considerable study in recent years. Groundwater modeling currently being conducted by the U.S. Geological Survey (USGS) will further define this relationship, which also is a function of the distance of specific wells to the river channel. USGS work is beginning to confirm many of the assumptions made by City staff in estimating this relationship for water balancing purposes.

Calculations by the City Public Works Department, which are based on both immediate and delayed impact theories of pumpage and effect on river flow, further affirm the above thesis that recharge of the groundwater with wastewater effluent, combined with river augmentation from San Juan-Chama surface water, could be accomplished in a manner which would considerably optimize the use of the City's water resources. Based on current growth projections, Figure 1 indicates that without a reclamation and recharge program, and using up to the full amount of the City's San Juan-Chama water to offset river depletions caused by groundwater pumping, the allowed annual river depletion rate of 20,000 a-f will begin to be exceeded in 2030, requiring the City to purchase additional supplies at that time. Also, by then Albuquerque would be pumping 183,000 a-f from the aquifer, far in excess of its current allocation of 132,000 a-f. On the other hand, as shown in Figure 2, a recharge program could result in the City's existing supply being adequate to meet projected demands until 2050, before excessive flow depletions (above 20,000 a-f) would occur in the river. This is because the recharged effluent is subsequentially pumped back into Albuquerque's water system, thereby reducing the amount of water pumped from the aquifer resource, and this in turn reduces the

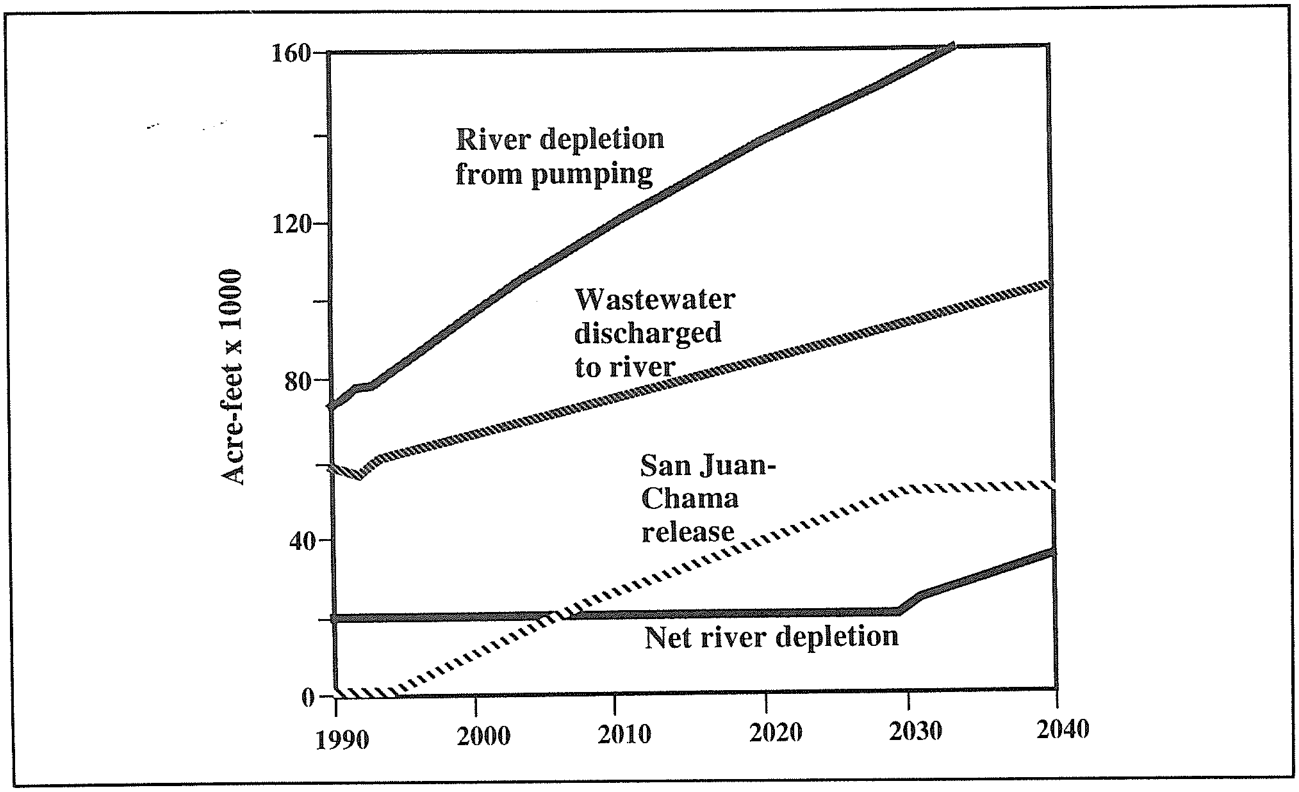

Figure 1. Effect of groundwater pumpage on Rio Grande.

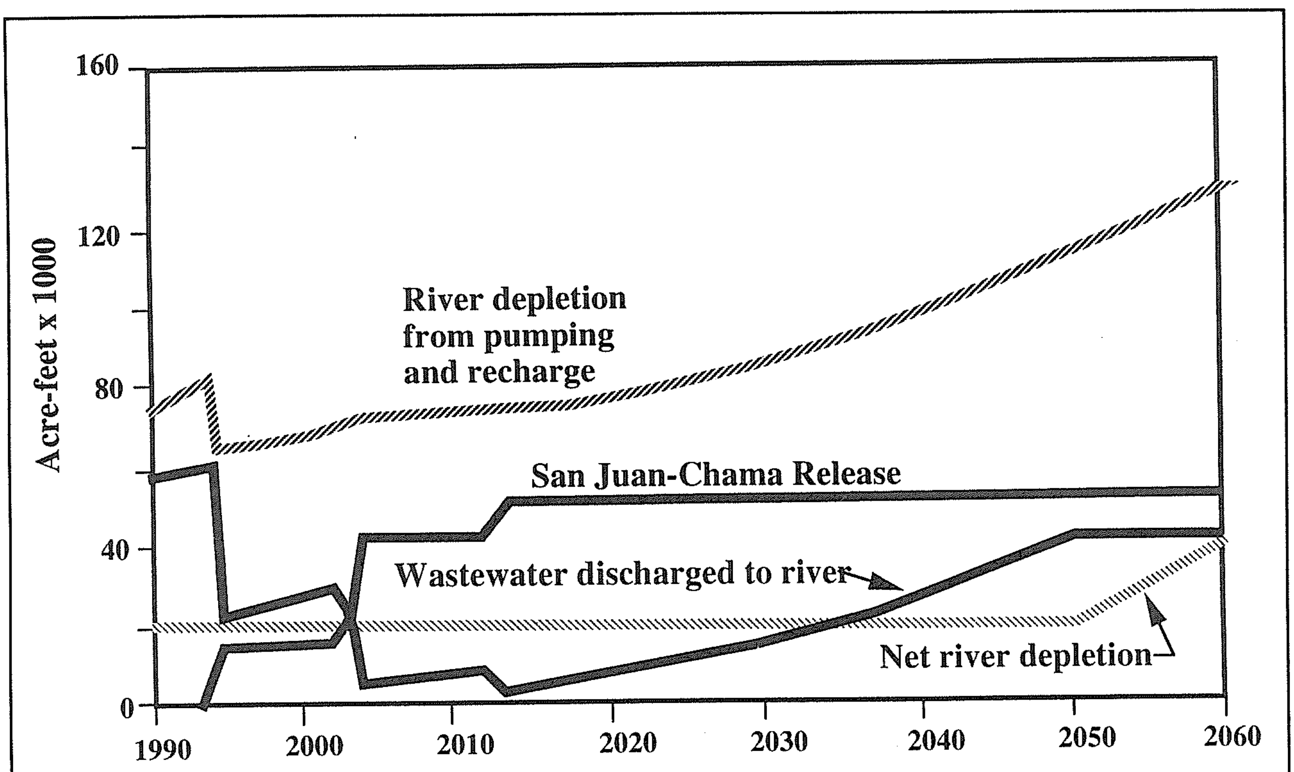

Figure 2. Effect of groundwater pumpage and reclamation/recharge on Rio Grande.

river depletion effect. Since river depletions are reduced, less San Juan-Chama water is needed to offset the depletions, and this fixed supply is adequate to offset depletions to a later time in the future. By 2050, only 155,000 a-f/y would need to be pumped from the aquifer resource, with the recycled effluent accounting for the remainder of the 220,000 a-f water demand.

Although direct recharging of surface flow would seem to have the same positive impact on reducing aquifer mining and river depletions as wastewater recycling does, the amount which can be injected is limited by the amount of San Juan-Chama water that the City owns, whereas using reclaimed wastewater allows recharge of larger amounts, up to the total SWRP effluent flow. Recharging at higher rates will result in corresponding greater reductions in aquifer pumping, thereby more rapidly reducing the accumulated depletion effect on the river (caused by the City's historic aquifer pumping). As the accumulated depletion debt is reduced, it will eventually be possible to recharge the aquifer at rates greater than the 48,200 a-f San Juan-Chama allocation, while releasing only this amount to the Rio Grande, without depleting the river more than allowed.

It is emphasized that in order to attain the condition where recharge rates can exceed the San Juan-Chama allocation, the recharge program needs to commence soon; otherwise river depletion effects will continue to accumulate and this trend will be difficult to reverse without purchasing additional water rights. Also, only the effluent recharge option provides the capability to inject more than 48,200 a-f/y and obtain this benefit, which greatly extends the life of the City's existing water resources.

Therefore, because of the manner in which Albuquerque's ground and surface water resources are administered, a recharge program has merit from a water rights aspect. And, using reclaimed wastewater as the source for recharge flow provides the greatest potential for optimal use of existing water supplies.

Wastewater Master Planning and the Zero Discharge Concept

In 1990 the City and CDM commenced work on a comprehensive 40-year wastewater master plan. This ongoing effort encompasses a wide range of activities, from interceptor evaluation and modeling, water quality studies, and GIS-based land use and population projections to short and long-range planning for expansion of the City's Southside Water Reclamation Plant (SWRP) beyond its current capacity of 76 mgd. A critical issue of the master planning process is the current and projected water quality requirements for the Rio Grande, and the corresponding effluent discharge limitations.

In the spring of 1994 the City was issued a new draft NPDES permit, which, along with expected biological and bacterial limitations, contained restrictive effluent requirements for ammonia, nitrate, arsenic, cyanide, silver, lead and aluminum. These limitations were based on instream use classifications and water quality requirements of both the State of New Mexico and the Isleta Pueblo, which is located within a few miles downstream of the wastewater treatment plant discharge point. Attainment of the standards in the draft permit, some of which are much more stringent than drinking water standards, would require costly high-technology based advanced waste treatment. The City undertook legal actions to prompt further review and consideration of these unusually high standards.

The final permit, which became effective on June 1, 1994, contains effluent limitations for ammonia and nitrate. New facilities to provide the required treatment are presently under design. Table 1 summarizes some of the more critical limitations contained in the permit. The numerical limits for the metals and other inorganics have been temporarily withheld, although a consent decree requires that further site-specific studies be conducted to determine appropriate water quality standards for these constituents. At the conclusion of these studies in 1997, effluent requirements which are similar to (or perhaps less restrictive than) the draft limitations could be reinstated into Albuquerque's permit.

TABLE 1. EFFECTIVE SWRP EFFLUENT LIMITATIONS

Constituent	Limit mg/l	Conditions	Basis
Ammonia	2	guar. low flow	Isleta WQ stds
Nitrate	24	guar. low flow	Isleta WQ stds
Nitrate	10	guar. low flow	GPPAP goals
Nitrate	9	4Q3 low flow	Isleta WQ stds
Fecal Coliform	100/100 ml	guar. low flow	NMED stds
Fecal Coliform	200/100 ml	daily max.	NMED stds

At the time that the draft NPDES permit was issued, engineering analyses were conducted to identify and evaluate options for meeting the proposed restrictive effluent limitations, in particular the requirements for arsenic and silver. Because of the high degree of advanced treatment necessary to attain the standards, one of the more favorable options was "zero discharge," which would be accomplished by treating the effluent to a suitable level and reusing the flow in a groundwater recharge program, thereby eliminating wastewater discharge to the river and the need to attain the required effluent limitations. It was found that the degree of treatment required to meet the Isleta water quality-based arsenic standard alone exceeded that needed to produce water of drinking water quality. Therefore, treatment for reuse and zero discharge would be less costly than that required to meet the effluent discharge standards in the draft NPDES permit. Following completion of the site-specific studies, this could continue to be the case.

Dual Benefits of Wastewater Reuse

The concept of wastewater reclamation and reuse can be viewed as a potential contributing solution to both the long-term water resource shortage as well as potential future restrictive effluent discharge standards. While there are other water management strategies that Albuquerque also needs to evaluate (outlined above), reclamation and reuse of wastewater is the only option that also offers a solution to future wastewater management restrictions.

INDIRECT POTABLE REUSE FOR ALBUQUERQUE

Recommended Approach

CDM's initial investigations led to the conclusion that an indirect potable reuse program would likely be the best reclamation approach for Albuquerque, rather than a non-potable (irrigation) program. Indirect potable reuse essentially consists of using highly-treated wastewater effluent to recharge the potable water supply, not directly but via the water source, that being the groundwater aquifer from which Albuquerque draws its municipal water.

Although non-potable reuse has been practiced to a limited extent in some suburban Albuquerque locations (e.g., Rio Rancho), there is relatively little agriculture in the Albuquerque area, and other potential non-potable users (golf courses, parks, etc.) are relatively few in number and widely distributed. To serve these sites would require extensive new infrastructure for a relatively small demand, compared to the very large volume of effluent produced by the SWRP. Further, landscape irrigation is being discouraged and reduced under Albuquerque's currently proposed conservation initiatives.

Indirect potable reuse, on the other hand, would recharge Albuquerque's groundwater supply, therefore directly reducing the mining effect of pumping, and would also provide for zero discharge to the river, since the full flow could physically be injected into the aquifer. It is recognized that implementation of a program to recharge the total effluent flow would also require acquisition of additional water rights and changes to water rights administration by the State Engineer.

Indirect Potable Reuse Options

To accomplish indirect potable reuse, reclaimed wastewater could be injected directly into the saturated zone, or introduced at the ground surface with spreading basins or in the vadose zone with shallow wells. Direct injection requires a higher degree of pretreatment than does surface spreading, since no opportunity is provided for soil-aquifer treatment prior to introducing the flow into the water supply. However, it was determined that the most favorable approach for Albuquerque would be direct injection below the water table, for several reasons:

- Local geology experts noted that clay lenses and other geological obstacles may impede or obstruct flow from the surface to saturated zones.
- High local evaporative rates would result in significant water loss if spreading basins were used.
- Spreading basins also require considerable open land area, which does not exist in the areas where recharge is most feasible.

The Proposed Reclamation and Recharge Concept

Treated wastewater from the City's SWRP would be further processed to drinking water quality, possibly blended with treated raw water diverted from the Rio Grande, and then pumped to new storage reservoirs and recharge wells located within existing City water supply well fields, where the water would be injected directly into the groundwater supply aquifer. This concept is schematically illustrated in Figure 3.

This groundwater recharge approach to indirect potable reuse is practiced currently at El Paso, Texas and in Orange County, California. Similar programs are being planned or designed at several other locations in southern California and Arizona, and surface recharge or augmentation options are planned for other communities such as Phoenix and Tampa. Extensive research was conducted for several years at the Denver Potable Reuse Demonstration Plant, providing information for full-scale design of treatment systems.

The El Paso (Fred Hervey WWTP) and Orange County (Water Factory 21) facilities have both been operating successfully for a number of years. Both begin with raw sewage and produce product water meeting federal and local drinking water standards prior to injection into local potable groundwater supplies. Both plants utilize proven technologies and incorporate high degrees of treatment redundancies and safeguards.

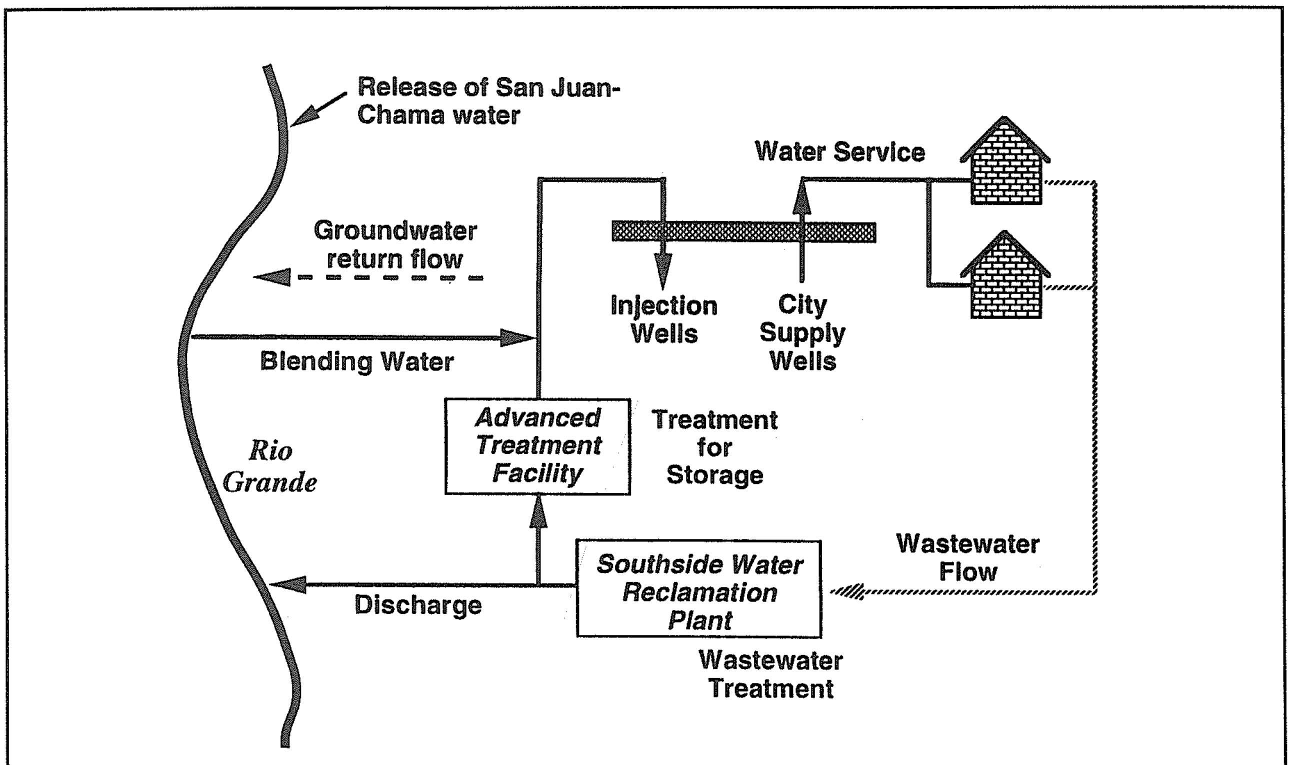

Figure 3. Indirect potable reuse via groundwater recharge.

SCOPE OF STUDY

Study Components

As a part of the Albuquerque Wastewater Master Plan, CDM is conducting a project entitled the Wastewater Reclamation and Recharge Program, the purpose of which is to provide a detailed assessment of the feasibility of implementing indirect potable reuse in Albuquerque, and to generate information and data for eventual full-scale design. The work's first phase is a study to determine infrastructure requirements and preliminary cost estimates for a conceptual reclamation and recharge system, in order to provide information which can be used to make a comparative assessment of this concept's feasibility against other long-term water management strategies described in the section entitled Options for Water Resource Management. The costs also will be compared with those which may be required for construction of treatment facilities to meet future restrictive effluent discharge requirements.

The primary elements of the Phase 1 study include:

- Establishment of water quality objectives for recharge
- Evaluation of treatment alternatives to attain those objectives
- Investigation of the groundwater geohydrology and potential recharge capacities, and identification of the best general locations for recharge well sites
- Development of conceptual-level complete reclamation and recharge systems for budget estimating purposes.

Recharge System Capacities

The Phase 1 evaluations have been conducted for two different recharge capacities:

- **76 million gallons per day (mgd)**, which is the design capacity of the SWRP, and would result in zero-discharge to the Rio Grande. Reclamation and recharge of the full 76 mgd would terminate all discharge to the river, and hence would also eliminate the need to comply with current or future restrictive effluent limitations. As previously mentioned, implementation of zero discharge would also require acquisition of additional water rights and changes to water rights administration by the State Engineer.
- **30 mgd**, which is the amount of effluent that presently could be recharged to the aquifer without any impact on the State Engineer's current administration of City water rights. Surface water from the City's San Juan-Chama supply would be released to offset the reduced discharge of treated wastewater to the river. Fully offsetting this depletion assumes full credit would be given for groundwater recharging and the corresponding reduction in aquifer pumping and associated beneficial impact on the streamflow.

Constraints for Reuse System Design

Both the El Paso and Orange County reuse plants operate under conditions that are conducive to the type of treatment provided. The El Paso facility uses a proprietary powdered activated carbon process that, while expensive, provides high quality water without membrane treatment, and thus the liquid residual waste stream is negligible. High-lime treatment is used, but sludge generation is manageable in this relatively small plant. At Water Factory 21 in Orange County, membrane technologies are used (in parallel with granular activated carbon) since total dissolved solids (TDS) removal is important. Low silica levels in the wastewater allow high treatment efficiency without excessive generation of wastewater (concentrate) from the membrane process, and disposal of this liquid is relatively simple and inexpensive via a short pipeline to the ocean.

Albuquerque's situation is less ideal. Relatively high natural silica levels in the groundwater greatly reduce recovery rates for membrane treatment, requiring low-pressure, less-selective processes (nanofiltration) to be considered. High-lime pretreatment for this large a plant would generate hundreds of tons of chemical sludge; and microfiltration is ineffective for silica. There is no economical means for liquid residual disposal, nor is it desirable to waste water in this arid region. Treating only with activated carbon will not achieve adequate total organic carbon (TOC) reduction (see following discussion), thus requiring blending with treated surface water prior to recharge. However, blending would require additional water rights, which are expensive and not readily available. Therefore, system design for Albuquerque must seek to achieve adequate quality to avoid blending, while minimizing the production of liquid and solid waste residuals.

WATER QUALITY CONSIDERATIONS FOR INDIRECT POTABLE REUSE

Sources of Regulations and Guidelines

Specific water quality and treatment objectives need to be established before alternative treatment technologies can be defined and evaluated. No regulations for intentional recharge of treated wastewater into potable supplies exist anywhere in the USA, although the EPA and some states have developed guidelines, and the state of California is in the process of developing specific regulations for this practice, which are proposed as Article 5.1 to the existing Title 22 of the California Code of Regulations, Division 4, Chapter 3 (Reclamation Criteria). A draft document currently exists.

Currently, groundwater discharge of effluent (via land application/irrigation, or intended or inadvertent percolation after surface discharge) is regulated under Part 3 of the New Mexico Water Quality Control Commission Regulations, which are written toward protecting groundwaters from degradation. Numeric criteria are specified for human health aspects as well as for domestic and irrigation water supply. These standards tend to be similar to or slightly less restrictive than those for drinking water under the national Safe Drinking Water Act amendments (SDWA). The New Mexico regulations also require a discharge plan for some types of subsurface discharge. Direct groundwater aquifer recharge in compliance with New Mexico's current groundwater protection standards would require that the numerical criteria for the affected groundwater not be exceeded as a result of such injection.

The lack of knowledge about the fate and long-term health effects of contaminants in reclaimed wastewater dictates conservative water quality standards for groundwater recharge where the injected water will later be extracted for potable uses. As no states have promulgated specific standards for intentional recharge into potable water supplies, attainment of drinking water standards has been used as a minimum guideline for the few such reclamation systems that exist, such as the Fred Hervey Water Reclamation Plant at El Paso, Texas. It is expected that attaining potable quality, in accordance with established and accepted regulations, prior to injection will help considerably in securing public acceptance of the reclamation/recharge concept.

The California standards, presently in draft form and not yet approved, require attainment of all SDWA standards, plus contain additional restrictions on total organic carbon (TOC), injection/extraction well spacing and in-ground retention time of injected reclaimed water.

Proposed Standards for Indirect Potable Reuse

A review of applicable regulations and discussions with City staff resulted in the following objectives being established for use in planning a reclamation and recharge program.

- Current and anticipated federal drinking water requirements stipulated under the Safe Drinking Water Act (SDWA). Since these requirements must be achieved prior to distribution of drinking water, treatment should only be necessary for those contaminants (if any) which surpass allowable levels as a result of the water passing through the City's water and wastewater systems and infrastructure. Arsenic is among those constituents for which maximum contaminant levels (MCLs) may likely become more restrictive in the future. As the future arsenic MCL will need to be complied with prior to distribution of drinking water, and since most arsenic in Albuquerque's wastewater originates from natural occurrence in the water supply, arsenic removal at the reclamation treatment works should not be required.
- Where current New Mexico groundwater protection standards are more restrictive than the SDWA criteria, those standards will apply to the recharge water at the surface. The New Mexico regulations allow the option of injecting water which does not meet the standards, but a discharge plan must be filed which ensures that the standards will be complied with in the ground as a result of dilution or other means (i.e., the plan must show that the

injected water will not cause the resulting blended groundwater to violate the standards). However, since subsurface blending ratios between reclaimed water and existing groundwater will be difficult to predict, and will undoubtedly change with time, the decision was made to attain the groundwater standards at the surface prior to recharge, therefore ensuring that groundwater standards are never violated as a result of a reclamation and recharge program.

- The Groundwater Protection Policy and Action Plan (GPPAP) has been adopted by the City of Albuquerque and Bernalillo County. This plan sets forth general goals toward preserving groundwater quality by nondegradation practices and by limiting recharge water quality characteristics to half the groundwater constituent levels allowed by the New Mexico groundwater protection standards. Compliance with these goals will require the use of treatment processes that produce wastewater with TDS concentrations at ambient groundwater levels or below, and reduce nitrate to 5 mg/l or less.

Additional Water Quality and Operating Parameters

Several other factors also may have impacts on public health and operational aspects of a wastewater reclamation and recharge system. Specific standards for certain of these factors are proposed in the California draft regulations.

Organics Removal

In the proposed California regulations, TOC concentration has been designated as the parameter for determining overall organics removal efficiency from wastewater prior to recharge. Since more than 90 percent of the organic chemicals comprising TOC are unidentified, there has been no attempt to establish MCLs for specific organics. In reality, there is no demonstrated link between TOC and health effects, and the position of some experts is that TOC is not a good surrogate for regulated organics. However, it serves as a useful means for controlling the discharge of unknown or unregulated organics, while the regulated ones are controlled by compliance with SDWA standards. Although most of the specific organics comprising TOC are unidentified, most are humic and fulvic acids (decay products), which also are THM precursors. Thus, chlorination should be minimized if possible.

The proposed California regulations for organics control are based on not exceeding 1 mg/l of TOC in that portion of the extracted well water which was contributed by the injected reclaimed water. Naturally occurring TOC does not count toward this total (naturally occurring TOC in Albuquerque's groundwater is generally less than 0.5 mg/l). Up to 5 mg/l TOC could be present in the injected water if a 1:5 dilution (injected reclaimed water/total blended water at extraction well) is obtained, at the surface prior to injection or in the ground prior to extraction, such that the extracted water TOC content is 1 mg/l or less as a result of the reclaimed water component. The proposed California regulations allow up to 50 percent reclaimed water to be contributed to the existing groundwater supply, although this requires TOC removal to 2 mg/l or less. Although the regulations allow for blending at any point prior to withdrawal (including taking credit for the presence of natural groundwater), mixing reclaimed water with dilution water at the surface is clearly the safest way of ensuring that the required dilution ratios are met.

Since the California regulation is based on TOC level in the withdrawn water, the provision exists for injection of undiluted flow where it can be shown that TOC dilution (or removal) occurs in the ground. Many years of operational data at Water Factory 21 have confirmed significant TOC reduction after injection, and this facility recently has been issued a revised permit allowing direct injection of undiluted plant effluent with TOC levels of 2 mg/l.

In some of the potential recharge areas around Albuquerque, below-ground blending may be difficult to control. For example, in areas of heavy concentrations of existing supply wells, ideal injection/extraction configurations (for ensuring proper dilution) may not exist; injected water may flow several directions to any of several extraction wells. Further, it is well known that groundwater table subsidence is occurring in some locations, which could cause initial dilution ratios to change significantly over time. For this study, it was decided that in areas near to existing established supply well fields, dilution of the reclaimed water should occur at the surface prior to injection, in order to ensure that the desired dilution rates are attained. In areas where new injection and extraction wells could be specifically "engineered," actual in-ground dilution could be expected, provided that spacing and residence time requirements are met (see below).

It is recommended that the proposed California standards be applied to Albuquerque's program, and that the standards continue to be reviewed as they are finalized. Rather than designating specific TOC removals to be attained, it is recommended that all feasible treatment techniques be evaluated for their potential TOC reduction capability, and considered in conjunction with their relative cost and associated dilution requirements. Potential sources of dilution water include the City's San Juan-Chama surface water, a portion of which could be immediately available for this purpose. "Imported" groundwater (groundwater conveyed from another nontributary location which does not contain any reclaimed water) could also be used for dilution.

Minimum Underground Retention Time

The proposed California regulation requires that the injected reclaimed water be retained underground a minimum of 12 months prior to extraction as part of the total flow at a water well, and this is to be verified annually. The residence time requirement is tied primarily to pathogen and virus destruction. The El Paso system was designed for 2 years, although typically provides more than 4 years' residence time. For this study, it was decided that a one-year residence time would be used for preliminary system layout. Modeling was used to determine approximate one-year flow distances (see Geohydrological Aspects of a Recharge Program section).

Spacing of Injection and Extraction Wells

The proposed California regulation requires that injection and extraction wells be located at least 2000 ft. apart, while spacing of wells in the El Paso system ranges from 1,200 ft to 4 miles. For Albuquerque, it is important that the injection well configuration be one that will not impose operational restrictions on the existing wells. A 2,000-ft. spacing appears feasible for Albuquerque, although it may be somewhat restrictive in areas where supply wells are concentrated. An "engineered" system of injection and extraction wells could be considered in a relatively undeveloped area, such as Mesa del Sol, where this criteria would be easily attainable.

Treatment Requirements for Albuquerque

A review of current secondary effluent characteristics at the SWRP, and comparison with requirements and goals of the above water quality regulations and guidelines, reveals that the effluent currently is in compliance with nearly all SDWA standards for trace minerals, radioactivity, VOCs, pesticides and Phase IV organics. A very few of these are exceeded, including heptachlor epoxide, Di(2-Ethylhexyl) Phthalate, and fluoride. There are several others for which SWRP data were not available. However, process selection or bench and pilot testing will not be affected by these data gaps, because treatment alternatives are formulated on the basis that trace organics, regulated or unregulated, *may* be present, and therefore appropriate removal processes should be included. The potential presence of trace organics in SWRP effluent is enough to warrant inclusion of treatment processes such as granular activated carbon (GAC) and membrane systems, which effectively remove trace organics. Therefore, it is anticipated that the known and unknown trace organics present in SWRP effluent will be reduced to acceptable levels by the treatment methods to be provided.

As would be expected, high reductions will be necessary for pathogens, microbials, organics (TOC), and turbidity. Disinfection and pathogen barrier processes will be designed for:

- 6-Log reduction
- Total coliforms to <1CFU/100 ml (SDWA standard)
- Fecal coliforms to <1CFU/100 ml (CA proposed GW recharge standards)
- Virus, Cryptosporidium, Giardia, and Legionella to below detection limit (SDWA standard)
- Turbidity to 0.5 NTU (SDWA standard)

A TOC limit of 1 mg/l of wastewater origin in recovered water will be used, as previously discussed. Major inorganics requiring reduction include nitrate (to 5 mg/l per the GPPAP goals), and TDS. For TDS, both the GPPAP goal of 300 mg/l (based on nondegradation) and the 500 mg/l SDWA standard will be considered, since this is not a health-related parameter, and compliance with the lower standard could have significant impact on treatment system requirements and costs.

Current Improvements at the SWRP

The ammonia and nitrogen removal facilities currently being designed for the SWRP will provide for partial removal of total nitrogen, which will be required whether the effluent is discharged to the river or recharged to the ground as described above. Therefore, these facilities are fully compatible with a reclamation and recharge program. Although the nitrification/denitrification facilities are being designed to remove nitrate to 9 mg/l, process adjustments should allow removals to the 5-6 mg/l range, therefore attaining or nearly attaining the GPPAP nitrate goal of 5 mg/l for groundwater recharge.

TREATMENT FOR POTABLE REUSE

Treatment Technologies

The study initially considered a wide range of methodologies for achieving the treatment requirements, including membranes, activated carbon adsorption, chemical precipitation, oxidation, ion exchange, air stripping and normal wastewater biological and disinfection processes. An initial screening was conducted, focusing on those found to best produce the water quality required and to be compatible with planned SWRP modifications (for ammonia and nitrogen removal). Table 2 lists those treatment techniques which were judged most feasible, also indicating contaminants for which each process is considered to be an effective removal method. Specific process alternatives were derived from the technologies contained in this table.

Because of the need to provide multiple barriers for health-related constituents, and due to the desire to effectively remove TOC (to minimize the need for blending water), all alternatives derived from Table 2 are based on either GAC or membrane treatment, or both.

TABLE 2. POTENTIAL TREATMENT PROCESSES

Treatment Process	Contaminant: TOC	Trace Organics	NH_3	NO_3	TDS	Bacteria	Viruses	Suspended Solids/ Turbidity	Fluoride	Metals	Silica
Membranes											
RO	X	X	X	X	X	X	X	X	X	X	
NF	X	X	X	X	X	X	X	X	X	X	
UF	X	X				X	X	X			
MF						X	X	X		X[1]	X[1]
GAC	X	X							X	X[3]	
Chem. Pptn.											
Lime	X[2]					X	X	X		X	X
Ferric	X[2]					X	X	X		X	
Air Stripping		X									
BNR			X	X							
Disinfection											
Chlorine						X	X				
Ozone						X	X				
Uv						X	X				

Notes:
[1] MF has the potential to remove metals and silica if chemical addition upstream of MF is used.
[2] Typically less than 50% TOC reduction.
[3] GAC is selective for certain metals.

Treatment Alternatives

A total of nine initial alternatives were identified. These are summarized below:

- Alt. 1: Reverse Osmosis (RO) with Lime Pretreatment
- Alt. 2: Reverse Osmosis with Microfiltration (MF) Pretreatment
- Alt. 3A: Nanofiltration (NF) with Microfiltration Pretreatment
- Alt. 3B: Nanofiltration with Denitrification Filters as Pretreatment
- Alt. 4: Ultrafiltration (UF) with Microfiltration Pretreatment
- Alt. 5A: Granular Activated Carbon (GAC) with Gravity Filtration as Pretreatment and Microfiltration Post-Treatment
- Alt. 5B: GAC with Microfiltration Post-Treatment
- Alt. 5C: GAC with Denitrification Filters as Pretreatment and Microfiltration Post-Treatment
- Alt. 6: Nanofiltration and GAC Treatment in Parallel

In identifying final alternatives for detailed evaluations, major emphasis was placed on the design constraints previously discussed. The need to minimize waste residual generation while also attaining efficient TOC reduction (to minimize the need for blending prior to recharge) was a critical issue in process selection. None of the alternatives were ideal in all aspects, and the final alternatives are not all equal in treatment capacity or waste generation characteristics. Rather, the final alternatives range from reverse osmosis with lime pretreatment (which produces very low TOC but generates high volumes of waste concentrate and sludge), to GAC (which produces very little waste, but reduces TOC only to about 4 mg/l, not low enough for direct injection).

More detailed descriptions of the final four alternatives are provided below:

Alternative 1: Reverse Osmosis (RO) with Lime Pretreatment

Schematically illustrated in Figure 4, this alternative uses excess lime treatment to reduce silica levels in order to attain a recovery rate of 90 percent across the reverse osmosis process. The high lime process consists of reactor clarifiers, two stage recarbonation with an intermediate settling basin, and gravity filtration. Additional RO pretreatment includes ultraviolet disinfection to reduce biofouling of RO membranes, and cartridge filtration to reduce solids fouling. An antiscalant is used to control scaling from silica and other salts. This treatment scheme provides the highest level of treatment of all alternatives considered (reducing TOC to less than 1 mg/l), but also will generate 4 to 8 mgd of liquid concentrate waste, and up to 270 tons per day of chemical sludge.

Alternative 3A: Nanofiltration (NF) with MF Pretreatment

This alternative uses microfiltration instead of excess lime as the primary pretreatment step. MF will reduce suspended solids to nearly zero and act as a disinfection barrier, but silica will not be affected significantly. Recovery of an RO system with this pretreatment could only be estimated at 75 percent. Therefore, this alternative utilizes nanofiltration rather than full RO. Expected recovery with NF is in the 90 to 95 percent range, while still providing all of the treatment necessary to meet the water quality standards for recharge, including further nitrate removal if needed. Figure 5 is a schematic drawing of this alternative. While highly effective for TOC removal, a liquid waste residual of 4 to 8 mgd is produced (based on a process flow of 76 mgd).

Alternative 5B: GAC with Microfiltration Post-Treatment

Shown in Figure 6, this alternative incorporates upflow pulsed-bed GAC contactors. This process is tolerant of suspended solids in the feed water, and therefore prefiltration would probably not be required. MF and disinfection follow the GAC columns in order to provide 6-log inactivation of total coliforms and ensure disinfection to drinking water standards. Disinfection alone would likely not be adequate since biological growth occurs on the GAC, and chlorine would achieve only a 3-log inactivation. Air stripping would follow GAC to provide additional removal of low-molecular weight VOCs, which can adsorb onto carbon and then desorb at a later time. Waste residual flow is minimal with this alternative, but TOC reduction to less than 4 mg/l cannot be expected, at least not without very frequent (and costly) carbon re-

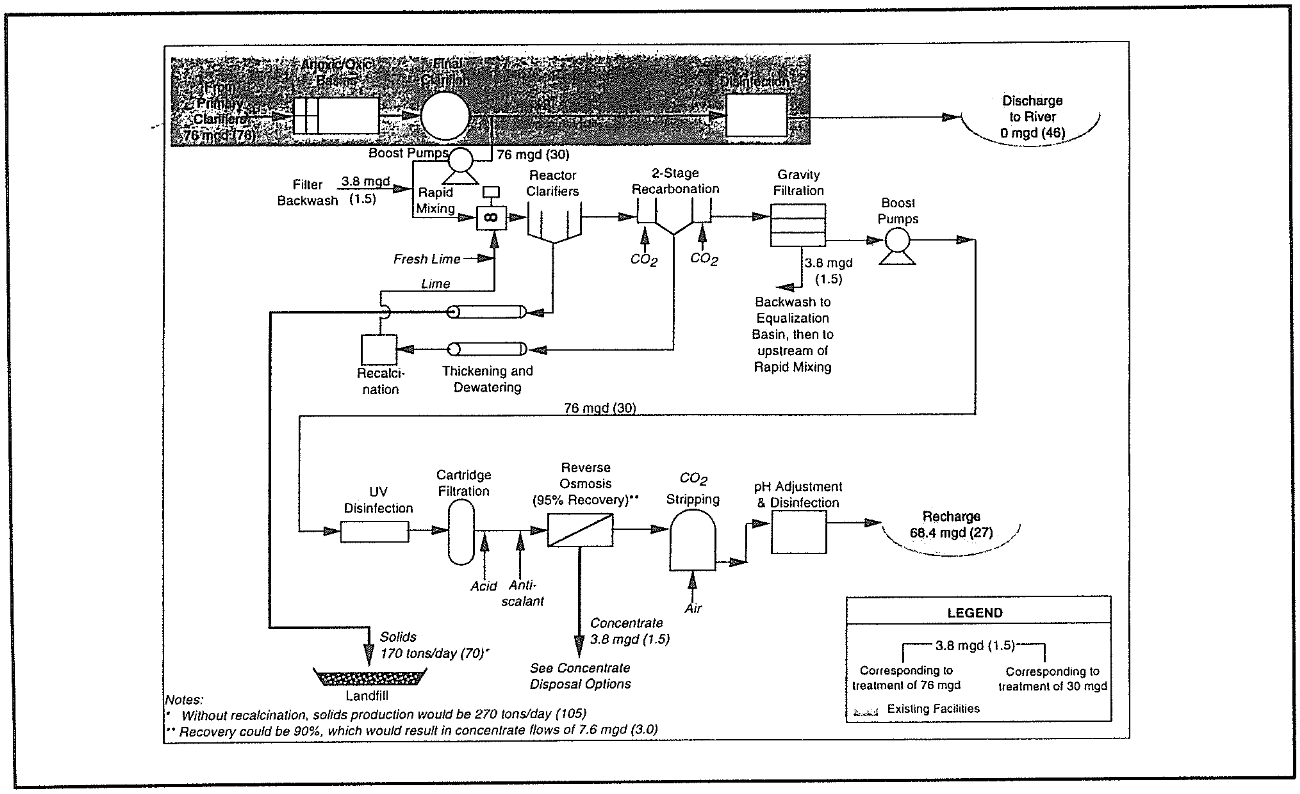

Figure 4. Alternative 1 - Reverse osmosis with lime pretreatment.

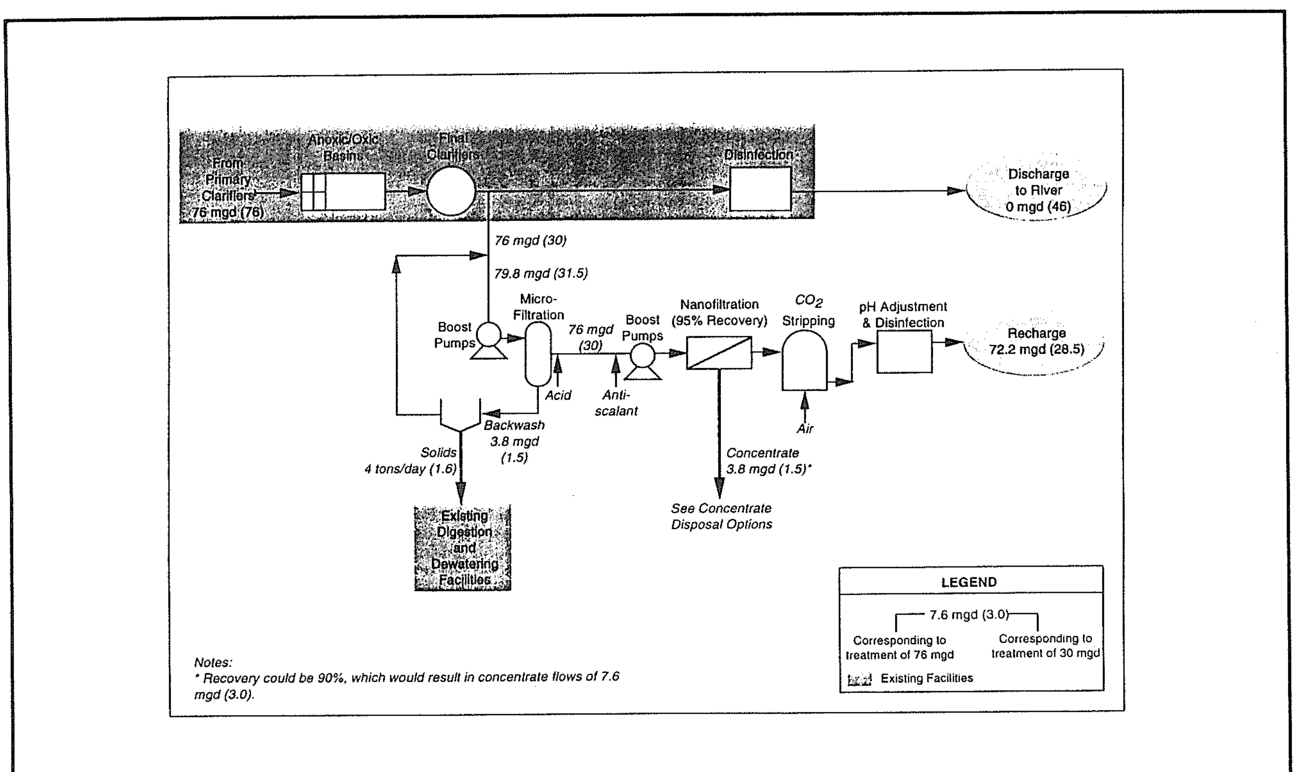

Figure 5. Alternative 3A - Nanofiltration with microfiltration pretreatment.

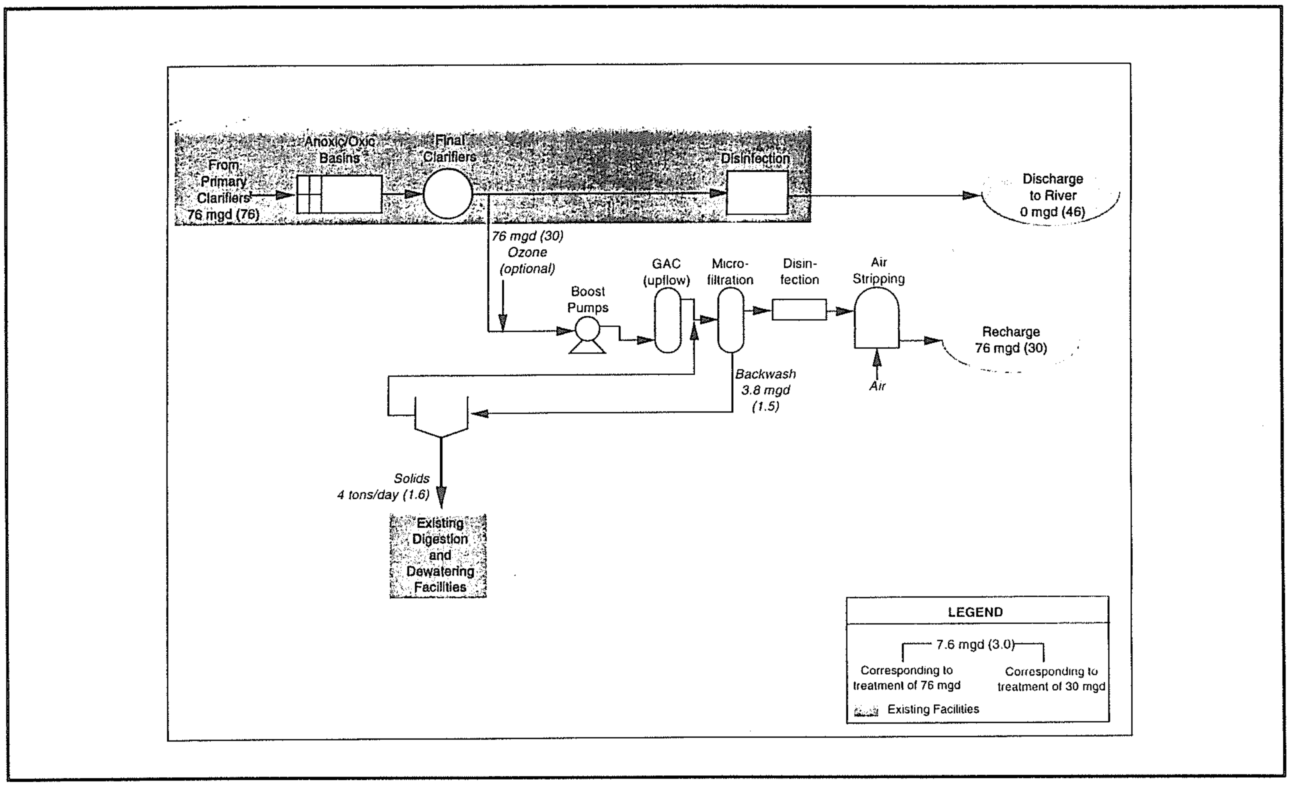

Figure 6. Alternative 5B - GAC with microfiltration post-treatment.

generation. Thus, blending effluent with treated surface water would likely be necessary prior to recharge. With no membrane treatment provided, any necessary further reduction of nitrate would not be achieved with this alternative.

Alternative 6: Nanofiltration and GAC Treatment in Parallel

As indicated in Figure 7, this alternative combines the use of NF with GAC to provide a relatively high degree of TOC removal while reducing the residual generation to levels lower than those associated with purely membrane options. The relative percentages of GAC and NF treatment will be dictated by the treatment goals, although it is anticipated that the GAC portion would treat 25 to 35 percent of the load, with the remainder being treated by the NF train. The Water Factory 21 facility in Orange County, CA is designed around this parallel treatment concept. TOC levels of 2 mg/l can be achieved, with waste residual in the 3 to 5 mgd range for a 76 mgd system.

Disinfection

Disinfection of the effluent prior to recharge is a necessary measure to ensure that adequate pathogen barriers are provided in the treatment train. The various disinfection techniques considered are summarized in Table 3. Because of concern about potential creation of carcinogenic disinfection byproducts in the water supply resulting from the use of chlorine for disinfecting the reclaimed water, it is proposed that ozone be used as the primary disinfectant for all alternatives. However, in order to maintain a residual into the recharge well fields and reduce biofouling on and near well screens, a small dosage of chlorine is recommended. Ozonation and chlorination as described above are provided at the Fred Hervey Plant at El Paso. Control of TOC, and in particular assimilable organic carbon (AOC), has also been shown to be an effective way to minimize biofouling of injection wells.

Membrane Concentrate Disposal

Those alternatives which utilize membrane technology must also include measures for disposal

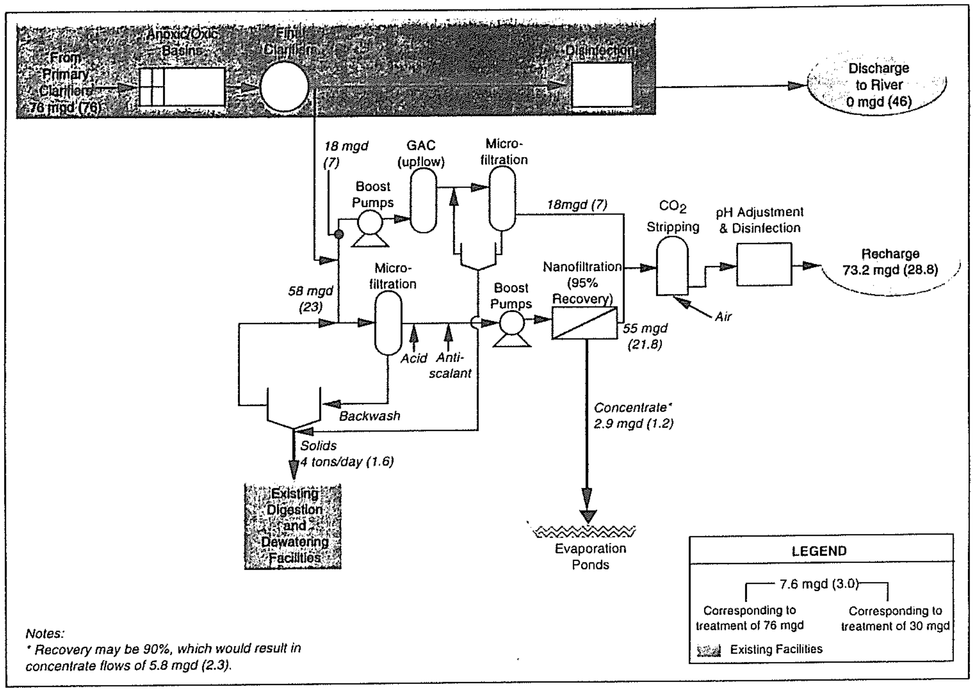

Figure 7. Alternative 6 - Nanofiltration and GAC combination.

TABLE 3. ALTERNATIVE DISINFECTION TECHNOLOGIES (adapted from *Water Quality and Treatment*, AWWARF 1990)

Consideration	Cl_2†	Cl_2/deCl_2	O_3	ClO_2	UV
Size of plant	all sizes	all sizes	medium to large	small to medium	small to medium
Equipment reliability	good	fair to good	fair to good	good	fair to good
Relative complexity of technology	simple to moderate	moderate	complex	moderate	simple to moderate
Safety concerns	yes	yes	moderate	yes	minimal
Bactericidal	good	good	good	good	good
Virucidal	1‡	1‡	good	good	good
By-products of possible health concern	2‡	2‡	3‡	yes	no
Persistent residual	long	none	none	moderate	none
Contact time	moderate	moderate	short (minutes)	moderate	short (seconds)
Reacts with ammonia	yes	yes	limited	no	no
pH dependent	yes	yes	slight	slight	no
Process control	well developed	well developed	developing	developing	developing

† includes chloramination
1‡ moderate for free residual chlorination; poor for combined residual chlorination
2‡ fewer by-products with combined residual chlorination
3‡ health significance of by-products is unresolved at present

of the waste residual (concentrate) generated by RO or NF processes. Concentrate flows for a 76 mgd facility would be in the range of 3.8 mgd (95 percent recovery) to 7.6 mgd (90 percent recovery).

The primary disadvantage to concentrate handling and disposal is cost. Methods are available for recovering most of the water, and hence avoiding wasting this valuable resource. Concentration (distillation) and crystallization will accomplish this, but these techniques can nearly double the cost of the overall treatment system.

Table 4 summarizes the various methods considered for treatment and disposal of concentrate. The most feasible technologies for Albuquerque are illustrated in Figure 8. For costing purposes, the conceptual system layout utilizes concentrators followed by evaporation ponds for the concentrated residual. Other alternatives are still being considered.

TABLE 4. POTENTIAL MEMBRANE CONCENTRATE DISPOSAL TECHNOLOGIES

Concentrate	No
Discharge to surface water	No
Discharge to sanitary sewer	No
Percolation ponds	No
Brine concentrator	Yes
Brine crystallizer	Yes
Evaporation ponds	Yes
Deep well injection	Yes
Saline marshes	No
Electrodialysis	No

GEOHYDROLOGICAL ASPECTS OF A RECHARGE PROGRAM

Scope of Geohydrology Tasks

The key elements of the geohydrologic work to be accomplished under this first phase study were:

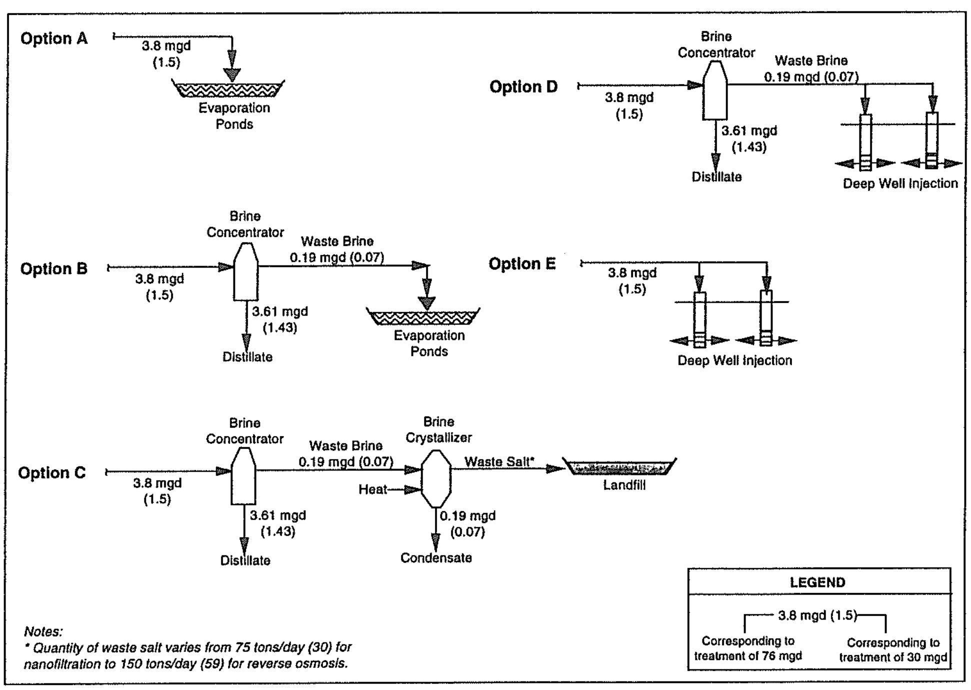

Figure 8. Membrane concentrate disposal options (95% recovery).

1. Define potential areas where injection wells would most feasibly be located. Technical, environmental, economic and political/institutional factors all contribute to identifying potential recharge zones in the Albuquerque metropolitan area.
2. Refine the known characteristics of the basic geohydrologic, geochemical and water quality conditions, including aquifer transmissivity and flow rates, spatial and temporal distribution of supply well pumping, and geologic characteristics. Information sources included the USGS, NMBMMR, the U.S. Bureau of Reclamation, and several local experts associated with these and other organizations.
3. To further evaluate the aquifer system, conduct simple flow modeling for the best potential recharge areas, to determine typical cones of depression/impression, flowfield effects of injection and extraction, annual travel distances and zones of influence, potential injection rates and capacities, and sensitivity to artificial recharge variables.
4. Based on the obtained information and modeling results, select the best zones in the Albuquerque area for groundwater recharge, with adequate areas identified to accommodate up to the full 76 mgd flow plus 50 percent blending (total of 152 mgd).
5. Review existing information relative to groundwater geochemical characteristics and conduct a limited amount of simple geochemical modeling, primarily to determine the sensitivity of the groundwater to varying pH levels and oxidation (DO and chemical) conditions that might be introduced by the injected stream.

Initial Recharge Area Identification

It has been assumed that existing City water supply wells will be used for extraction of recharged water, and one or more general areas (zones) will be required to accept all of the treated wastewater, particularly for the zero-discharge (76 mgd) scenario. An initial evaluation was made of 13 potential recharge areas, located on Figure 9. A matrix-based screening of these areas was conducted, with direct input from local agency officials and City staff. Table 5 is the evaluation matrix which was used. The evaluation found several of the areas to be more favorable than others, with most of these located east of the river and aligned with the north-south axial gravel deposits associated with the ancestral Rio Grande. Several specific zones along this alignment were noted, including the North and Mesa del Sol areas, as being the most preferred. Other favorable locations were the Midtown area, the I-25 corridor, and along the Tijeras Arroyo.

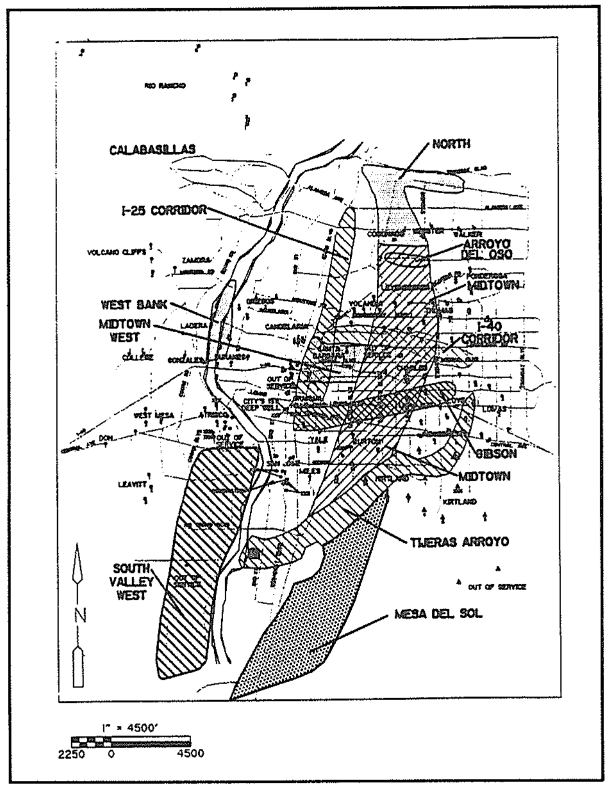

Figure 9. Proposed recharge areas.

Recommended Recharge Zones

Incorporation of Additional Data

Additional sources of information made available to CDM for these efforts included:

- Electronic transfer of GIS-based files and mapping from the City of Albuquerque, including well locations and aquifer properties, along with well records (locations, depths, screen intervals, historic pumping rates, and groundwater quality). Figures 10 and 11 depict groundwater elevations and hydraulic conductivity, respectively, for the aquifer in the general Albuquerque area.

TABLE 5. FACTORS FOR RECHARGE AREA EVALUATION MATRIX

Evaluation Factors	Recharge Areas: North	Midtown	I-40 Corridor	Tijeras Arroyo	Mesa del Sol	West Bank	Calaba-cillas	Gibson	I-25 Corridor	S. Valley West	Arroyo del Oso	Midtown West
Technical/ Environmental												
Aquifer capacity	3	5	4	3	3	2	1	3	2	2	4	2
Existing drawdown	3	4	5	3	2	1	1	4	4	2	5	3
Mounding potential	3	5	4	3	2	2	1	3	3	1	4	3
Low supply well density	4	1	1	4	5	3	5	2	3	5	1	3
GW dilution potential	3	1	2	5	5	4	5	3	2	3	1	2
Contamination proximity	5	3	2	2	4	5	5	2	1	3	4	2
System complexity	3	1	1	4	5	3	5	2	2	4	1	2
Economic												
Proximity to SWRP	1	3	2	4	5	2	1	4	2	3	2	3
Site elevation	4	3	2	2	3	4	2	3	4	5	3	4
Site access*	3	2	3	3	4	2	4	2	3	4	2	1
Treatment level required	1	3	5	3	2	2	1	4	3	3	2	3
Political/ Institutional												
Public acceptance	4	1	3	4	5	2	4	3	3	2	1	1
Benefit to tribal aquifers	5	2	1	4	5	1	4	2	2	4	3	1
Land ownership*	2	1	4	3	5	2	3	2	4	3	2	1
Offset of river depletion*	3	2	3	3	4	5	4	2	4	5	2	3

Notes:
5 = most favorable
3 = neutral
1 = least favorable
* denotes factors to be addressed in later phases of study

- USGS data on aquifer properties, such as hydraulic conductivity, aquifer thickness, hydraulic gradients, and other input from their MODFLOW model.
- New Mexico Bureau of Mines and Mineral Resources reports on the hydrogeologic framework of Albuquerque Basin geology and aquifer characteristics.
- New Mexico Tech reports and a thesis addressing aquifer geochemistry.

CDM conducted groundwater modeling in those general areas judged most favorable for recharge in the initial evaluations, using aquifer property information provided by the USGS. The tool used by CDM was the U.S. EPA Water Hydraulic Profile Analysis (WHPA) Model, GPTRAC Module. This two-dimensional semi-analytical model identified capture zones for existing supply wells, and zones of influence for proposed recharge wells or wells clusters, both for one-year travel times per the criteria previously established. Recharge rates equivalent to 30 mgd and 76 mgd were simulated in the preferred recharge areas, with target injection rates at about one-half of the typical pumping rates. A second groundwater flow model based on the Theis analysis was used to evaluate mounding in the recharge areas. In the North area, the model projected mounding heights of 45 ft. in one year and 80 ft. in 10 years, based on a continuous injection and withdrawal program during those periods. This degree of mounding would not cause the saturated zone to rise above the historic water table surface.

Description of Final Recommended Zones

From these refined analyses, and taking into consideration the actual locations of existing City

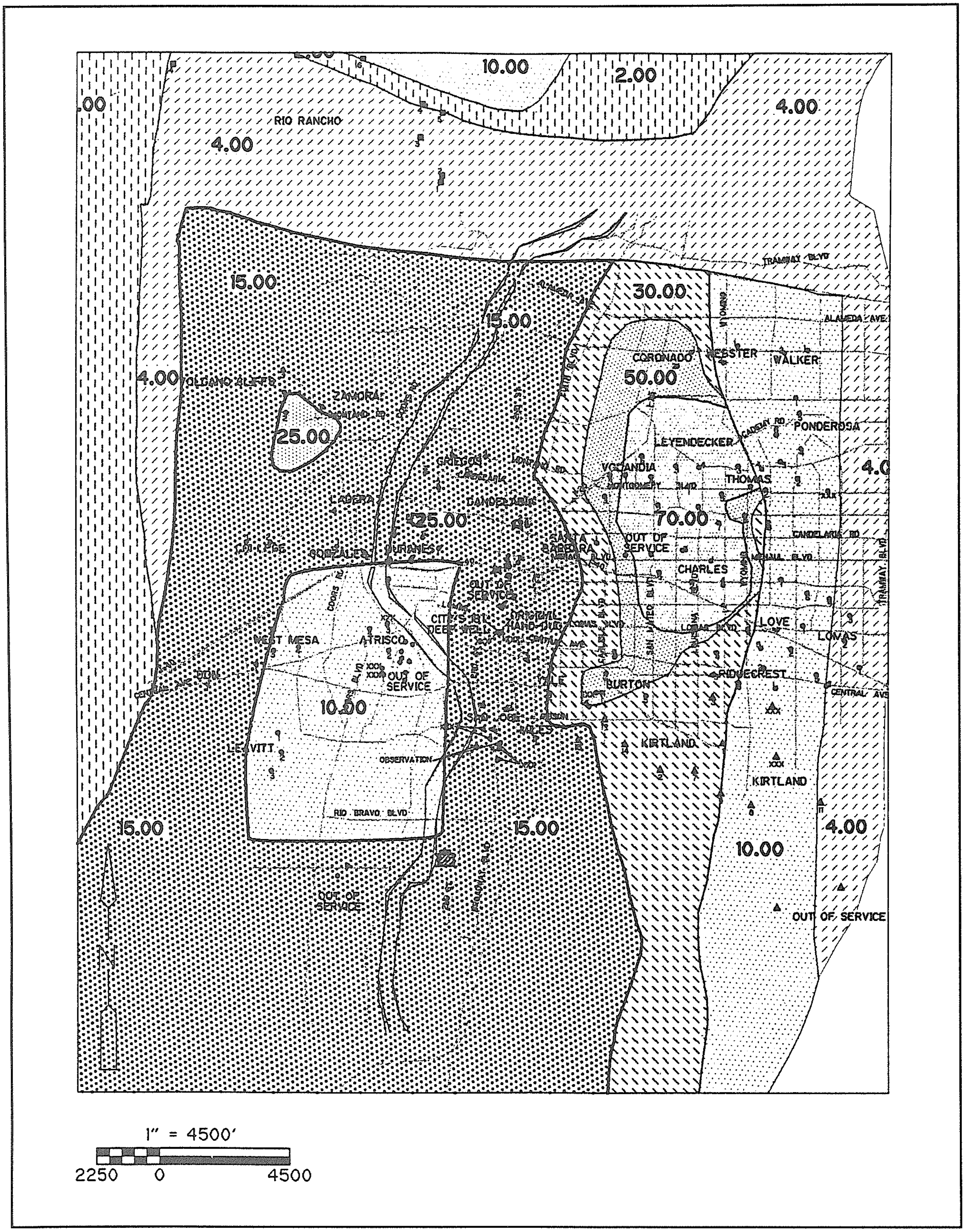

Figure 10. Hydraulic conductivity zones (K in ft/day).

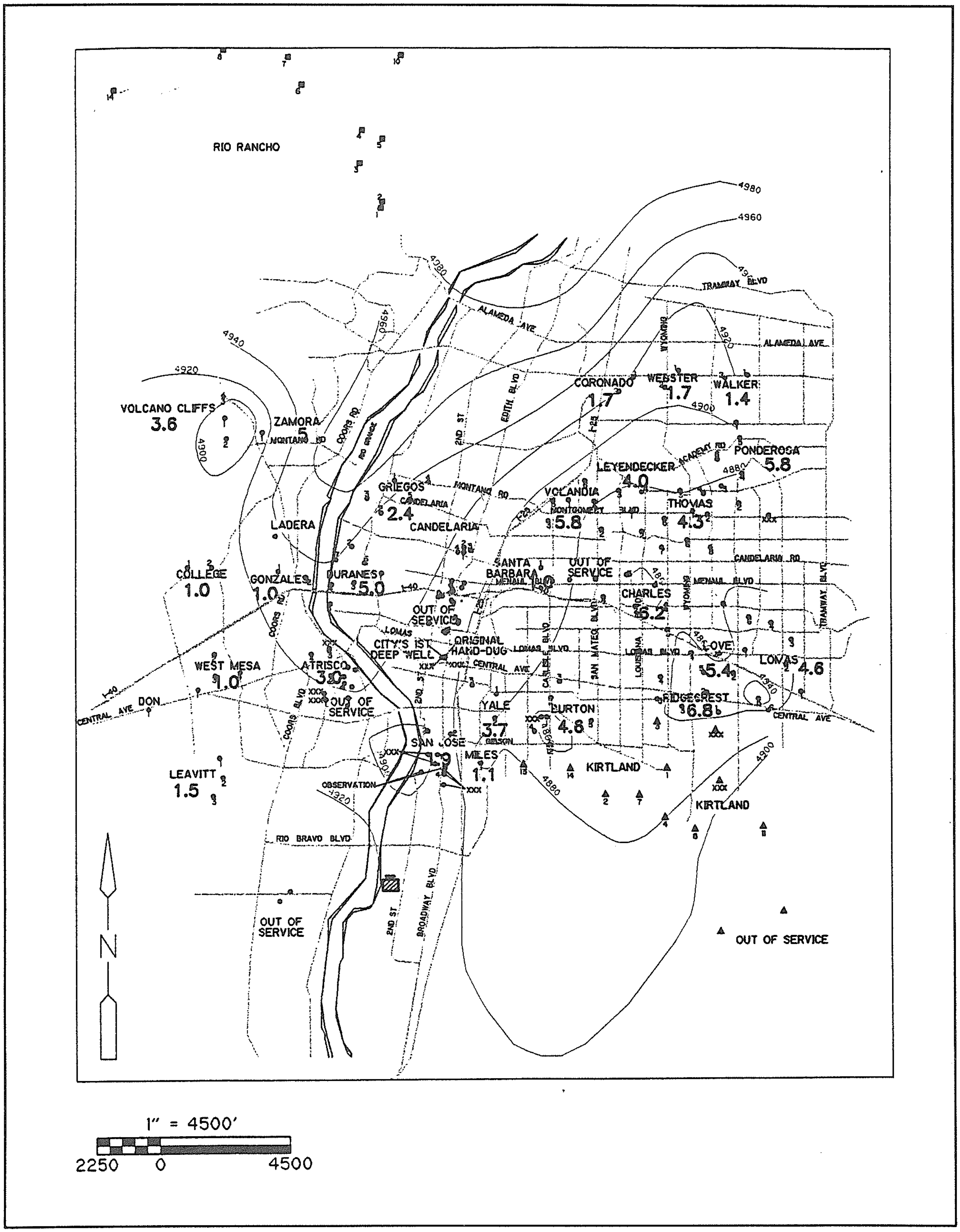

Figure 11. Groundwater elevations and average well field pumping rates (per 1,000 gpm).

supply wells, three recommended recharge zones were defined. These are shown on Figure 12 and are defined as:

- North Zone - to the north and south along San Antonio Boulevard between I-25 and Eubank Boulevard.
- Middle Zone - to the north and south along Lomas Boulevard between I-25 and Wyoming Boulevard.
- South Zone - east of Broadway and immediately to the south of Kirtland Air Force Base and its supply wells.

These three zones all exhibit relatively high conductivity and transmissivity. Drawdown and groundwater depletion are most evident in these areas, due to the high density of wells and the favorable hydraulic characteristics. It is in these areas that Albuquerque's supply wells would benefit most significantly from a recharge program.

Modeling Results and Recharge Zone Capacities

Modeling conducted in these three zones revealed that all have numerous sites where reclaimed wastewater could be injected without intersection with the one-year capture zones of the City's supply wells. If actual injection well sites are available or obtainable in the density and approximate locations needed, then it appears that the full 76 mgd could be injected into any one of these general zones, although using two recharge areas for this flow rate would be more realistic. If 50-percent blending required 152 mgd to be injected, then all three zones, and/or possibly others, would likely be needed.

It also appears probable that the suggested 2,000-ft. setback requirement for well siting could also be obtained, although there is some question as to the need for this restriction, given that the one-year groundwater travel distance was found to be less than 500 feet in most areas. However, based on uncertainties inherent in the modeling simulations as well as future production rates, it was decided that the 2,000-ft. limits should be retained. On the other hand, the GPPAP goals for well head protection, which would require groundwater discharges to be set back from City supply wells based on a 10-year time-of-travel distance, do not apply to this recharge program, since water of potable quality will be injected into the aquifer.

Geochemical Characteristics of the Aquifer

The geochemistry evaluations indicated that iron precipitation could be a limiting factor for recharge if chemical conditioning were not provided to the reclaimed water. This was consistent with geochemical modeling recently conducted by the Bureau of Reclamation. Iron removal, accomplished with membranes or oxidation/separation, or lime precipitation, can be incorporated into any of the final treatment alternatives previously discussed.

LAYOUT AND ESTIMATED COSTS FOR A CONCEPTUAL RECLAMATION AND RECHARGE SYSTEM

At the present stage of the Phase 1 study, the preferred recharge sites and most feasible treatment technologies have been identified. Further research, as well as pilot and demonstration scale studies, are needed to refine the final alternatives and select the best plan. However, the intent of this first phase study is the development of information in sufficient detail to provide a basis for conceptual-level estimates to be made of the infrastructure and associated costs for a complete wastewater reclamation and recharge program. This concept can then be assessed against other long-term water management strategies as well as approaches to meet potential future surface discharge effluent limitations.

Costs for several alternative scenarios currently are being developed. Preliminary estimates for two potential system layouts were recently requested by the City, and are described below. System descriptions are only approximate at this time and subject to revision.

Reclamation and Recharge Program for 30 mgd

Facilities comprising a complete recharge and reclamation scheme for 30 mgd capacity would include an advanced wastewater treatment system constructed at the SWRP utilizing activated carbon and nanofiltration technologies, distillation concentrators and evaporation ponds for resulting waste streams, on-site treated effluent storage, two pumping stations to convey the effluent to well fields, 10 miles of large-diameter transmission piping, approximately 12 miles of small-diameter well and tank service lines, 5 holding reservoirs near the injection sites, and about 26 injection wells with

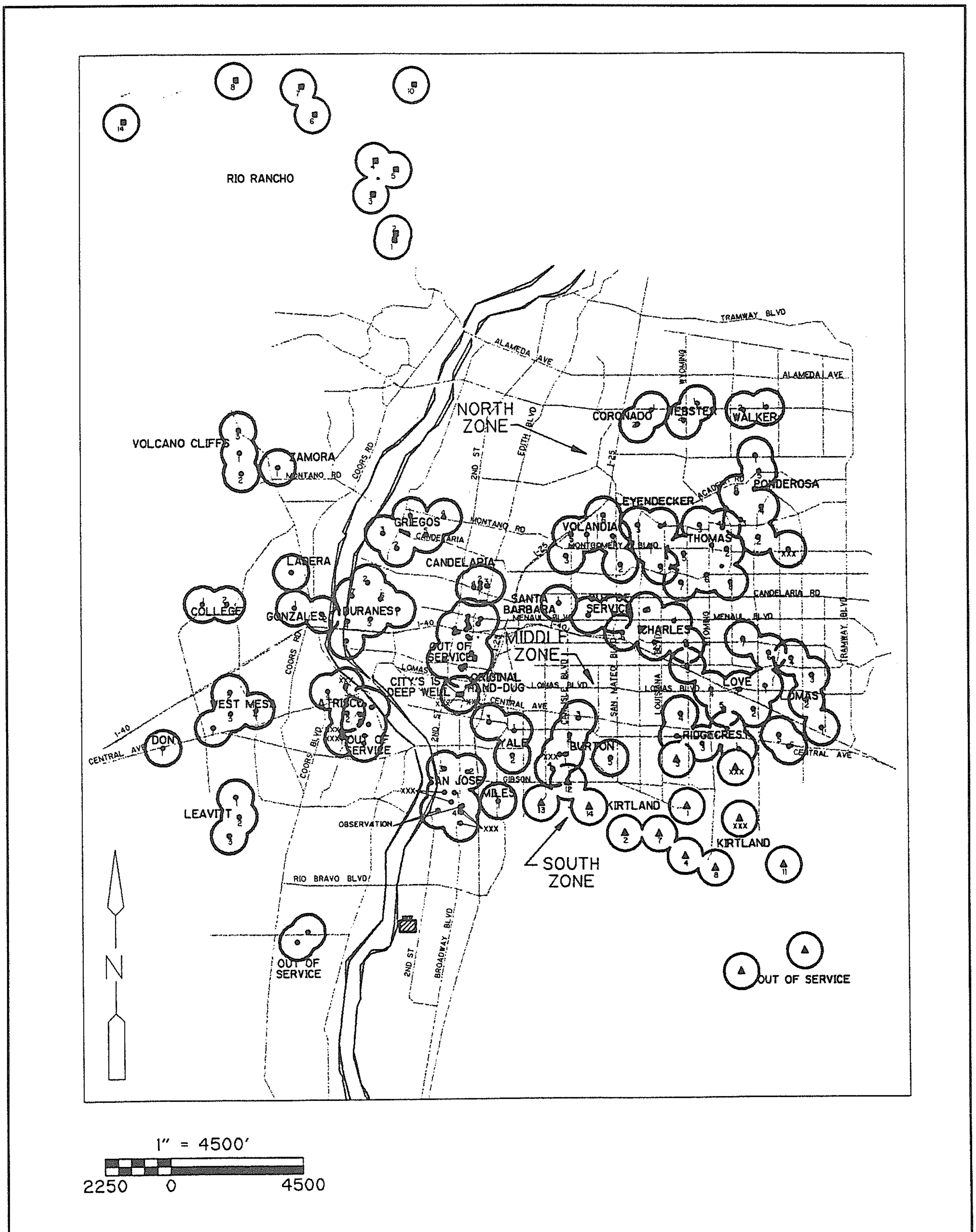

Figure 12. Supply wells with 2,000 ft. exclusion zones.

pumps. The recharge wells would be sited in the Middle Zone, as previously defined. For this alternative it is assumed that blending with treated surface water would not be required for maintaining a 1 mg/l TOC concentration in the aquifer, although further study, along with demonstration-scale testing, is recommended to confirm this. It is possible that blending would be required in the Middle Zone, which would increase the cost.

Reclamation and Recharge Program for 76 mgd

For this zero-discharge option, the assumption is also made that blending with treated surface water would not be required. For this system, it is assumed that the reclaimed water would be injected in both the Middle and North zones. This larger system would require an additional 46 mgd of advanced treatment process capacity, 39 more recharge wells, 10 additional miles of transmission piping, 18 more miles of tank and well service lines, another booster station and 7 additional holding reservoirs, along with additional pumps, clear well capacity, and support equipment.

While not included in the preliminary system layouts described above, the South Zone, or Mesa del Sol area, provides an opportunity to construct an "engineered" system of both injection and extraction wells. The need for blending is far less likely in this area, even with an injected TOC of 2 mg/l or more, since the system could be designed conservatively to minimize the possibility of any short-circuiting. On the other hand, savings in blending water needs may be offset by the costs of constructing new supply wells and interconnecting these facilities, both physically and operationally, with the City's existing water distribution system.

Preliminary Costs for Conceptual Recharge Programs

The estimates provided below are very preliminary in nature, and **exclude** costs for land acquisition, right-of-way, additional water rights for blending or river depletion offsets, and other institutional, legal, and administrative requirements. Recharge rates per well have been conservatively estimated at 800 gpm, although lower rates (and additional wells) could be required depending on final well spacing, locations, and pilot testing. All costs are based on 1994 dollars.

- Capital costs for the 30 mgd reclamation and recharge system as described above would be from $250 to $300 million, with annual operation costs in the $20-25 million range.
- Total capital costs for the 76 mgd system are estimated from $600 to 700 million, with annual operating costs in the vicinity of $50 million.

WORK TO BE ACCOMPLISHED UNDER PHASE 2 OF THE RECLAMATION AND RECHARGE PROGRAM

Significant additional work will be required to further assess the feasibility of indirect potable reuse for Albuquerque prior to identifying the best plan and committing to major financial investments. Phase 2 of the program will address many of these needed efforts, which include:

- Further assessment of water quality requirements, particularly limitations for total organic carbon (TOC) and total dissolved solids (TDS).
- Identification of options for blending water sources.
- Development of agreements with the State Engineer Office regarding credits for aquifer recharge and reduced depletion effects on flow in the Rio Grande.
- Pilot-scale testing of advanced and high-technology treatment and residuals management systems and equipment, to refine technologies and operation parameters for the final alternatives.
- Pilot and demonstration-scale testing of groundwater injection systems to refine current geohydrologic information, geochemical condition data, and blending water requirements.
- Further consideration of other indirect potable reuse techniques, potential non-potable reuse applications (in combination with recharge), and other long-term water management strategies.
- Determination of the locations and availability of actual recharge well sites, and actions needed, and associated costs, for acquisition of sites.

- Further assessment of other defined recharge areas beyond the three recommended zones.
- Implementation of a public information and involvement program.

CONCLUSION

Indirect potable reuse is a technically feasible concept for the City of Albuquerque, both from a water quality point of view and as a long-term water resource management strategy. Wastewater effluent can be reliably treated to meet or exceed drinking water standards and groundwater protection regulations. Local hydrogeological conditions are favorable for direct injection of 30 mgd or 76 mgd, the two flow scenarios considered in this feasibility study.

Indirect potable reuse is a potential solution to two concerns of the City. First, reuse of 76 mgd would be one means of addressing very restrictive limitations which may be imposed on the City's effluent discharge in the future. By reclaiming the entire effluent flow, zero discharge to the Rio Grande could be achieved and compliance with potential discharge limitations would not be necessary. Alternatively, the City could provide advanced treatment to meet the discharge limitations, which may be much more restrictive than drinking water standards, and continue discharging to the Rio Grande.

A second concern of the City is the need for a long-term water resources management strategy which addresses water supply quality and quantity considerations together with wastewater management issues. Reuse of effluent via a direct injection scheme could extend the useful life of the City's water rights and reduce depletion of the groundwater resource. There are water resource management options other than indirect potable reuse, and these are also being investigated by the City.

The capital and operating costs of indirect potable reuse for the City will be very high, as the result of stringent treatment requirements, residual waste management difficulties and extensive infrastructure requirements. The cost of reclamation and recharge will therefore need to be compared along with the estimated costs of other water management strategies and with the cost of treatment alternatives to meet potential future effluent discharge limitations.