Alternative: Aquifer Storage and Recovery

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1. Summary of Alternative

Aquifer storage and recovery (ASR) involves recharge to and recovery of water from an aquifer, that is, both artificial recharge of the aquifer and recovery of the water for subsequent use. Artificial recharge facilities include infiltration basins (spreading basins), infiltration galleries (recharge trenches), vadose zone recharge wells (dry wells), and combination groundwater recharge/recovery wells (Bouwer, 1996).

ASR is increasingly being used in the United States to assist in managing water resources, particularly in the arid Southwest. For example, more than 20 full-scale artificial recharge projects are currently operating in the vicinity of Phoenix, Arizona, with several of these having storage capacities in excess of 100,000 acre-feet (Unangst et al., 1999). Source water for some of these projects is surface water derived from the Colorado River, while others recharge treated wastewater effluent. ASR has not yet been implemented on a large scale in New Mexico, but all indications are that it will become increasingly important over the coming years.

Potential benefits of ASR and artificial recharge include:

- Seasonal and long-term storage of excess surface water (water banking)
- Minimization of surface storage costs
- Method of accommodating supply and demand peaks
- Disposal and storage of excess stormwater
- Disposal of treated wastewater effluent (zero discharge)
- Replenishment of groundwater supply
- Improved water quality (soil-aquifer treatment)
- Attenuation of water quality changes over time

- Minimization of evaporative water losses (vs. surface storage)
- Opportunity to obtain return flow credits
- Reduction of land subsidence rates

In the Jemez y Sangre region, ASR is applicable to three of the alternatives identified by the Planning Council: (1) bank water (inject surface waters for retrieval at a later time), (2) treat wastewater and inject as artificial recharge, and (3) manage storm water. Because existing water/water rights must be used for ASR, new water is not created to meet growing demand. ASR will however, provide a mechanism for reusing effluent or storing other water rights when surface water rights and supply exceed current demand.

2. Technical Feasibility

The technical feasibility of ASR within the study area depends primarily on (1) locating a suitable water source and (2) identifying a suitable recharge site. The Jemez y Sangre planning region includes many areas where suitable hydrogeologic conditions exist to implement ASR. In particular, arroyos and stream channels containing thick sequences of coarse-grained alluvium are ideal candidates. Site-specific hydrogeologic studies would be required within a given sub-basin to identify the preferred sites.

Availability of surface water and treatment requirements for wastewater are considered in separate white papers (DBS&A, 2002a, 2002b). Assuming that a suitable water source is available, the technical feasibility of ASR depends largely on hydrogeologic conditions underlying the area of interest. In most situations, pilot testing of a small-scale recharge facility is required to ensure that the chosen design (e.g., infiltration basin) will work at the site and to provide information necessary for developing a full-scale system. Pilot testing also provides insurance against “fatal flaws” in the site conceptual model and can provide useful information regarding hydraulic capacities, water table responses, water travel times, and water quality changes that may occur in the vadose (unsaturated) zone. The various types of artificial recharge facilities are described briefly in Sections 2.1 through 2.4. Figure 1 illustrates each type of system.

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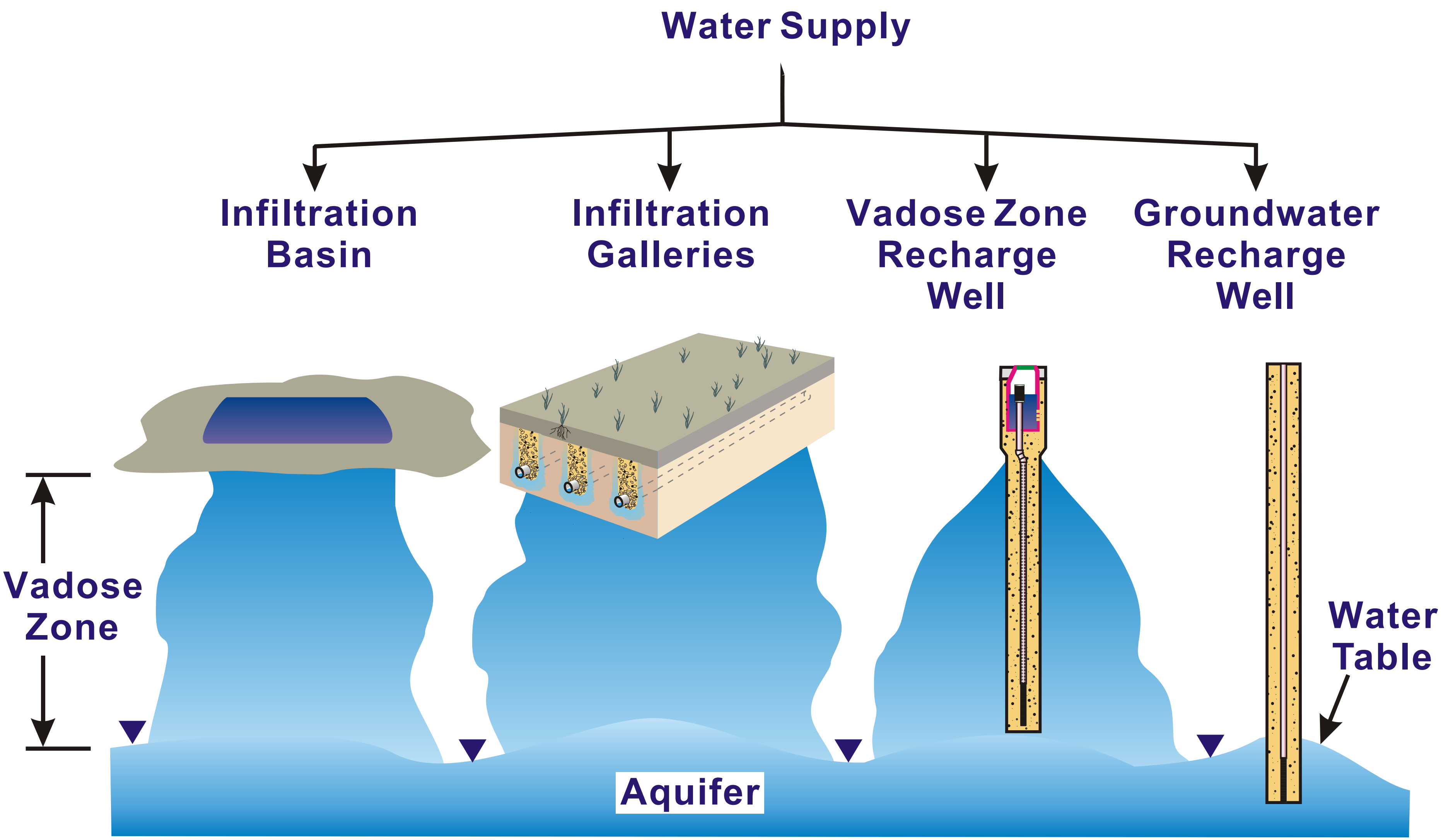

Not to Scale

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JEMEZ Y SANGRE WATER PLAN
Artificial Recharge Technologies

Figure 1

2.1 Infiltration Basins

Infiltration basins, also know as spreading basins, are shallow ponds with leaky bottoms that are designed to maximize the downward infiltration of water. Where favorable geology exists, infiltration basins are perhaps the least costly means of recharging groundwater. Basins require (1) the presence of permeable soils or sediments at or near the land surface and (2) an unconfined aquifer beneath. Shallow basins with water depths of less than 1 meter are more effective in maximizing infiltration rates over time (Bouwer, 1989) for the following reasons:

- They result in short pool water residence times.
- Growth of algae is minimized.
- Shallow depths reduce compaction of the clogging layer that develops on the basin floor and, when clogging does begin to occur, basins are more easily maintained by draining and removing a thin layer of sediment from the basin floor.
- Construction costs are lower for shallow excavations.

Although evaporation is sometimes perceived as a drawback of this technology, evaporative losses for properly functioning infiltration basins should total no more than a few percent of inflow.

Infiltration basins also provide a beneficial effect on water quality as a result of soil-aquifer treatment (Bouwer, 1992). Among the more important processes are reduction in the concentrations of nitrogen, organic carbon, bacteria, and viruses, and removal of taste and odor. Nitrate, if present in the supply water, may be removed by denitrification in the soil, and pathogenic bacteria and viruses tend to become adsorbed onto the soil matrix and thereby immobilized.

One disadvantage of infiltration basins is that they require relatively large areas of land to construct, as compared with recharge wells. If the land must be purchased, this can add considerably to project costs. Furthermore, groundwater mounding may preclude use of basins in shallow groundwater settings (Bouwer et al., 1999).

Depending on their proximity to surface water channels, infiltration basins may be categorized as either in-channel or off-channel. Where arroyos or stream valleys are underlain by permeable sediments, in-channel recharge basins could be viable options within the Jemez y Sangre planning region. It has been shown that infiltration rates into the bed of the Santa Fe River are appreciable (Thomas et al., 2000), indicating that in-channel recharge basins may be feasible within the study area. In-channel recharge is being successfully performed at several locations in Arizona and California. For some of these projects, inflatable rubber dams or temporary “T dikes” have been used to pond or spread water to maximize infiltration during low flow periods.

2.2 Infiltration Galleries (Seepage Trenches)

Galleries or trenches for recharge purposes are typically excavated using a backhoe to depths of up to 15 or 20 feet below surface. The trench is backfilled with permeable coarse sand or fine gravel. Perforated or slotted pipe laid on top of the backfill in the trench allows the introduction of water along its length. Similar to infiltration basins, seepage trenches require the presence of permeable soil close to land surface, although trenches can be excavated deeper than basins, exposing more permeable sediments below the low-permeability clayey soils that can exist at the surface. Less land is required for trenches than for basins, and trenches are much less conspicuous because they can be covered to blend in with the surroundings. Construction costs for trenches are intermediate, between those for low-cost infiltration basins and those for drilling of expensive recharge wells. Unlike basins, which can be easily cleaned, little can be done to reverse the effects of clogging of trench walls, aside from installing additional lengths of trench.

2.3 Vadose Zone Recharge Wells (Dry Wells)

Vadose zone recharge wells, also known as dry wells, are large-diameter wells completed above the water table that are designed to optimize infiltration of water. Recharge water is delivered to a vertical well screen or perforated pipe that permits water to enter permeable sediments within the vadose (unsaturated) zone. Well diameters of 3 or 4 feet are common, and well depths may be up to 150 or 200 feet. Thus dry wells can be used where permeable sediments are not present at the shallower depths required for basins or trenches. Special drilling methods (e.g., bucket auger drilling) are used to drill the large-diameter holes without introduction of drilling muds, and the wells are backfilled with fine gravel.

Although construction costs can be significantly higher than for basins or trenches, vadose zone wells are by nature shallower than groundwater recharge wells. Where depths to groundwater are great, vadose zone wells can therefore be less expensive to drill and install than groundwater recharge wells. Recharge wells require only a minimum amount of land, which is a particular advantage in urban settings. Like trenches, however, only limited maintenance is possible should clogging of the vadose zone well occur. For this reason, it is imperative that the turbidity and organic carbon content of the influent water be as low as possible to preclude premature clogging of the well with fine sediment or biological solids. Pretreatment of treated wastewater effluent or turbid surface water would therefore be required.

2.4 Groundwater Injection/Withdrawal Wells

Groundwater recharge wells penetrate an aquifer and can be used either for injection or withdrawal of water (Pyne, 1998). Because of their deeper depth, they are more expensive to install than any of the shallower technologies. It is possible, however, to convert inactive water-supply wells to groundwater recharge wells, resulting in considerable cost savings.

As with all wells, land requirements are minimal. Because water can also be pumped out of the well, maintenance by periodic well redevelopment is possible. Regular pumping of the well, for example 15 minutes every day, may delay or prevent serious clogging of the well and the need for redevelopment. Because water is injected directly into the aquifer, the beneficial effect on water quality that is observed during recharge into infiltration basins (Section 2.1) does not occur with recharge wells. For this reason, it can be assumed that the quality of influent water put into groundwater recharge wells must comply with drinking water or New Mexico Water Quality Control Commission (NMWQCC) groundwater standards. To achieve these standards in wastewater effluent would require extensive and costly pretreatment, such as reverse osmosis or other membrane filtration.

3. Financial Feasibility

The cost to implement aquifer storage and recovery will depend on many site-specific factors, including site hydrogeology and the water quality of the proposed influent. Infiltration basins are generally the least expensive option, followed by recharge trenches and vadose zone wells, with groundwater recharge wells being the most costly.

Costs to implement ASR at a given location may include:

- Pilot testing costs
- Land acquisition costs
- Influent water pretreatment costs
- Environmental permitting costs
- Design and construction costs
- Operation and maintenance costs

The costs for pilot testing of the proposed technology at the site must be included in any ASR plan. The information gained from pilot testing can result in much larger savings during implementation of full-scale ASR.

Costs to obtain environmental permits from regulatory agencies can be significant for treated wastewater effluent, which raises concerns over the potential for contamination of aquifers. Such projects must comply with the requirements of the New Mexico Underground Storage and Recovery Regulations and Underground Injection Control (UIC) regulations. Even if the water meets all drinking water standards, concerns persist over the possible presence of pharmaceutical compounds in the treated effluent and the need for reverse osmosis to remove them (Sedlak, 1999). Additional discussion of wastewater treatment is provided in a separate white paper.

An idea of design and construction costs for a system of infiltration basins may be appreciated by considering three active projects in Arizona, as outlined in Table 1.

Table 1. Example Infiltration Basin Costs

Project Name	No. of Basins	Total Basin Acreage	Infiltration Rate (af/yr)	Approximate Project Costs [a] ($)		
				Design	Construction	O&M
GRUSP [b]	6	211	100,000	NA	NA	250,000/yr
CAVSARP [c]	9	290	100,000	1.3 million	8.0 million	NA
Sweetwater [c]	4	14	14,000	0.5 million	1.5 million	NA

[a] Does not include delivery pipeline, recovery wells, monitoring network, or O&M costs.
[b] Granite Reef Underground Storage Project (Lluria, 1999; Herman Bouwer, personal communication, 2002.)
[c] Central Aura Valley Storage and Recovery Project (CAVSARP) and Sweetwater Project information from Marie Light (Tucson Water), personal communication, 1999.

af/yr = Acre-feet per year
O&M = Operation and maintenance
NA = Information not available

4. Legal Feasibility

The Ground Water Storage and Recovery Act, NMSA 1978, §72-5A-2 (Act), provides the legal mechanism for aquifer storage and recovery. In enacting the Act, the Legislature specifically found that the “conjunctive use and administration of both surface and ground waters are essential to the effective and efficient use of the state’s limited water supplies” and that ground water recharge, storage and recovery have the potential to reduce the rate of aquifer decline, promote conservation, serve public welfare, and lead to more effective use of water resources. Water stored pursuant to the Act is exempt from forfeiture (NMSA 1978, §72-5A-8). Water can be stored pursuant to this statute only by permit, and a number of criteria must be met before a permit will issue (NMSA 1978, §72-5A-6). The State Engineer has adopted Underground Storage and Recovery regulations (19.25.8.1 NMAC). These regulations govern the application process, the hydrologic, technical and financial capability report requirements, and the permit terms and conditions authorized under the Act.

Storage of water under the Act would also have to comply with all requirements of New Mexico’s Underground Injection Control (UIC) Program, as implemented through the Water

Quality Act (NMSA 1978, §74-6-1 *et seq.*) and the UIC regulations (20.6.2.5000 NMAC). The UIC regulations control discharges from UIC wells to protect groundwater that has an existing concentration of 10,000 mg/L or less of total dissolved solids. Groundwater management injection wells used to replenish water in an aquifer are governed by the UIC regulations. Pursuant to the UIC regulations, a groundwater discharge permit must be obtained from the New Mexico Environment Department prior to use of a groundwater management injection well.

5. Effectiveness in Either Increasing the Available Supply or Reducing the Projected Demand

The effectiveness of ASR at other sites around the U.S. and the world is well documented. While ASR does not provide a new source of water, it does constitute a very effective means of storing large volumes of water underground for subsequent use at costs that are much less than the equivalent storage in surface reservoirs, and with the added benefit that evaporative losses are nearly eliminated. Stormwater flood flows represent another potential water source for recharge of aquifers using ASR (Bouwer and Rice, 2001). Moreover, if permitting issues for recharge of treated effluent can be resolved, ASR provides an inexpensive and effective means of “polishing” water quality, using SAT, to remove trace constituents prior to consumption.

6. Environmental Implications

The environmental implications of ASR projects depend largely on the quality of the proposed influent water. Regulatory agencies are understandably much less concerned about clean water ASR projects, such as stormwater recharge, than about projects involving reuse or recharge of wastewater effluent. On the other hand, public perception of wastewater reuse is increasingly favorable, especially if the project does not involve “toilet to tap” connections. In this regard, ASR is quite attractive in that it offers the possibility that treated effluent undergo some degree of cleansing and blending with natural groundwater in the subsurface prior to reuse (Bouwer, 1991, 1992). Two major health effects studies in California have shown that such a potable water supply that contains an appreciable component of reclaimed water has no adverse human health effects (Nellor et al., 1984; Sloss et al., 1996). However, some public concerns may be raised about the prudence of blending treated wastewater with a limited supply of clean groundwater.

7. Socioeconomic Impacts

The Jemez y Sangre region of northern New Mexico is distinguished by its rural and agricultural character, predominantly Indian and Hispano population, localized land-based economies, and pockets of persistent poverty. In particular, its Indian and Hispano populations represent some of the most unique cultures in the world, products of a long history of continuous human habitation, adaptation, and cultural blending. Land-based Indian and Hispano cultures still thrive, carrying on centuries-old cultural traditions that include distinctive land-use and settlement patterns, agricultural and irrigation practices, natural resource stewardship practices, social relations, religious activities, and architecture. An example is the ancient acacia tradition, which is vital both as a sustainable irrigation system for subsistence and market agriculture and as part of the social glue that holds together rural communities.

The survival of these deeply rooted local traditions is essential for the continuity of rural culture and communities and, in turn, for the local tourism industry, which is built in large part upon the singular cultural and historical personality of the region. Preservation of these traditions is therefore an important consideration in determining the socioeconomic and cultural impacts of regional water planning.

By making more water available to more populous urban areas, this alternative would have the primary indirect socioeconomic and cultural benefit of reducing the desire for and pressure on upstream rural and agricultural surface water rights to support municipal and industrial needs. In addition, increasing available water would probably reduce the cost for all water users. A possible detrimental impact that should be carefully considered is the reduction of available streamflow for downstream water right owners if stormwater spikes or discharge from wastewater treatment facilities are reduced.

8. Actions Needed to Implement/Ease of Implementation

Because of the importance of site-specific hydrogeologic variables, experience has shown that ASR projects are best implemented using a phased approach for scale-up from pilot studies to the full-scale system (ADWR, 1999). A pilot recharge study is first performed to demonstrate proof of concept and to select the most appropriate technology (e.g., basins or wells). The pilot system can then be safely expanded to an intermediate-size system with assurance that it will function as expected.

9. Summary of Advantages and Disadvantages

Advantages of ASR over surface storage reservoirs may include:

- Little or no evaporative water loss underground
- Much smaller land requirements
- Potentially lesser permitting requirements
- Much lower costs per acre-foot of water stored
- Beneficial water quality effects
- Possibility of return flow credits
- Restoration of declining groundwater levels
- Reduction of land subsidence
- Prolonged lifetime of existing well fields

Disadvantages of ASR could include:

- Need for pilot testing
- Need for favorable subsurface hydrogeology
- Increased pumping costs to recover groundwater

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