Appendix F

White Papers

Jemez y Sangre
Regional Water Plan

March 2003

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Jemez y Sangre Regional Water Plan

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White Paper 1

Alternative: Restore and Manage Forests, Piñon-Juniper Woodlands, and Riparian Systems

Alternative: Restore and Manage Forests, Piñon-Juniper Woodlands, and Riparian Systems

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Lee MacDonald, Colorado State University (primary author), Mike Wirtz (financial and technical), Alletta Belin (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

The alternative addressed in this white paper looks at the management of three distinct ecosystems: forests, piñon-juniper woodlands, and riparian systems. For the purpose of this white paper, these ecosystems are defined as follows:

- Forests are the areas dominated by conifers and aspens. In general, the forest zone can be broken up into three main vegetation types: (1) the lower-elevation ponderosa pine zone, (2) the middle-elevation mixed conifer zone, and (3) the upper-elevation zone dominated by spruce or aspen.

- Piñon-juniper woodlands are those areas where the overstory is dominated by piñon pine, juniper, or both.

- Riparian zones technically occur along all streams and rivers, but for the purpose of this white paper the term “riparian systems” will only refer to the areas along lower-elevation intermittent or perennial streams below the forest zone. Riparian zones within the forest are explicitly or implicitly included in the discussion of the management options in forested areas.

The focus of this alternative is assumed to be the potential to increase water yields through vegetation management. However, the potential for increasing water yields cannot be separated from the potential effects on runoff processes, erosion, and water quality. Hence the discussion of management alternatives includes an assessment of the potential positive and negative effects on water quality.

The potential increase in yield will increase the amount of wet water available for existing water rights in the region. This alternative is not considered as one that will provide new water to meet growing demand, but rather as an alternative that protects and restores existing water supplies (and ecosystems), thus reducing the need to purchase additional water supplies.

In the past couple of decades forest density has generally increased due to the suppression of fire and the limited amount of timber harvest. This has almost certainly resulted in a decrease in water yields. Management activities such as forest harvest or thinning could potentially increase water yields. In addition, reducing vegetation density can help lower the risk of severe wildfires. As seen in the case of the Cerro Grande and numerous other fires (Robichaud et al., 2000; Moody and Martin, 2001), high-severity fires can greatly increase the size of peak flows and surface erosion rates, increase channel erosion, cause downstream sedimentation, and adversely affect water quality.

In the piñon-juniper zone there also has been a general increase in tree density, as well as a corresponding reduction in the abundance of forbs and grasses. Past management practices have focused on reducing woody vegetation and increasing the amount of forbs and grasses, but increases in herbaceous vegetation have generally been short-lived. Efforts to reduce the amount of woody vegetation will have a negligible effect on water yields, as the annual precipitation is simply too low; any reduction in transpiration will be lost to a corresponding increase in evaporation (e.g., Bosch and Hewlett, 1982). Changes in the intensity of grazing could potentially affect the partitioning of rainfall between surface runoff and infiltration and, hence, the amount of hillslope and riparian erosion, as well as water quality, channel morphology, and aquatic habitat.

In the riparian zones the two primary management issues are grazing and the invasion of exotic species. Grazing practices would have little or no effect on water quantity, but can have a much bigger effect on water quality than efforts to control exotic species. The control of exotics is primarily an ecological issue and cannot be expected to greatly affect either water quality or water quantity within the Jemez y Sangre region.

2. Technical Feasibility

2.1 Restore and Manage Forests

The management activity with the greatest potential to increase water yields is to reduce forest density. In general, water yield increases are proportional to annual precipitation and the proportion of the forest canopy (usually expressed in terms of basal area) that is removed (Bosch and Hewlett, 1982; Troendle and Kaufmann, 1987). Little or no water yield increases can be expected in areas where annual precipitation is less than about 450 to 500 mm (18 to 20 inches) (Ffolliott and Thorud, 1975; Bosch and Hewlett, 1982; Stednick, 1996) or in areas at or near timberline, where there is insufficient vegetation to make transpiration a dominant source of water "loss."

Research in Colorado has shown that water yield increases in the higher elevation lodgepole and spruce-fir forests are directly proportional to the amount of basal area that is removed (Troendle and King, 1987). However, limitations in the accuracy of streamflow measurements and the regressions between paired basins means that at least 20 to 25 percent of the basal area within a watershed must be removed in order to detect a statistically significant change in runoff (Troendle and King, 1987; Troendle et al., 2001). Smaller reductions in basal area would be expected to increase streamflow, but one cannot expect to measure these predicted increases.

The large variability in annual precipitation is another important limitation to managing forests for water yield. Water yield increases are directly proportional to precipitation, and the coefficient of variation for annual rainfall for forested areas in and around the study area is close to 25 percent (DE&S, 2001). Data from the Fool Creek study in central Colorado showed that water yield increases in dry years were only about one-quarter of the increases in wet years (Troendle and King, 1985). This means that water yield increases from forest harvest would be least in the dry years, when they are most needed, and greatest in the wet years, when they are least needed. The presence of storage reservoirs with sufficient capacity to carry over excess water from wet years is therefore an important factor in determining whether forest management is a feasible option for increasing water yields.

It also is important to recognize that most of the increase in water yield in snow-dominated areas comes on the rising limb of the snowmelt hydrograph. At Fool Creek in Colorado, May was the only month with a statistically significant increase in monthly water yields (Troendle and King, 1985). Paired watershed experiments in areas with more substantial amounts of summer rainfall have sometimes yielded large increases in summer runoff in percentage terms, but the amounts are very small in absolute terms (e.g., less than 0.1 cubic feet per second [cfs] per square mile) (Austin, 1999). Again this suggests that some storage will be required if most of the harvest-generated increases in runoff are to be used between the beginning of July and approximately mid-April.

Another technical limitation for increasing water yields is the fact that the increased water yields diminish as the forest regrows. Long-term data from the Fool Creek study suggest that approximately 60 to 70 years are required for water yields in the subalpine zone to return to pre-harvest levels (Troendle and King, 1985). The recovery rate for aspen, however, is substantially shorter. In the Wagon Wheel Gap paired watershed study, the increase in water yield disappeared within a few years due to a series of dry years and rapid regrowth of aspens (Bates and Henry, 1928; C. Troendle, 1983, U.S. Forest Service, personal communication, 2000). More recent modeling efforts have assumed that aspen reaches full hydrologic recovery in 30 years, although the potential range is from 15 to 45 years (Troendle and Nankervis, 2000). The hydrologic recovery associated with forest regrowth means that the average, long-term increase in water yield is much less than the water yield increase observed in the first few years after treatment (Rector and MacDonald, 1987).

In summary, the average long-term increase in water yield depends on the annual precipitation, the species being treated, the proportion of the canopy that is removed, the regrowth rate, and the length of time between treatments. The timing of the increase in runoff may not match up well with the timing of peak demand, so some storage capacity may be required to obtain the full benefits of any projected increase in streamflow.

These principles mean that the greatest potential for increasing water yields is in the higher-elevation spruce forests. The aspen and mixed conifer forests have a more limited potential for increasing water yields because of the lower annual precipitation and the more rapid hydrologic recovery of aspen sites.

The smallest potential for increasing water yields is in the ponderosa pine forests. In these drier sites the remaining vegetation and soil evaporation will take up more of the water that is ”saved” by the reductions in interception and transpiration, and less regrowth will be needed before the site has hydrologically recovered. Observed increases in flow from the harvest of ponderosa pine stands in other areas has ranged from zero to a maximum of 2 inches per unit area (Rich, 1972; Brown et al., 1974; Ffolliott and Thorud, 1975; Gary, 1975; Troendle, 1983). A recent study of the potential for increasing water yields in north-central Colorado assumed that harvesting ponderosa pine would result in no net increase in water yield (Troendle and Nankervis, 2000). Reiland’s (1976) study of annual water yields in the Pojoaque basin assumed that areas below about 9,000 feet generated, on average, less than 1.0 inch of annual runoff per unit area.

An extensive program of forest harvest or thinning could increase erosion rates and adversely affect water quality as a result of increased turbidity and sediment loads. The magnitude of these effects will depend more on the methods used to yard and remove the woody material than on the harvest itself, as roads and skid trails are the primary sources of sediment from well designed and carefully executed forest management programs. To minimize the increase in erosion from the harvested areas and impacts on water quality, best management practices, including the use of buffer strips along both perennial and ephemeral streams, should be applied.

Prescribed fire would not be expected to cause an increase in water yields because most prescribed burns are designed to remove only the brush and suppressed trees, not to extend into the crowns and kill the larger overstory trees. In some cases small patches of high-severity burns may occur, but there is little reason to expect an increase in water yields unless there is a substantial reduction in basal area. Because prescribed fires typically do not burn all of the protective litter and humus layer and do not result in large patches of water-repellent soils, prescribed fires are not expected to cause a significant increase in runoff or adversely affect water quality (Tiedeman et al., 1979; Robichaud and Waldrop, 1997).

Two key limitations to the increased use of prescribed fire are the limited meteorologic windows for conducting prescribed burns and the amount of smoke and particulates generated from prescribed fires. Prescribed fires require conditions that are dry enough to burn, but sufficiently wet so that the fire has relatively little risk of escaping and causing unwanted damage. Only a few days each year may be suitable for igniting a controlled burn, and the limited number of trained personnel constrains the amount of area that can be treated at one time. The production of particulates is a concern for both public health and visual air quality. Both of these issues may pose serious constraints to the initiation of larger-scale prescribed burning programs.

In the absence of any efforts to reduce forest density, one can expect a continuing high risk, or a gradual increase in risk, for high-severity wildfires. High-severity fires are of considerable concern because of the potential to destroy property and greatly increase runoff and erosion rates (Robichaud et al., 2000; Moody and Martin, 2001). These increases can then have severe effects on downstream channels, aquatic habitat, and reservoir sedimentation rates. Wildfires in the forested portion of the study area are a very real threat, but because these are the result of inaction rather than a specific management activity, they will not be discussed further.

2.2 Restore and Manage Piñon-Juniper

The opportunities for management actions to affect water yields and water quality in the piñon-juniper zone are much more limited than in the forested areas. There is virtually no opportunity to increase water yields through removal or reductions in the tree canopy, as the annual precipitation in this zone is less than 450 mm. However, some improvements in the ecological health of the area and the timing of runoff events can be expected. The critical issue with respect to runoff and erosion is the amount of cover and surface roughness in the intercanopy areas. Hence the effect of increasing tree density on water quality can vary, but runoff and erosion rates are generally less under the tree canopy than in the intercanopy areas (e.g., Reid et al., 1999). Increased fuelwood harvests would probably have minimal effects on runoff, but the corresponding increase in herbaceous vegetation could improve water quality. A decrease in water quality could occur if there is substantial ground disturbance associated with the tree cutting and increased vehicle traffic.

In one example near Ruidoso, dramatic changes in streamflow were observed after removal of piñon-juniper from a property. The dry, downcut arroyos became perennial streams. The newly established grass held the moisture, reducing the peak of the hydrograph and allowing the runoff to occur over a longer time. While no more runoff may occur on an annual basis, the nature of the runoff is drastically changed. This effect, however, is highly site-specific and depends on a variety of factors such as soil depth, changes in ground cover, slope, bedrock type, and precipitation.

With respect to runoff and water quality, the most significant management issue in this zone is the intensity, timing, type, and location of grazing activities. Although the effects of grazing can be highly variable, the scientific literature generally indicates that high-intensity grazing causes a significant reduction in plant cover and infiltration rates, potentially leading to increased runoff, an increase in surface erosion, a decrease in site productivity, and a decline in water quality (Blackburn et al., 1982; Trimble and Mendel, 1995; Belsky et al., 1999).

Cattle tend to concentrate in riparian areas within the piñon-juniper zone because of the better forage, water for drinking, and shade. The concentration of cattle in the riparian areas usually has a more direct and largely adverse effect on aquatic resources than high-intensity grazing outside the riparian area, as the delivery of sediment and animal wastes into the stream channel is much more direct. The concentration of cattle or other animals in riparian areas and the resultant trampling and reduction of riparian vegetation can also destabilize the streambanks and further increase the amount of sediment being delivered to the stream. The large number of studies on grazing have reached varying conclusions, but the general consensus is that heavy grazing can have relatively severe effects on runoff, erosion, and stream channels, while light to moderate grazing has much less effect in terms of soil compaction, surface erosion, and degradation of riparian areas and stream channels.

The adverse impacts of grazing within the study area have been noted by the U.S. Forest Service, other agencies, and private consultants (e.g., USFS, 1987; Wirtz, 1998). Some of these effects can be alleviated by simply reducing the number of animals, but the total number of animals is often not as much of a problem as the distribution of animals within the areas being grazed. A combination of fencing, herding, and the provision of salt and watering points away from the stream can help ensure a more even distribution of grazing pressure and reduce the concentration of animals in the riparian zone. The use of such management techniques could be expected to have a beneficial effect on riparian health and water quality. However, quantitative estimates of the likely change for a given change in management are extremely difficult to provide.

An important limitation to a better match between site productivity and the number of grazing animals is the interannual variability in the amount and quality of forage. In dry years a given parcel of land can support fewer animals than in wet years, but it is very difficult for landowners to rapidly adjust the size of their herds in response to short-term changes in range productivity. The social and economic issues associated with changes in grazing management are discussed in Section 7 of this paper.

2.3 Restore and Manage Riparian Zones

The two main issues with respect to the restoration and management of riparian zones are the control of grazing and the control of exotic species. Both of these issues also apply to the riparian areas in other zones, particularly the piñon-juniper zone. The same issues of grazing in riparian areas discussed in Section 2.2 also apply to the lower-elevation riparian zones.

The control of exotic species is a concern primarily for ecological reasons rather than the effect of exotic species on water quantity or water quality. Recent studies indicate that exotic species such as salt cedar *(Tamarix ramosissiama* [tamarisk]*)* use similar amounts of water per unit leaf area as native woody riparian species (e.g., Sala et al., 1996; Smith et al., 1998). If tamarisk has more leaf area on a stand basis than the native riparian species, or if it can occupy areas that are too dry or too saline for native woody riparian species, the shift from native riparian species to tamarisk could result in a decrease in water yields.

This suggests that in some cases the removal of tamarisk might increase water yields per unit area, but the question then becomes whether the size of the treated area is large enough to cause a significant change in water yields on a watershed basis. In many cases the total area of riparian vegetation is only a small proportion of the total area of a watershed and it may not be possible to treat all of the riparian zones within a watershed, so the control of exotic species will not have a significant effect on water yields at the watershed scale in the Jemez y Sangre region.

The similarities in water use per unit leaf area between natives and exotics also suggest that the greatest potential increase in water yields will result from changing a dense, woody vegetation dominated by tamarisk to an open savannah with only scattered native woody riparian plants. The actual magnitude of a change in water yields will depend on the species involved, soil type, depth to groundwater, amount of woody versus shallow-rooted vegetation, and the relative dependence of each vegetation type on groundwater, precipitation, and soil moisture.

The effects of exotic species on bank erosion and water quality are not as clearly documented, even though many of the exotic riparian species were introduced for erosion control purposes. The high density of tamarisk stands probably increases the amount of overbank deposition, and this should reduce downstream sediment loads and possibly even improve downstream water quality.

In general, the primary concern with exotic species is their ecological effect, particularly the extent to which exotic species reduce the amount and quality of riparian habitat available for other key species, such as the southwest willow flycatcher. Even though the riparian areas are a small percentage of the Jemez y Sangre region, they provide habitat for a large number of species, and community-based riparian restoration projects may be beneficial in preserving biodiversity. These issues are discussed in more detail in Section 6.

3. Financial Feasibility

Efforts to reduce vegetation density and increase water yields in the forested zones will generally require a net investment of public funds. Commercial timber sales have not been offered over the past 15 to 20 years due to environmental concerns and public opposition, and the lack of timber from public lands has probably contributed to the closure of several small sawmills that traditionally processed small-diameter products.

In flatter areas (e.g., less than 30 percent slope) with an existing road network, it may be feasible to commercially thin some forest stands, but much of the marketable timber is in the Pecos Wilderness or the Santa Fe Municipal Watershed. In most areas, however, non-commercial thinning would have to be carried out. In areas with road access, costs for non-commercial thinning would be approximately $250 to $500 per acre; in steeper areas and areas without an existing road network, the costs would be considerably higher. For example, the estimated cost of treating the Santa Fe watershed is approximately $1,000 per acre, due in part to the steep slopes. In addition, the $250- to $500-per-acre cost range includes physical treatments only; costs for planning, conducting environmental (i.e., NEPA) studies, or treating the slash can make the overall cost of the project significantly higher.

The lack of local mills means that the primary uses of the thinned material would be for poles, posts, or fuelwood. If there is not a commercial market for the harvested material, the thinnings would have to be chipped and scattered, piled and burned, or broadcast burned. Lopping and scattering costs approximately $55 to $65 per acre, while the cost of chipping and scattering is slightly less. Piling costs around $65 to $75 per acre, and burning slash piles costs another $26 to $35 per acre, depending on the number, size, and accessibility of the slash piles. Prescribed fire, or broadcast burning after thinning, is the cheapest treatment at $9 to $12 per acre.

Piñon-juniper areas are used primarily for fuelwood and livestock production. Past practices included chaining followed by seeding, but this was costly, induced severe erosion in some areas, and was subject to considerable public resistance. Broadcast burning is generally not feasible because there is not enough fuel to carry the fire during the conditions conducive for well controlled burns. Overall, the costs of trying to alter or intensively manage these areas have far exceeded the potential return, and these practices have thus been largely discontinued.

Costs for a new, four-wire fence to control grazing are approximately $3,500 to $4,000 per mile. Grazing permittees on federal land average only 22 to 25 head of livestock per household, and this simply doesn't provide enough income to support major changes in management.

Simple removal of the exotic overstory in riparian zones costs from $45 to $55 per acre, but multiple treatments may be required to completely eliminate the exotic species. In many cases it could cost much more to re-establish a functioning riparian zone with native riparian vegetation, as many streams and rivers have been subjected to substantial alterations in channel morphology and their natural flow regimes (National Research Council, 1992). In such cases, extensive earth moving may be required to establish a functional channel and floodplain at the appropriate elevation relative to the existing flow regime and sediment load and thereby restore the natural processes such as overbank flooding and sediment deposition. These areas often have to be planted and seeded, and relatively intensive efforts to control exotic species may also be required, particularly in the first few years after planting.

A high proportion of the riparian and piñon-juniper vegetation types are either in private ownership or under Pueblo jurisdiction. The control of exotic species, the restoration of riparian areas, and the implementation of an aggressive range management program all represent substantial expenditures with relatively small financial returns, at least in the short or medium term, and some kind of financial assistance program will therefore be necessary if significant areas are to be treated or restored.

4. Legal Feasibility

The focus of this legal paper will be management of high-elevation forests, which present the greatest opportunities for increased water yield, rather than piñon-juniper or riparian forests.

Two different types of legal requirements affect implementation of this alternative. The first type is the laws, mostly federal, that govern what you can do to land and trees and surface waters and how you can do it. These laws place constraints on how you carry out forest management activities. Presumably, most lands that would be affected by high-elevation forest management would be in national forests or national forest Wilderness Areas, although it is possible that some such lands might be within national parks or monuments (e.g., Bandelier). Since no roads, commercial enterprises, or motorized equipment are permitted in Wilderness Areas, little significant forest management can occur in those areas, other than non-invasive fire management.

In the national forests, any management actions taken to increase water supply emanating from the forests must comply with a number of federal laws, including the National Forest Management Act, 16 U.S.C. §1600, *et seq.* (NFMA), the National Environmental Policy Act, 42 U.S.C. §4321 *et seq.* (NEPA), the Clean Water Act, 33 U.S.C. §1251 et *seq.* (CWA), the Endangered Species Act, 16 U.S.C. §1531 *et seq.* (ESA), and possibly the National Historic Preservation Act, 16 U.S.C. §470 *et seq.* (NHPA) and the American Indian Religious Freedom Act, 42 U.S.C. §1996 (AIRFA). Most of the constraints placed by these laws relate to process, studies, and planning that must be done before significant surface-disturbing work is done. There will, however, also be substantive constraints on how much logging and road-building can be done. NFMA (and its regulations) places limits on methods and locations of logging and road-building (e.g., limiting clear-cuts and certain other methods of logging, prohibiting logging on very steep slopes, limiting logging adjacent to rivers), the ESA may limit these actions where species listed as threatened or endangered are located, the CWA may limit the amount of sediment that can run into streams from logging and road-building actions, and AIRFA and NHPA may limit land disturbance near sites of religious, cultural, or historical significance. In addition, some local governments, such as Santa Fe County, assert environmental and land use constraints on logging and road-building in national forests within the County's jurisdiction (e.g., limited or no land disturbance on steep slopes, no logging or road-building on ridgelines).

To measurably increase water yield requires removal of a significant percentage of basal area, that is, a substantial amount of tree harvest. In general, the greater the amount of harvest proposed, the more difficult it will be to comply with all of the laws discussed above. In addition, the planning and environmental studies for any major watershed thinning operation can be expected to take many months or even years in areas where there is significant opposition to a proposed project.

In addition to these legal constraints, there is the question, “who would own any surplus water that is generated by watershed management?” The quick answer to this question is that any additional water created by watershed management would simply become part of the public water supply and be subject to the prior appropriation system. Thus any increase in supply through land management activities would occasionally allow more junior appropriators to obtain their water which would not be the case without the management actions. No mechanism exists whereby the person or entity that funds a program to enhance the amount of runoff can claim any of that water except by obtaining a new, very junior permit.

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

The technical, financial, and political issues associated with increased forest harvest suggest that the usable increases in water yield that might be gained from active forest management are likely to be relatively small. The potential gains could be quantified by sub-basin once one specifies the areas to be treated, the amount of basal area that would be removed per year, and the intervals between treatments. A relatively accurate estimate of the change in water yield would also require estimates of the monthly precipitation in each of the areas to be treated as well as the density and composition of the stands to be treated. Estimates of the potential adverse environmental effects would require specific information on the harvest method(s), slash treatment(s), and transportation network.

As a basis for comparison, only 24 percent of the 4,100-acre Coon Creek basin in the Medicine Bow National Forest was able to be harvested due to various management constraints, and the observed initial increase in seasonal water yield was 3.0 inches per unit area harvested, or 0.7 inches when averaged over the entire watershed (Troendle et al., 2001). This observed increase in water yield is consistent with other paired-watershed studies in the central Rocky Mountains. On a larger scale, Rector and MacDonald (1987) estimated that intensive management of national forest lands in the California Sierra Nevada could result in a sustained increase in water yields of only about 0.1 inch, as much of the land is not suitable for timber harvest or is subject to other management constraints.

Troendle and Nankervis (2000) estimated that the increased forest density on the 1.34 million acres of national forest land in the North Platte River basin has probably decreased water yields since the late 1800s by about 185,000 acre-feet per year. This equates to about 1.7 inches of water per unit area, or 2.0 inches of water per unit area of forest land. Approximately 54 percent of the total area, or 66 percent of the forested area, was classified as land suitable or potentially suitable for timber harvest. Intensive forest management on these lands could potentially yield an average of 55,000 acre-feet of additional water per year, or slightly more than one-third of the “losses” that are already occurring as a result of the increased forest density. The 55,000 acre-feet converts to 0.9 inch per unit of suitable forest land, or 0.5 inch per unit of national forest land.

These values from the North Platte study probably represent an upper bound on what might be expected from the forested areas addressed in this alternative, as two-thirds of the forested areas on national forest lands in the North Platte basin were classified as suitable or potentially suitable for timber harvest. Furthermore, species with a relatively high potential for increasing water yields (spruce-fir and lodgepole pine) accounted for nearly 85 percent of the forested area; ponderosa pine and aspen occupied only 13.5 percent of the forested area (Troendle and Nankervis, 2000).

Given the strong dependence of precipitation and forest vegetation on elevation, only some of the higher elevation sub-basins in the Jemez y Sangre region would have any potential to increase water yields through forest management. Thus the potential for increasing water yields can be evaluated simply by determining the proportion of the study area and each sub-basin that lies within different elevation zones. Figure 1 shows that 12.5 percent of the total study area lies above 7,500 feet, and less than 5 percent lies above 9,000 feet. Area-elevation curves (Appendix A) show that the sub-basins with at least 3 percent of their area above 9,000 feet are

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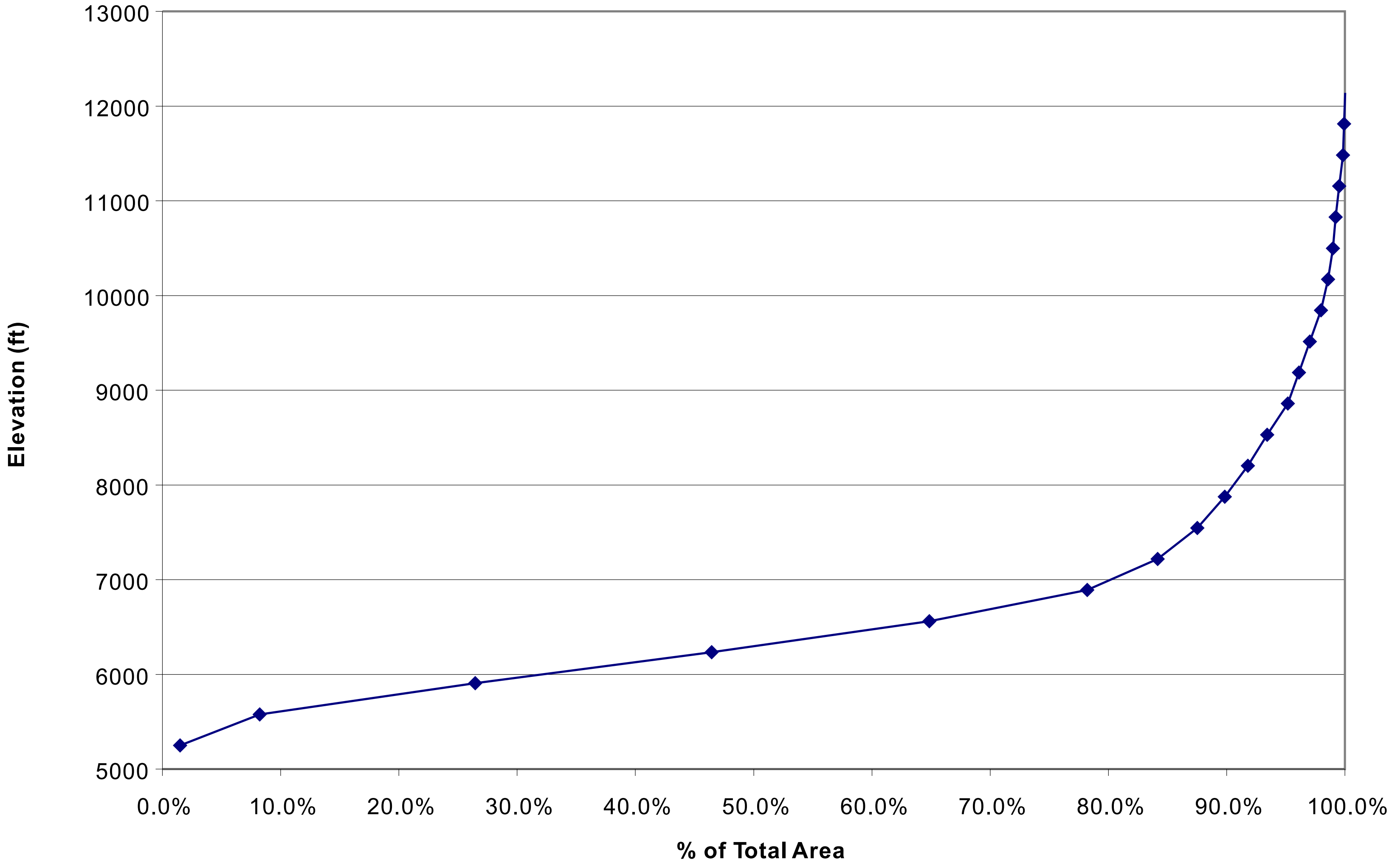

JEMEZ Y SANGRE WATER PLAN

Hypsometric Curve for the Planning Area

Figure 1

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2-14-02

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Pojoaque (16 percent), Santa Fe (4 percent), Los Alamos (3 percent), Velarde (4 percent), Tesuque (6 percent), Santa Cruz (20 percent), and Santa Clara (17 percent). Of these, the only sub-basins with significant surface water storage are Pojoaque and Santa Fe.

To provide an initial approximation of potential yield increases, the total acreage above 9,000 feet was computed (Table 1). A total of 83,000 acres in the region are above 9,000 feet, 74,000 of which are within the National Forest and 44,000 within wilderness areas. Assuming that all non-wilderness National Forest acreage can be treated, 30,000 acres could potentially be treated for improved yields (wilderness acres could possibly also be treated, but thinning in wilderness areas may encounter legal and logistical difficulties). Using the yield increases from previous studies in the Rocky Mountains of 0.7 to 0.9 inch (0.058 to 0.075 foot) per unit of land (Troendle et al., 2001; Troendle and Nankervis, 2000), the potential yield increase in the Jemez y Sangre region would be 1,750 to 2,250 acre-feet on average. More yield would be expected in the wet years and less would be expected in the dry years.

Table 1. Total Forested Acres above 9,000 Feet in the Jemez y Sangre Water Planning Region

Basin Name	Forested Acres above 9,000 feet	
	Total [a]	National Forest [b]
Los Alamos	7,773	6,941
Pojoaque-Nambe	14,460	15,252
Santa Clara	12,179	2,488
Santa Cruz River	28,356	29,093
Santa Fe River	8,284	8,854
South Galisteo Creek	1,771	3,540
Tesuque	3,878	3,963
Velarde	5,818	3,941
Total	82,520	74,073

[a] Includes land use classes (1) deciduous forest land, (2) evergreen forest land, and (3) mixed forest land.

[b] Does not include National Park Service lands (i.e., the small portion of Bandelier National Monument in the Los Alamos sub-basin).

As noted in Section 2.1, prescribed fires would not be expected to cause an increase in water yields because they would not eliminate much of the dominant tree canopy. From a purely hydrologic perspective, wildfires can cause a large increase in runoff, but this is usually regarded as a negative effect because high-severity-fires can greatly increase the size of peak flows and erosion rates both on the hillslope and in the stream channels (Robichaud et al, 2000). The combination of higher peak flows and large increases in sediment loads can have severe adverse effects on downstream water resources. Of course, there are other, obvious reasons why wildfires are not a viable management option.

In the piñon-juniper zone, management actions might change the flow paths of water, potentially causing some changes in water quality as well as the amount and timing of runoff. Without specific information on the proposed management actions, it is very difficult to provide explicit, qualitative predictions on the possible effect. Explicit quantitative predictions would also be very difficult (i.e., carry a very high degree of uncertainty) because of the spatial and temporal variability in key processes such as rainfall amounts and intensity, infiltration rates, and vegetative cover.

In general, efforts to reduce overgrazing and increase infiltration would reduce the amount of surface runoff and improve water quality. Most of this additional infiltrated water would be lost to evapotranspiration, suggesting that the reduction in surface runoff resulting from improved range conditions would be larger than the associated increase in groundwater recharge (Hillel, 1998). A reduction in surface runoff and an increase in infiltration could be expected to reduce the size of peak flows and possibly result in more sustained flows, depending on how much of the infiltrated water passes through the rooting zone and into the stream channel. The effect of management changes on hillslopes and riparian zones could potentially have a much greater effect on water quality than water quantity. Extensive outreach programs would be required, as a high percentage of the piñon-juniper lands are either private or under Pueblo jurisdiction. Rapid or extensive changes in piñon-juniper management over large areas will be difficult to achieve.

Similarly, the effect of efforts to restore or manage riparian zones will depend on the actions taken, the location and magnitude of these actions, and the site conditions where these actions are taken. In general, management actions to control exotic species should not be expected to have large effects on either water yields or water quality. The control and eventual eradication of exotic species is costly and requires more time, money, and expertise than most private landowners can summon, and an extensive outreach program will again be needed to treat a substantial proportion of the riparian areas. Programs using herbicides would engender considerable public opposition (e.g., the City of Santa Fe has an ordinance banning all class 1 herbicides within city limits). This means that mechanical treatments may become the primary management option for controlling exotic species.

6. Environmental Implications

The primary forest management options are some combination of commercial harvest, commercial and non-commercial thinning, and prescribed fires. While each of these treatments can be expected to increase erosion rates, studies have shown that the careful design of treatments and the use of best management practices can reduce the watershed-scale impacts of thinning or prescribed fire to very low levels (Troendle et al., 2001; Benavides-Solorio and MacDonald, 2001). In steeper areas, more expensive and less ground-disturbing yarding methods should be used to minimize erosion, and this may further increase the costs of any proposed management action. In general, one of the greatest concerns in forest management is the effect of the roads on runoff and erosion. If new roads have to be constructed, particularly in steep areas, this could have a much bigger effect on erosion rates than the various treatments, even though the latter will affect a much larger proportion of the watershed.

The change in forest density from any of these treatments will have different effects on different species. A more open forest will generally increase the amount of feed for large ungulates such as deer and elk, while a high canopy density will favor other species. In many cases, not enough is known about the habitat requirements of all the different species to accurately predict the likely effects of a proposed treatment. Another limitation is that the net effect of a treatment will depend on the relative value assigned to each species that is affected, and there may be considerable disagreement about those values.

The primary environmental advantage of reducing forest density is the reduced risk of high-severity fires. As noted in Section 2.1, high-severity fires in coniferous forests can increase runoff and erosion rates by one or more orders of magnitude relative to unburned conditions. These increases can have severe downstream effects in terms of flooding, reservoir sedimentation, and adverse effects on aquatic habitat.

An important concern in the case of prescribed fire and broadcast burning is the effect on air quality. Fires in forested areas produce a large number of particulates that are a hazard to human health. Smoke also has an adverse effect on visibility and visual esthetics. For this reason, prescribed burning programs often encounter considerable public resistance, and the agencies that regulate air quality may also have some reservations about issuing permits that may result in a substantial, albeit temporary, reduction in air quality.

Management goals for piñon-juniper woodlands are typically to increase the amount of forage and vegetative ground cover, reduce erosion, and re-establish native riparian species. More aggressive treatments such as chaining are generally not acceptable because of the excessive ground disturbance and potential increases in erosion. In general, efforts to improve range and reduce the impacts of grazing should be beneficial in terms of reducing erosion, enhancing habitat quality in the riparian zone, and improving water quality.

As in the case of the forest zone, any vegetative treatment in piñon-juniper woodlands will favor some species at the expense of others. The net effect will depend on the relative values of the species affected and the intended use of the area after treatment. In most cases, a reduction in tree density will increase the ground cover, thereby increasing the productivity of the land for grazing by large ungulates. The use of fencing and the more regular movement of livestock will help eliminate the tendency to overuse some areas and underuse others, with a net benefit on erosion rates and downstream water quality.

The removal of exotic species and the restoration of riparian zones are generally regarded as being environmentally beneficial. Whereas tamarisk stands provide little habitat for native fauna and are often dense, flammable monocultures, healthy stands of native riparian vegetation provide critical habitat for threatened or endangered species. A healthy riparian ecosystem is critical to the health of the adjacent stream in terms of temperature regulation, bank stability and sediment inputs, the input of organic matter and large wood, and the filtering of sediment and nutrients from overland flow.

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 acequia 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.

If it is successful in increasing surface water flows and groundwater infiltration, restoring and better managing forests, piñon-juniper woodlands, and riparian systems would have clear, if indirect, socioeconomic and cultural benefits. Stewardship of watershed resources is consistent with local history, land-based economies, and land-use traditions. Local communities and economies have always relied on the health of these fundamental resources. An increase in streamflow could help ensure adequate water for local acequias and other traditional uses and help recharge local domestic wells, while improved water quality could reduce irrigation system maintenance.

Restoration and better management of local natural resources that is successful in increasing streamflow could also benefit the outdoor-based tourism economy and all downstream communities, residents, and irrigators. In general, increasing available streamflow would probably reduce the cost of water for all users.

Given the general enhancement of environmental conditions and watershed productivity possible with the management options discussed herein, local rural residents are likely to be allies in these efforts. However, some of the management actions discussed herein may encounter local opposition. Piñon and juniper have long been the preferred fuelwood in New Mexico, and any program or action that would reduce or strictly limit access or supply might encounter local opposition. Grazing of sheep and cattle is also a tradition and a source of livelihood for local people within in the Jemez y Sangre planning region, and efforts to restrict or control the number of animals and the intensity of use in piñon-juniper lands and riparian areas could also meet with local opposition. In both of these cases, involvement of the local community in designing projects and prescriptions would largely alleviate any potential opposition.

In addition, prescribed burning programs often encounter considerable public resistance due to the adverse effect of smoke from the fire on visibility and visual esthetics. An extended period of prescribed fire will also raise issues such as the potential effect on tourism.

Designing restoration and management plans in collaborative consultation with affected local communities would help enlist local support and involvement and would integrate valuable traditional knowledge about local resources. Direct socioeconomic and cultural benefits would flow from contracting with local communities and small-scale local enterprises for forest thinning and fire management, riparian system enhancement, erosion control, and/or other stewardship work.

8. Actions Needed to Implement/Ease of Implementation

The impediments to initiating an active program to manage or restore forests, piñon-juniper woodlands, and riparian zones are many and difficult. Foremost among these are public concerns, which stem from a variety of different issues and perceptions. Efforts to harvest or thin forested areas typically meet with considerable local opposition, even though these actions might substantially reduce the risk of high-severity wildfires while having minimal effect on water quality. Efforts to alter the management of piñon-juniper woodlands and riparian zones are likely to be seen as a threat to traditional, local resource use, especially since large portions of these areas are in private hands or under Pueblo jurisdiction. Other than forest harvest, the costs of any proposed management action will probably be much greater than the estimated short- and medium-term economic benefits. As much of the cost will have to come from public funds, any proposed management actions will have to have clear public support. Programs to alter management or improve the condition of piñon-juniper woodlands and riparian zones may directly benefit only a small proportion of the population, again making it difficult to generate the support necessary for proposed management actions.

Efforts to restore the native vegetation and the natural geomorphic processes in riparian zones will often be constrained by the existing alterations of the flow regime and channel morphology. In many (if not nearly all) cases, the restoration of the natural flow regime cannot be achieved given the existing water needs and infrastructure of impoundments, diversions, and water rights. Extensive negotiations will be needed to balance human needs with ecological restoration. The restoration of riparian areas may also be impossible without extensive modifications to the existing channel morphology and in-channel structures such as diversions, bridges, reservoirs, riprap, and weirs for grade control. However, some local improvements to channel morphology can be made through grazing management and induced meandering. Monitoring of such projects is important to understanding changes in morphology.

9. Summary of Advantages and Disadvantages

Advantages of the forest, woodland, and riparian system management options discussed herein are:

- Reduced risk of wildfires
- Potential for small increases in water yield from forested areas
- Reduced surface runoff, surface erosion, and channel incision in piñon-juniper woodlands
- Improved range and riparian conditions in piñon-juniper woodlands and possibly an improvement in water quality
- Increased amount and quality of forage in all vegetation types
- Improved habitat for native riparian and aquatic species at lower elevations

Disadvantages of these options include:

- Considerable public opposition to forest harvest and thinning
- Poor cost-benefit ratios
- Limited potential to increase water yields and the likely timing of any increases
- Smaller water yield increases in dry years
- Potential decline in air quality and threat to human health from increased particulates from prescribed fires

- Financial and logistical difficulties of implementing management actions on private lands
- Restoration only partial in nearly all cases

References

Austin, S.A., 1999. Streamflow response to forest management: A meta-analysis using published data and flow duration curves. M.S. thesis, Dept. of Earth Resources, Colorado State University, Fort Collins, Colorado. 121p. plus app.

Bates, C.G., and A.J. Henry. 1928. Forest and stream-flow experiment at Wagon Wheel Gap, Colo. *Monthly Weather Review* Supp. No. 3, USDA Weather Bureau, Washington, DC. 79p.

Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. *Journal of Soil and Water Conservation* 54(1):419-431.

Benavides-Solorio, J., and L.H. MacDonald. 2000. Post-fire sediment production from hillslopes in the Colorado Front Range. *Eos Trans. AGU* 82(47):F510.

Blackburn, W.H., R.W. Knight, and M.K. Wood. 1982. *Impacts of grazing on watersheds: A state of knowledge.* Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas. 30p.

Bosch, J.M. and J.D. Hewlett. 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. *J. Hydrology* 55:3-23.

Brown, H.E., M.B. Baker, Jr., J.J. Rogers, W.P. Clary, J.L. Kovner, F.R. Larsen, C.C. Avery, and R.E. Campbell. 1974. *Opportunities for increasing water yields and other multiple use values on ponderosa pine forest lands.* USDA Forest Service Research Paper RM-256, Fort Collins, Colorado. 36p.

Duke Engineering & Services (DE&S). 2001. *Water supply study, Jemez y Sangre water planning region, New Mexico*. Prepared for Jemez y Sangre Water Planning Council, Sangre de Cristo Water, and City of Santa Fe, Santa Fe, New Mexico. January 2001.

Ffolliott, P.F., and D.B. Thorud. 1975. *Vegetation management for increased water yield in Arizona.* Tech. Bull. 215, Agricultural Experiment Station, University of Arizona, Tucson, Arizona. 38p.

Gary, H.L. 1975. *Watershed management problems and opportunities for the Colorado Front Range ponderosa pine zone: The status of our knowledge.* USDA Forest Service Research Paper RM-139, Fort Collins, Colorado. 32p.

Hillel, D.. 1998. *Environmental Soil Physics*. Academic Press, San Diego, California. 771p.

Moody, J.A. and D.A. Martin. 2001. Initial hydrologic and geomorphic response following a wildfire in the Colorado Front Range. *Earth Surface Processes and Landforms* 26:1049-1070.

National Research Council. 1992. *Restoration of aquatic ecosystems*. National Academy Press. 552p.

Rector, J.R., and L.H. MacDonald. 1987. Water yield opportunities on National Forest lands in the Pacific Southwest Region. pp. 68-73. *In Proceedings, California Watershed Management Conference.* Report No. 11, Wildland Resources Center, University of California, Berkeley, California.

Reid, K.D., B.P. Wilcox, D.D. Breshears, and L. MacDonald. 1999. Runoff and erosion in a pinon-juniper woodland: Influence of vegetation patches. *Soil Science Society of American Journal* 63(6):1869-1879.

Reiland, L.J. 1976. *Estimated mean-monthly and annual runoff at selected sites in the Pojoaque River drainage basin, Santa Fe County, New Mexico.* U.S. Geological Survey Open-File Report 74-150, Albuquerque, New Mexico. 21p.

Rich, L.R. 1972. Managing a ponderosa pine forest to increase water yield. *Water Resources Research* 8:422-428.

Robichaud, P.R., J.L. Beyers, and D.G. Neary. 2000. *Evaluating the effectiveness of postfire rehabilitation treatments*. USDA Forest Service Gen. Tech. Rep. RMRS-GTR-63, Rocky Mountain Research Station, Fort Collins, Colorado. 85p.

Robichaud, P.R., and T.A. Waldrop. 1994. A comparison of surface runoff and sediment yields from low-and-high severity site preparation burns. *Water Resources Bulletin* 30:27-34.

Sala, A., S.D. Smith, and D.A. Devitt. 1996. Water use by *Tamarix ramosissima* and associated phreatophytes in a Mojave Desert floodplain. *Ecological Applications* 6(3):888-898.

Smith, S.D., D.A. Devitt, A. Sala, J.R. Cleverly, and D.E. Busch. 1998. Water relations of plants from warm desert regions. *Wetlands* 18(4):687-696.

Stednick, J.D. 1996. Monitoring the effects of timber harvest on annual water yield. *Journal of Hydrology* 176:79-95.

Tiedemann, A.R., C.E. Conrad, J.H. Dieterich, J.W. Hornbeck, and W.F. Megahan. 1979. *Effects of fire on water. A state-of-knowledge review*. USDA Forest Service, General Technical Report WO-10, Washington, DC. 28p.

Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent, a critical review. *Geomorphology* 13:233-253.

Troendle, C.A. 1983. The potential for water yield augmentation from forest management in the Rocky Mountain region. *Water Resources Bulletin* 19(3):359-373.

Troendle, C.A., and M.R. Kaufmann. 1987. Influence of forests on the hydrology of sub alpine forests. pp. 68-76. *In Management of subalpine forests: Building on fifty years of research.* USDA Forest Service General Technical Report RM-149, Fort Collins, Colorado.

Troendle, C.A. and R.M. King. 1985. The effects of timber harvest on the Fool Creek watershed, 30 years later. *Water Resources Research* 21(12):1915-1922.

Troendle, C.A. and R.M. King. 1987. The effect of partial and clearcutting on streamflow at Deadhorse Creek, Colorado. *Journal of Hydrology* 90:145-157.

Troendle, C.A., and J.M. Nankervis. 2000. *Estimating additional water yield from changes in management of national forests in the North Platte Basin.* 51p.

Troendle, C.A., M.S. Wilcox, G.S. Bevenger, and L.S. Porth. 2001. The Coon Creek water yield augmentation project: Implementation of timber harvesting technology to increase streamflow. *Forest Ecology and Management* 143:179-187

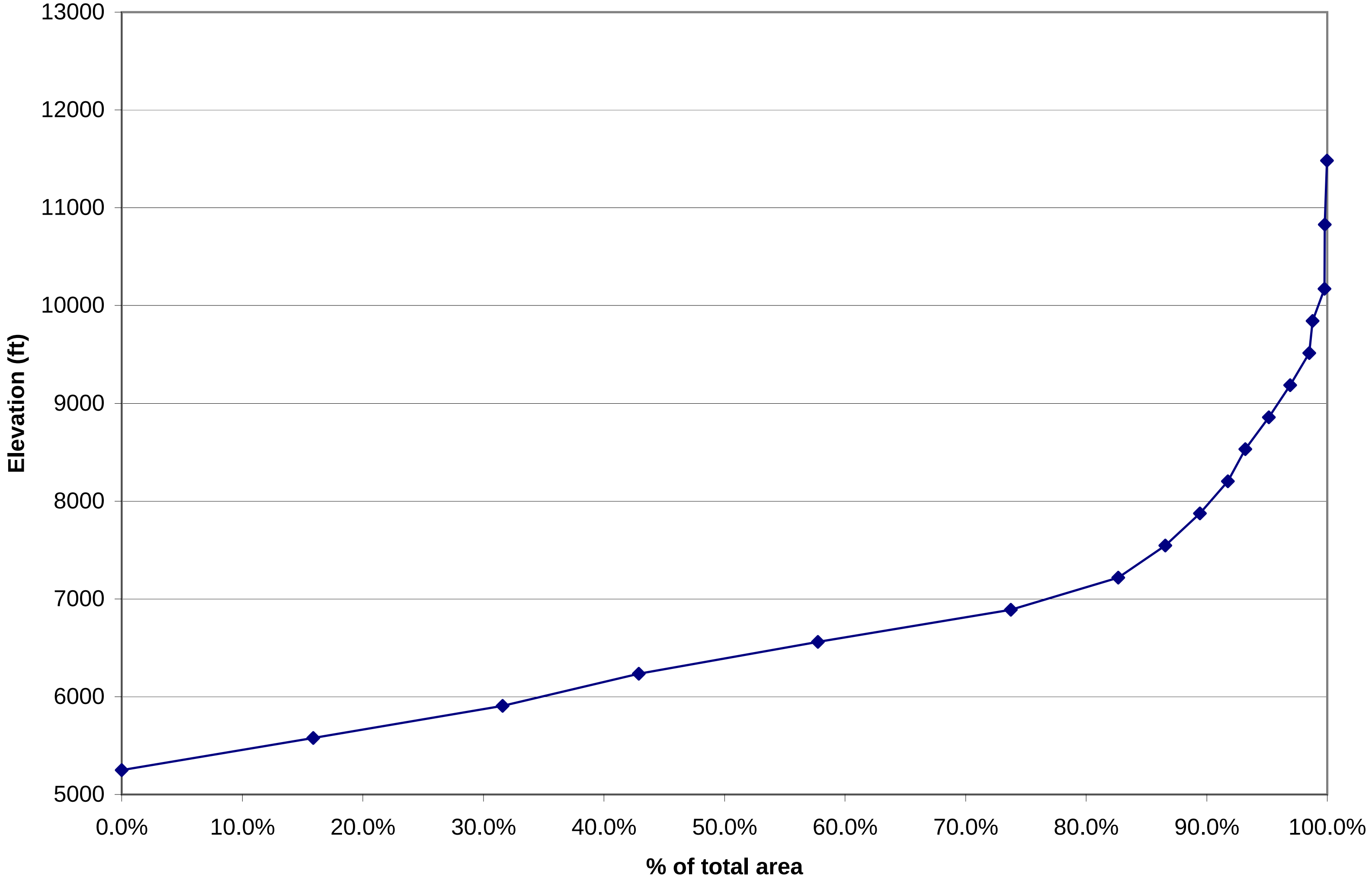
U.S. Forest Service (USFS). 1987. *Santa Fe National Forest land management plan.*

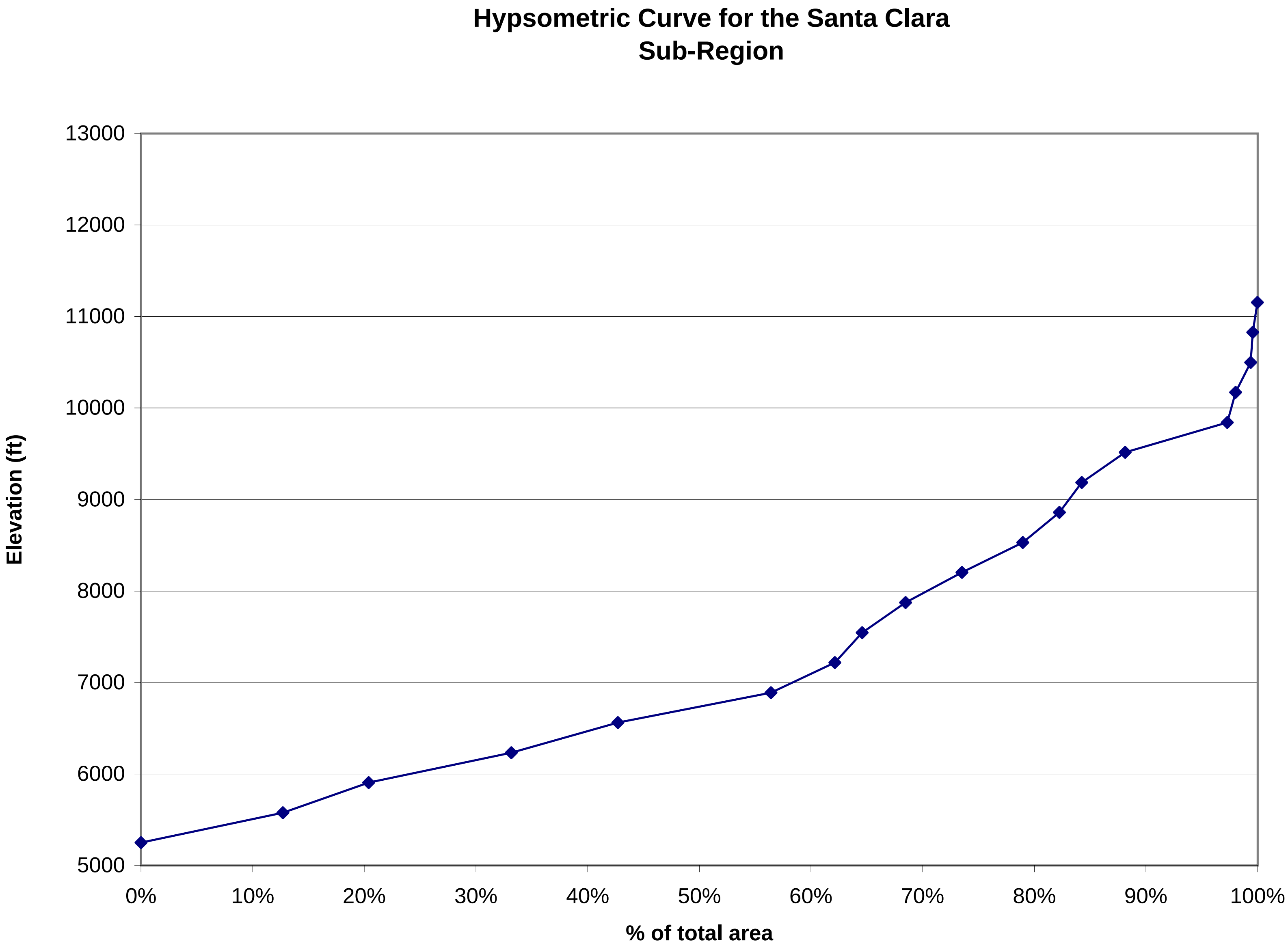
Wirtz, M. 1998. *Stewardship incentive plan, Pueblo of Pojoaque, New Mexico.*

Appendix A

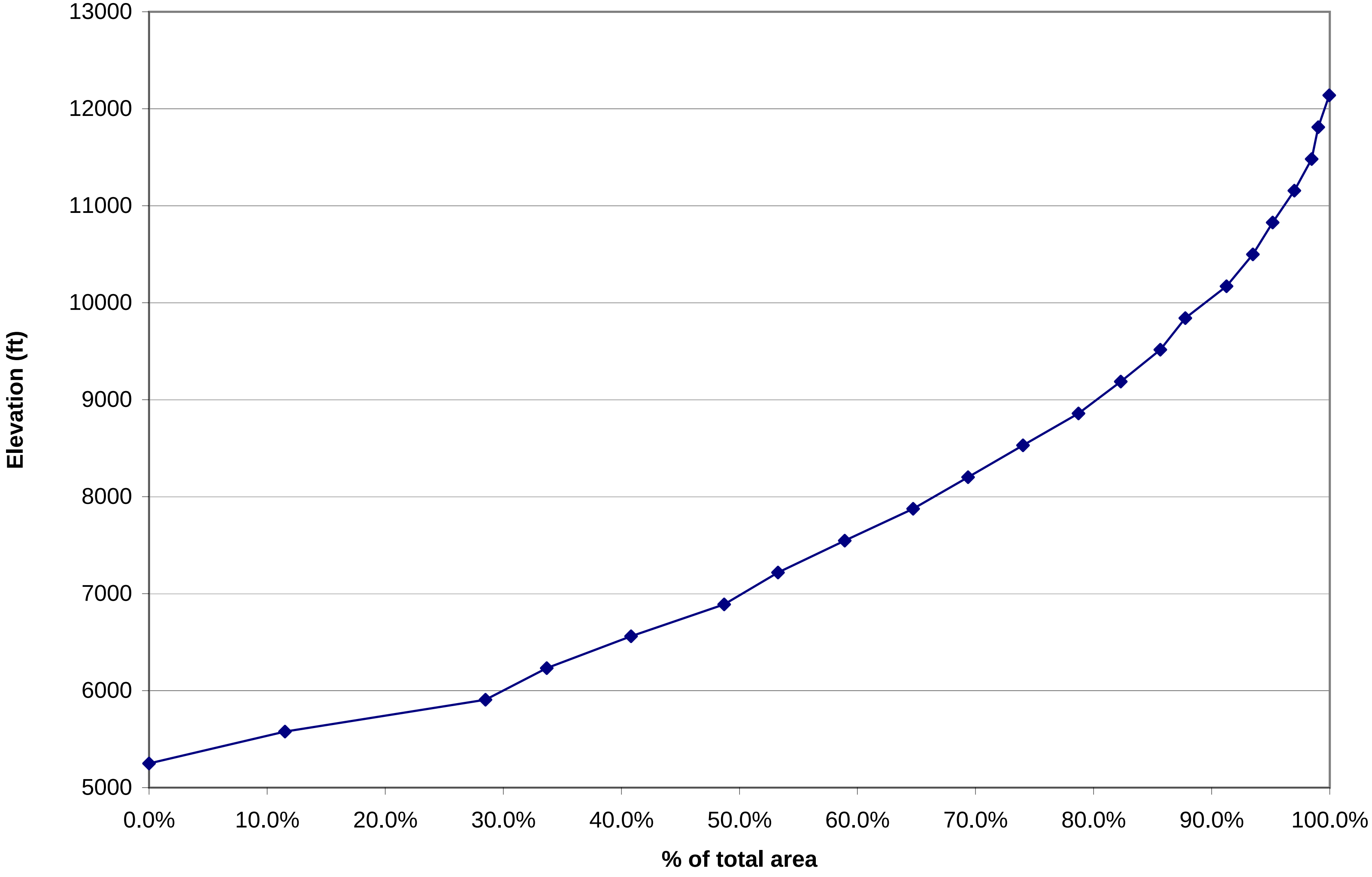
Hypsometric Curves

Hypsometric Curve for the Velarde Sub-Region

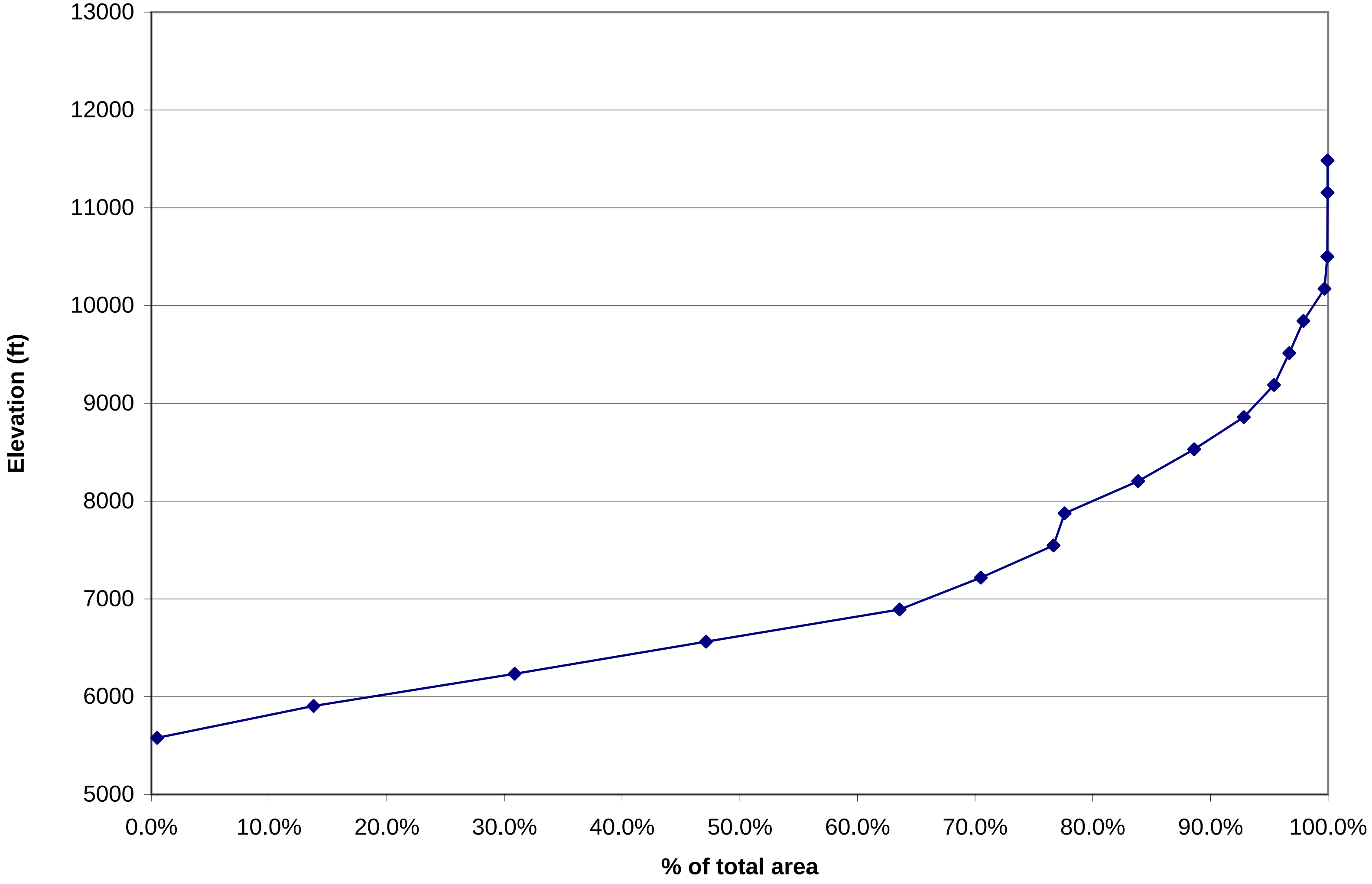



Hypsometric Curve for the Santa Clara Sub-Region
Elevation (ft)
13000
12000
11000
10000
9000
8000
7000
6000
5000
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of total area

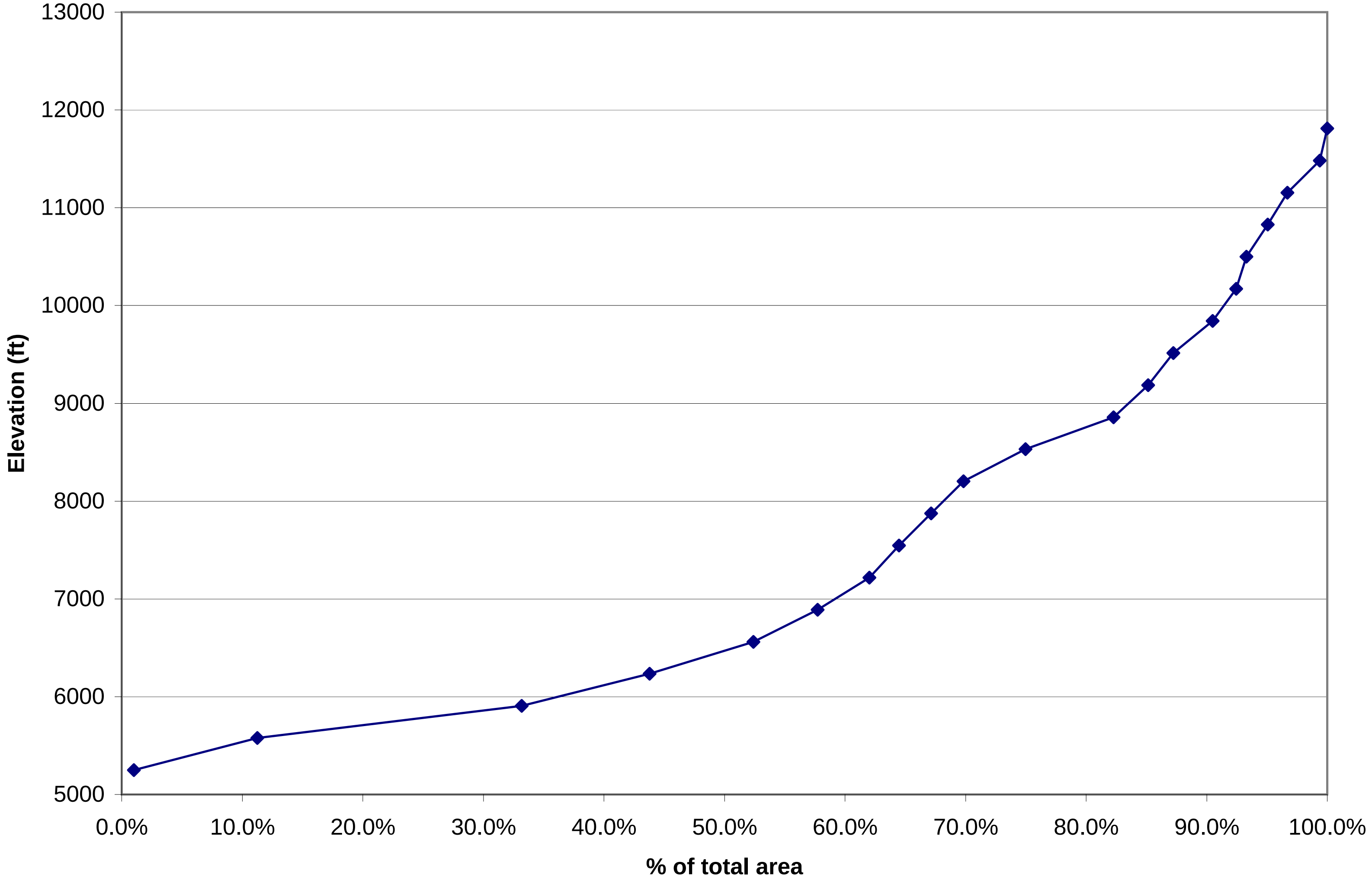
Hypsometric Curve for the Santa Cruz Sub-Region

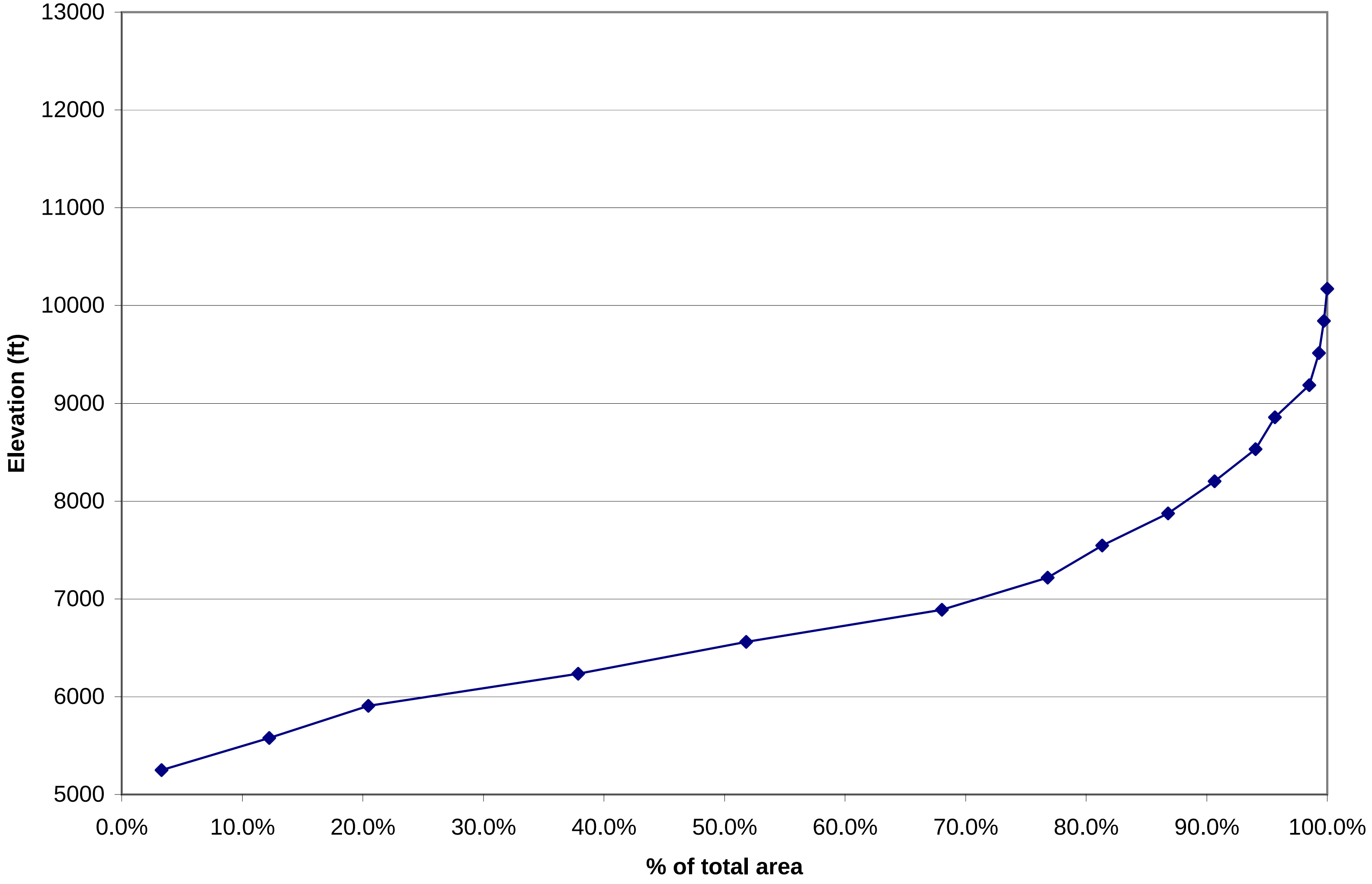


Hypsometric Curve for the Tesuque Sub-Region



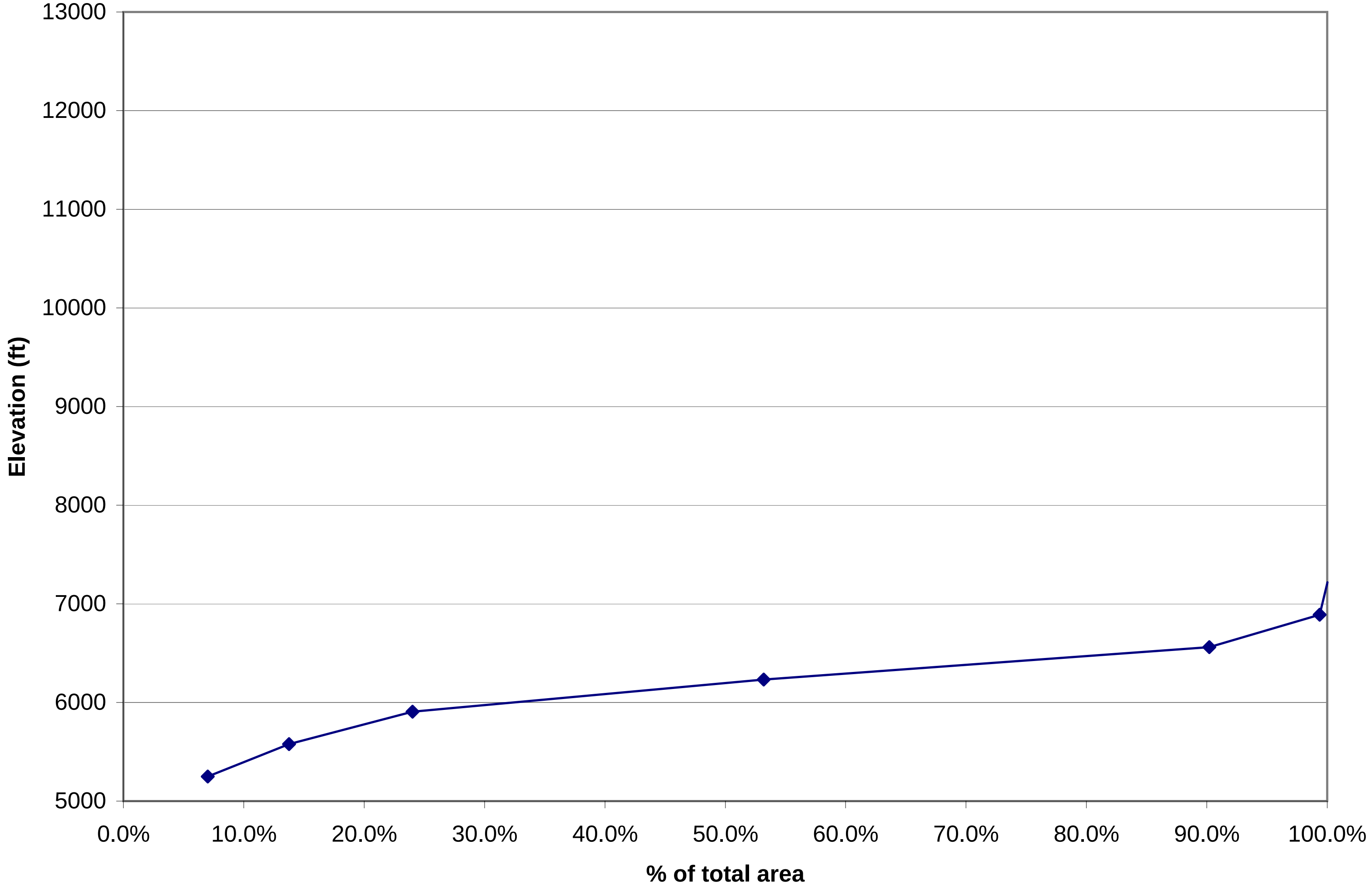
Hypsometric Curve for the Pojoaque Sub-Region

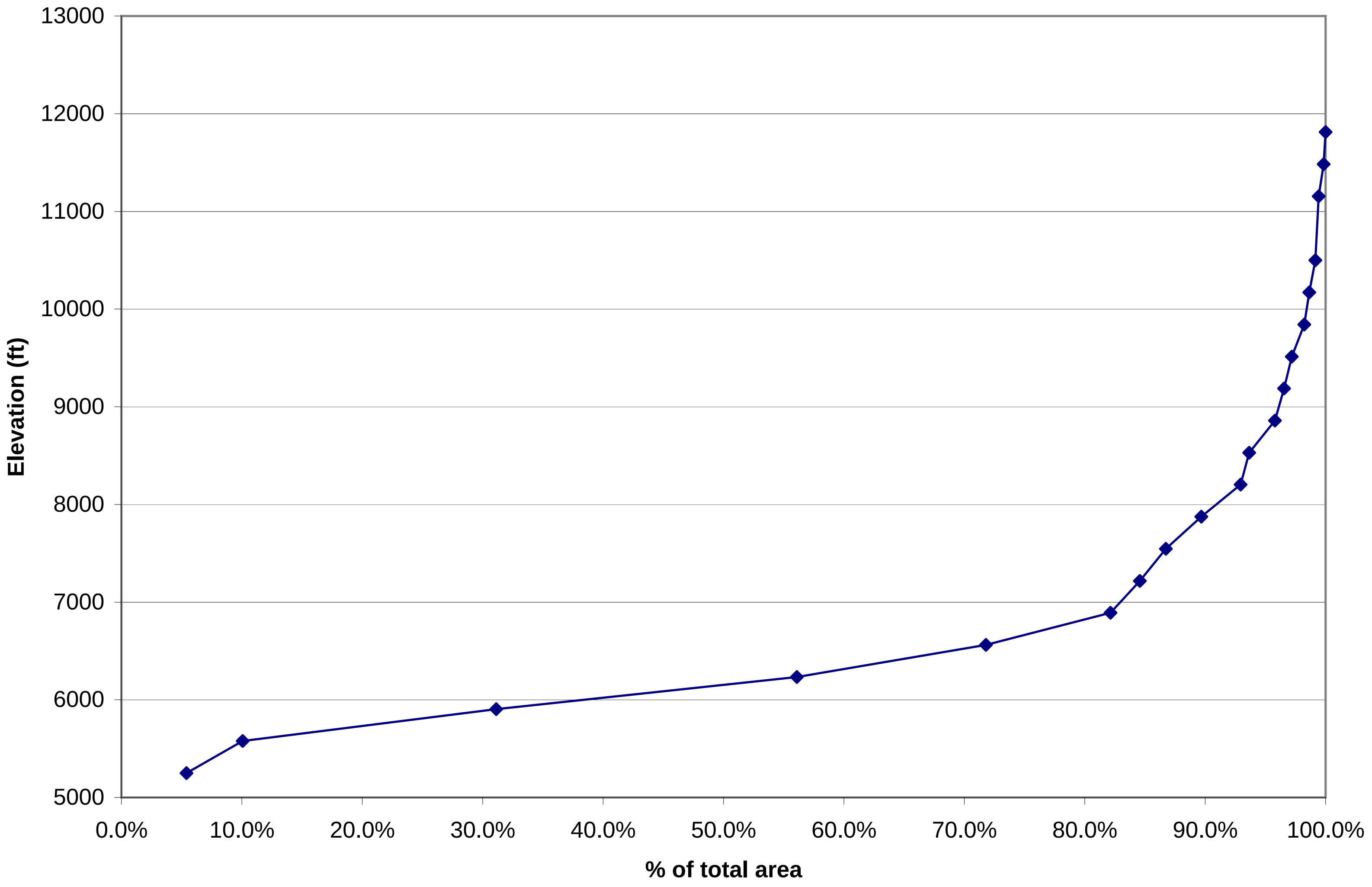




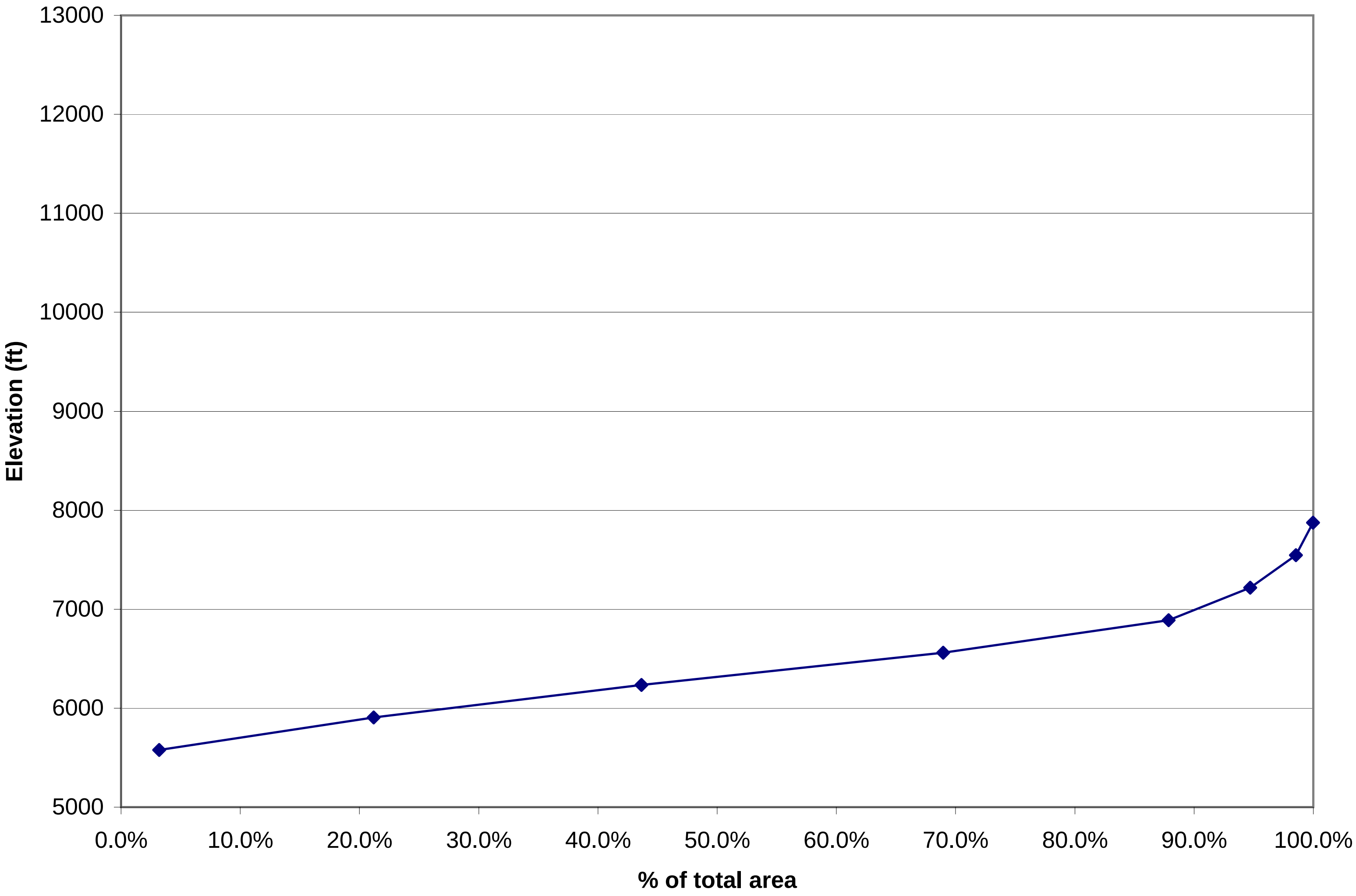
Hypsometric Curve for the Los Alamos Sub-Region

Hypsometric Curve for the Caja del Rio Sub-Region



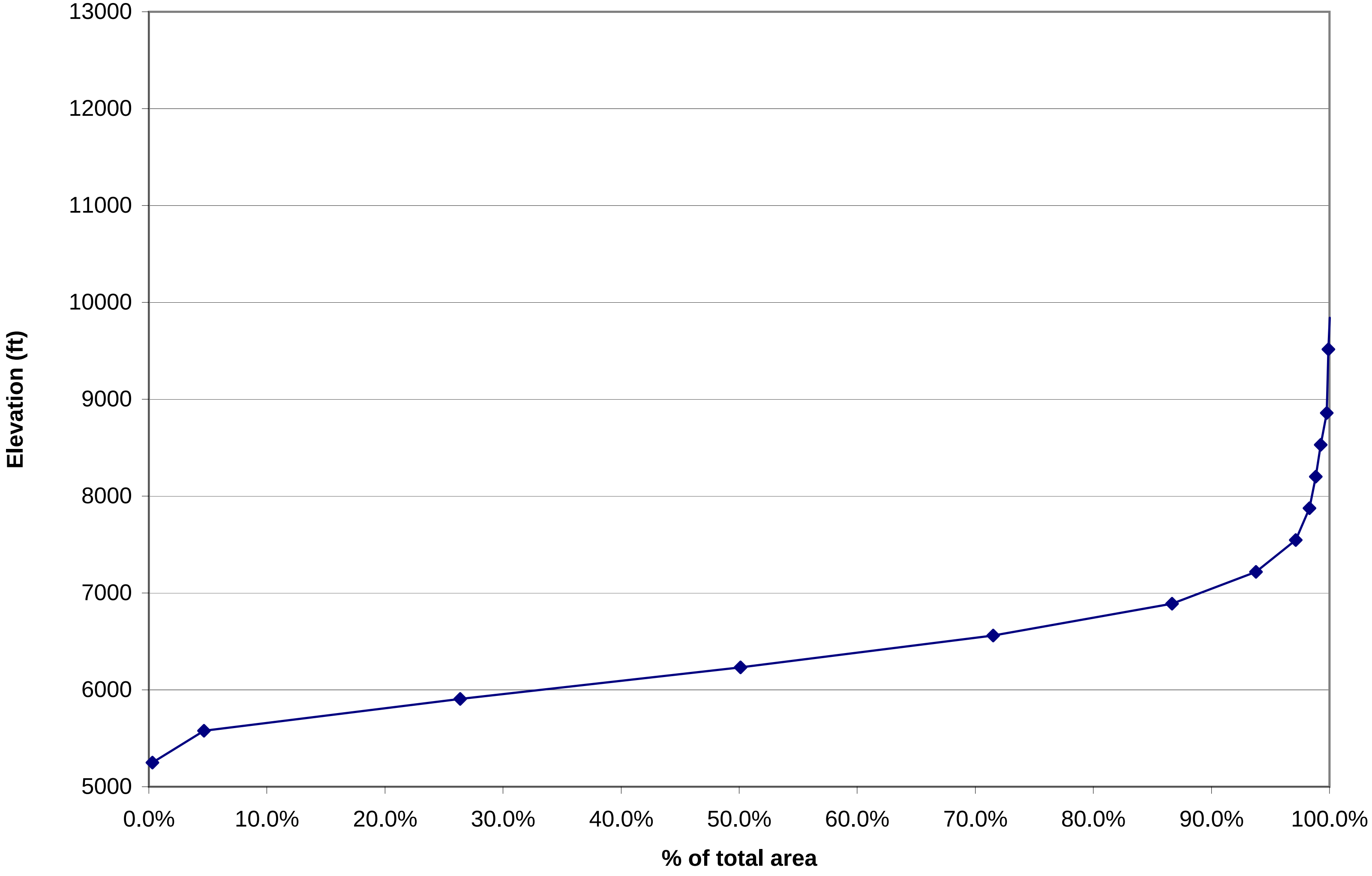


Hypsometric Curve for the Santa Fe Sub-Region



Hypsometric Curve for the North Galisteo Sub-Region

Hypsometric Curve for the South Galisteo Sub-Region



White Paper 2

Alternative: Conjunctive Use of Surface and Groundwater

Alternative: Conjunctive Use of Surface and Groundwater

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Dominique Cartron (primary author), Susan C. Kery (legal), and Bonnie Colby (socioeconomic).

1. Summary of the Alternative

Conjunctive management allows water managers to use a combination of surface water and groundwater resources to meet demand. For purposes of this white paper, conjunctive management does not include injection of surface water into the aquifer for storage and retrieval at a later time (which is being discussed in a separate white paper [DBS&A, 2002a]) but simply means combined use of surface and groundwater rights.

Conjunctive use of the two types of rights would allow water rights holders who own both surface water and groundwater rights to rely entirely on surface water in wet year while allowing the aquifer to recover through natural recharge. When surface water is less available, water suppliers can then rely on groundwater and forgo diverting their surface water rights. This would benefit the river system and downstream users by leaving additional water in the river in times of drought. Over time, conjunctive management can benefit the region by providing flexibility to switch from groundwater to surface water supplies depending on availability. Conjunctive management can also address water quality issues. By mixing poor-quality water with higher-quality water, expensive treatment options may be somewhat reduced.

Conjunctive use will help protect existing supplies by improving the sustainability of the resource. Conjunctive use will not increase the supply for meeting the growing demand in the region.

In the Jemez y Sangre region, conjunctive management could represent a tool for water resource managers to take advantage of spring snowmelt runoff and heavy precipitation during the summer "monsoon" months. Water entities with both groundwater and surface water rights would greatly benefit from the ability to extract all the water rights from the most available source of supply. Under the current system, water rights are generally restricted to the point of diversion (either the well or the surface water diversion). For example, groundwater rights must be extracted from the permitted well and cannot be taken from a surface water diversion. Similarly, surface water rights can be diverted at the surface water point of diversion and may be limited by available supply. This means that water suppliers with surface water rights are limited in times of drought and may not be able to use all their water rights.

As an example of how conjunctive management can enhance water resource availability in the region, assume a water supplier with 100 acre-feet of surface water rights and 100 acre-feet of groundwater rights, who must meet a demand of 200 acre-feet of water per year. If the water supplier cannot manage these water rights conjunctively, it may not be able to use its full water rights in drier years because of limitations in surface water availability. If, however, the water rights holder is allowed to take all 200 acre-feet per year of water from surface supplies in a particularly wet year, the aquifer would be allowed to recharge naturally, which would help maintain water levels. In a drier year, instead of forgoing a portion of its water right (or the entire water right if it's a junior water right) and failing to meet demand, the entity could divert the entire 200 acre-feet from groundwater. This would allow the supplier to meet demand while leaving additional water in the river for downstream users.

2. Technical Feasibility

In cases where a water rights holder already is using both surface water and groundwater supplies, such as the City of Santa Fe, there should not be any significant technical issues regarding conjunctive management of the two supplies. Because existing infrastructure and treatment capacity may be limited and therefore unable to accommodate increased water diversions and treatment, conjunctive use of surface and groundwater would be the means to obtain sufficient water to meet already existing demand (for which capacity would already exist) rather than increasing the amount of water in the system.

Gaging of the surface water supply (streamflow and snow pack) and monitoring of reservoir stage will be required to determine whether more or less surface water should be used in a given year; in many cases, this information is already being collected. Additionally, monitoring of groundwater levels will also be valuable to evaluate the effects of the conjunctive management on the aquifer.

In locations where only groundwater is used, purchase of surface water rights and the installation of a surface diversion would be required. For example, Española currently uses only groundwater for its municipal water supply, but is investigating a surface diversion to use San Juan-Chama Project water. It is technically feasible to install surface diversions, but additional costs and environmental issues may arise.

Conversely, if acequias that only use surface water want to supplement their supply during drought periods, wells would need to be installed. The feasibility of well installation is dependent on local geologic conditions. Wells are widely used throughout the Jemez y Sangre region and in most locations wells could be installed, if Office of the State Engineer (OSE) approval for conjunctive management and additional water rights were obtained. Additional discussion regarding the feasibility and costs of installing wells is provided in a separate white paper (DBS&A, 2002b).

To obtain Office of the State Engineer (OSE) approval for conjunctive management, the water rights holder would apply for a change in point of diversion under certain conditions. The applicant would need to show that this change in management would not result in impairment to existing users. Supporting technical analyses, including extensive modeling of stream-aquifer interaction, would be required, particularly regarding:

- The effects on the river and other groundwater users due to pumping more in dry years
- The impacts on the river system and other users due to greater surface withdrawals in wet years

3. Financial Feasibility

Where a water rights holder is already using both surface water and groundwater supplies, there should be no significant financial implications due to managing the water rights conjunctively, and this alternative may even result in long-term cost savings. The costs for initiating this program would include filing and obtaining OSE approval of an application and possibly ongoing monitoring costs. Obtaining OSE approval would entail fees for legal counsel unless the applying entity is prepared to internally submit the application.

Technical studies showing the connection between surface and groundwater, and possibly models illustrating the potential impacts of this type of management would most likely also be required to obtain OSE approval. Combined legal and technical studies to obtain OSE approval could possibly be completed for $100,000 to $200,000; however, if extensive modeling is required and/or contested legal issues are present, implementing this alternative could cost up to $1 million or more. Potential funding sources for analysis of surface and groundwater supplies include the U.S. Environmental Protection Agency (EPA), Bureau of Reclamation, and Community Development Block Grants. Funding from these sources could possibly be used for monitoring programs as well.

For entities that would need to install municipal supply wells, typically costs are approximately $300 to $600 per foot, depending on well depth, diameter, and capacity. These costs cover full well completion but do not include costs for pump, well house, pressure tank, and other peripherals, nor for surface infrastructure, which if not already in place, will add costs that may be even greater than the well cost. The cost of a surface diversion is dependent on the size and location. Raw water conveyance and treatment and treated water transmission facilities could also be required. Finally, treatment costs could be higher if greater capacity is needed to treat greater quantities of surface water in wet years.

4. Legal Feasibility

The conjunctive use of surface water and groundwater in the Jemez y Sangre planning region could potentially allow for the optimum use of all water sources in the region. An example of a conjunctive use regime can be understood in light of the City Of Santa Fe's water rights. Under a conjunctive use scheme, all of the City's water rights would be inventoried and a maximum amount of water determined, with a certain percentage of water consisting of permitted groundwater rights and a certain percentage consisting of the surface water available for use by the City. With conjunctive use, the City could plan to use a higher percentage of surface water in those years where surface flows are available and a higher percentage of groundwater in those years where surface flows are minimal. The total maximum amount the City could use in any given year would always remain the same, but the City would have the flexibility to use its surface and groundwater in a manner which would maximize the amount available to the City at any given time.

The State Engineer has the power, through permit conditions, to allow the commingling of water rights and the conjunctive use of water. In order for new permit conditions to be implemented, a permit holder would have to apply for such changes with the State Engineer and go through the process of notice and publication. In examining any such proposed permit conditions, the State Engineer would permit such conditions if they did not impair existing water rights and were not contrary to the conservation of water or detrimental to the public welfare. Also, in permitting the conjunctive use of surface water and groundwater, the State Engineer may limit the amount of surface water available for such use to the historical supply of such surface water.

The adjudication process in District Court can also create a mechanism for conjunctive management in small watersheds. The Aamodt case, which covers water rights claims in the Pojoaque Valley, has set up a system for conjunctively managing water rights.

Besides complying with the conditions of permits, a water right holder contemplating the conjunctive use of water must also ensure that such use is not subject to any constraints by an adjudication court or any limitations under the Rio Grande Compact. Since New Mexico's delivery obligations are based on flows at the Otowi gage, the OSE and Interstate Stream Commission (ISC) would have to determine whether exercising this alternative would affect the Compact.

One issue that may arise in considering the conjunctive use of water is that of priority administration of the surface and groundwater that is being conjunctively used. In the Rio Grande Basin, groundwater is hydrologically interconnected to surface water. This presents a problem in priority administration because of the delayed hydrologic effects from pumping wells. For instance, when water is withdrawn by a well from an aquifer that is interconnected with a stream system, the well initially draws water from underground storage and has no effect on stream flow. However, as groundwater in storage is depleted over time, the well eventually begins to draw water from the stream system, resulting in decreased surface flow.

There is also a delay in impact when a groundwater appropriator ceases pumping a well. The impact from prior pumping on the stream system will continue until the depleted groundwater is substantially replaced. The time for impacts from well pumping to be realized on a stream system varies greatly and is usually directly related to the distance of the well from the stream. The effects from a well located immediately adjacent to a stream may be felt immediately. On the other hand, it could be years or even decades before impacts on surface flow would result from pumping a well located several miles from the stream.

The delay in impact from well pumping creates the problem in priority administration. When a senior surface water user is not receiving his full appropriation and "calls" the river, it would be expected that well appropriators with water rights junior to those of the surface appropriator would cease pumping. However, due to the delayed effect on the stream system from cessation of well pumping, curtailment of pumping from wells would result in no additional water for the senior appropriator. This situation can occur often because well rights are often junior to surface rights simply because early appropriators acquired surface water rights and the groundwater appropriators came later.

As might be expected, the futile call doctrine comes into play when a senior surface water appropriator calls the river and there are junior well rights on the stream system. Cessation of well pumping would result in no additional water for the senior; therefore, the junior wells could continue pumping. Such a result is contrary to the spirit of the prior appropriation doctrine, which requires that senior water rights holders fulfill their rights prior to junior water rights holders.

The State of Colorado has attempted to deal with priority administration of surface and ground water through legislation regulating “tributary ground water” (water that is hydrologically connected to a surface stream system) conjunctively with surface water. Through this legislation, Colorado has attempted to balance priority administration with the maximum utilization doctrine. Colorado's 1969 Water Right Determination and Administration Act declared that “[I]t is the policy of this state to integrate the appropriation, use, and administration of underground water tributary to a stream with the use of surface water in such a way as to maximize the beneficial use of all of the waters of the state” (Colo. Rev. Stat. §37-92-102(1)(a) (1997)). This policy recognizes that utilizing groundwater maximizes beneficial use because it uses stored groundwater that would otherwise not be beneficially used.

Colorado’s statutes expressly protect senior surface rights from junior well appropriators. ”[T]he operation of this section shall not be used to allow ground water withdrawal which would deprive senior surface rights of the amount of water to which said surface rights would have been entitled in the absence of such ground water withdrawal . . .” (Colo. Rev. Stat. §37-92-102(1)(a) (1997)). This same statute, however, also codifies the futile call doctrine as follows:

> [A]nd that ground water diversions shall not be curtailed nor required to replace water withdrawn, for the benefit of surface right priorities, even though such surface right priorities be senior in priority date, when, assuming the absence of groundwater withdrawal by junior priorities, water would not have been available for diversion by such surface right under the priority system. (Colo. Stat. §37-92-501)

Finally, Colorado provides for augmentation plans to offset depletions from wells. Wells that make out-of-priority diversions must replace their depletions through an augmentation plan. An essential component of an augmentation plan is to provide sufficient replacement water to prevent injury to senior appropriators (Colo. Rev. Stat. §37-92-305(5)). The process is similar to New Mexico's provisions for retiring water rights to offset depletions to surface water.

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

This alternative will not result in an overall increase in water rights, as it involves already allocated water rights that are currently available but cannot be exceeded. However, conjunctive management of existing water rights would effectively increase the usable supply by making a groundwater supply available during a drought when surface water would be otherwise unavailable. Due to local hydrologic and water rights factors, the Santa Fe, Española, and Pojoaque/Nambe areas would likely benefit the most from implementing this alternative.

6. Environmental Implications

Several environmental benefits are associated with conjunctive management:

- If stormflow is diverted as part of the conjunctive use strategy, potential slowing of summer stormflows could reduce erosion and runoff. However, any changes in flows should be examined for specific local environmental impacts.

- A water user taking advantage of a conjunctive use program will abstain from diverting in times of severe drought. This will benefit aquatic species in that the in-stream flow will be higher than it would otherwise have been.

7. Socioeconomic Impacts

Strategic conjunctive use of groundwater and surface water has many potential benefits, the foremost of which is improving water supply stability between wet and dry years. With conjunctive use, water providers can spend less on acquiring buffer supplies against dry years. If conjunctive use is implemented across multiple regional water providers, costs per unit of firm water supply can be lower for well fields and surface diversions. In addition, conjunctive use and regional water banks work well together as complementary mechanisms for coordinating among water users with differing combinations of surface water and groundwater rights who face differing exposures to dry year shortages.

Conjunctive use entails potential costs as well as benefits. If new well fields are necessary, groundwater tables and surface flows will be impacted to some degree. Conjunctive use requires detailed surface water supply assessments and groundwater monitoring, along with their attendant costs. Legal and technical expertise is needed to establish the appropriate procedures and criteria for implementing conjunctive use, consistent with OSE policies. New water storage and conveyance infrastructure may be necessary to accomplish regional conjunctive use, depending on how it is implemented.

Community and social impacts depend on the manner in which conjunctive use is accomplished. There is potential for disruption of local areas selected for infrastructure construction. However, conjunctive use can produce significant cost savings, potentially freeing up funds for other community needs.

Although the objective of conjunctive use is to create stable water supplies and a buffer against drought, it may inadvertently encourage growth in that water suppliers using their rights conjunctively could continue pumping groundwater in wet years to meet increasing demand. This result would diminish the usefulness of this alternative to alleviate water supply problems during times of drought. However, this is unlikely to occur because the OSE would impose restrictions on the permit that would prohibit over-diversion of the water rights.

8. Actions Needed to Implement/Ease of Implementation

In order to conjunctively manage water rights, permission of the State Engineer must be obtained, and modeling and/or other technical analyses will be needed to support an OSE application. The OSE and ISC must determine whether conjunctive management would impact the Rio Grande Compact. In locations other than Santa Fe (where surface and groundwater are currently used), technical and environmental issues would need to be resolved, and cost estimates/financing studies would need to be completed regarding installation of surface diversions or new wells. A regional model that has the buy-in of neighboring water users that are likely to protest such an appropriation would be an essential foundation for proceeding with this alternative in Santa Fe and other areas of the Jemez y Sangre water planning region.

9. Summary of Advantages and Disadvantages

Conjunctive management of surface and groundwater rights would give water rights holders additional flexibility to efficiently manage their water rights. However, because this alternative may be perceived as allowing water rights holders to take additional water, other water users in the system would likely protest. Technical studies showing how much water would actually be diverted over time and how the health and life of the aquifer would be enhanced could increase the likelihood of acceptance by the OSE and by other water rights holders.

Specific advantages of conjunctive management are:

- Flexibility in managing water rights
- Larger available supply during dry years
- Low cost where surface and groundwater diversions already exist

Disadvantages of implementing conjunctive management include:

- Potential impairment and Rio Grande Compact issues
- Potential high costs where surface diversions must be built
- Potential necessity to increase reservoir storage space and/or other infrastructure to divert greater volumes of surface and groundwater

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002a. *Alternative: Aquifer storage and recovery.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002b. *Alternative: Manage well field / install new municipal/industry supply wells and/or domestic supply wells*. White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

White Paper 3

Alternative: Manage Storm Water from Short Duration Precipitation Events Using Catchment Basins in Urban Areas

Alternative: Manage Storm Water from Short Duration Precipitation Events Using Catchment Basins in Urban Areas

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Neil Williams, Watershed West, LLC, (primary author), Alletta Belin (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

This white paper addresses increasing water supply in the Jemez y Sangre water planning region by capturing storm water flows in urban areas using catchment basins or other mechanisms such as roof harvesting. As discussed here, catchment basins refer to ephemeral reservoirs located on tributaries above the main stem of the local stream. Their intent is to moderate high flows resulting from short-duration precipitation events rather than to collect and store flows from longer-term seasonal variations in stream flows. The collected water is detained only briefly so that the basins are usually dry except for a period of one or two days after major precipitation events. In some cases a small permanent "water quality" pool is provided within the larger volume of the catchment basin to promote physical and biological treatment of storm water to meet water quality goals.

This white paper will consider four options:

- Use catchment basins to return infiltration/recharge to normal watershed rates (short-term retention).
- Use catchment basins to capture and divert surface waters (long-term "new" water supply).
- Harvest roof water for outdoor application simulating pre-dwelling conditions.
- Bank water (inject or infiltrate surface waters for retrieval at a later time).

These alternatives are designed to reduce flooding, enhance the natural recharge rate of downstream channels, and reduce demands for potable water for landscape irrigation. Their effectiveness is measured in additional acre-feet of water within the capture zones of water supply aquifers and reduction of irrigation demands on potable systems. Managing storm water in the Jemez y Sangre Water Planning Region will help protect the environment, protect the supply for existing demands, and improve the sustainability of the system. Because water rights are necessary for an increased diversion, this alternative is not expected to increase the supply available to meet the growing demand.

Urbanization of arid lands has numerous negative effects on natural hydrologic processes (Briggs, 1996; Riley, 1998) that are well understood. In the planning area such deleterious effects include:

- Major soil erosion from land and watercourse channels
- Significant impairment of surface water quality
- Increased flooding
- Reduction of natural infiltration rates
- Lowering of water tables
- Desiccation of aquatic and riparian habitat

The measures discussed here (Sections 1.1 through 1.4) in the context of water supply augmentation also mitigate some of these impacts, as discussed in Section 6.

1.1 Option 1: Short-Term Retention

Urban watersheds with large impervious areas produce runoff with higher flow peaks and discharge more volume of water in a shorter time than runoff from the same land before it was developed. These urban “flash” floods may greatly exceed the infiltrative capacity of the downstream natural channels and result in erosion and other negative impacts on the stream. Numerous small detention ponds can be constructed in developed areas to reduce storm water runoff rates below the current “flashy” urbanized rates. The capturing of storm water in these ponds can increase infiltration from the bottoms of the detention ponds themselves as well as downstream, where they discharge into existing sandy arroyos that are in communication with the local water supply aquifer. Outlets from these ponds should be designed with progressive discharge rates to control runoff from small as well as large storm events.

The net effect of properly designed detention ponds will be to decrease flood risk while increasing the duration of flow in the river after storms and increasing recharge. Detention ponds would be constructed in municipal drainage easements and would be maintained by the local municipality.

1.2 Option 2: Long-Term "New" Water Supply

Catchment basins, as discussed here, are not ordinarily used to divert storm water from one watercourse to another. Such a diversion requires an Office of the State Engineer (OSE) permit, and in the permitting process, valid water rights and non-impairment of other water rights must be demonstrated. This option is considered in more detail in the white paper that discusses the construction of new large reservoirs (DBS&A, 2002b).

1.3 Option 3: Roof Water Harvesting

Cisterns of one sort or another have long been used in arid areas to capture rainwater from roofs or other impervious areas for use during dry periods. Typically storage tanks are constructed below roof drains to capture runoff. The water is most often used to irrigate landscaping, thereby reducing the demand for potable irrigation water.

Cisterns have often been used historically for potable water supply as well. In this paper direct potable use of harvested roof water is not considered because (1) that involves additional measures to maintain water quality and (2) irrigation use is the larger demand. However, indirect potable use of roof and other urban runoff through groundwater recharge enhancement is accomplished by the other alternatives discussed here.

1.4 Option 4: Surface Water Injection

Banking of storm water is a broad concept that can be considered to be one of the goals of all of the options discussed in this paper. As discussed here, it means the transfer of urban storm water flow peaks into local groundwater. The methods to accomplish storm water banking can include engineered designs such as infiltration basins, galleries, in-stream infiltration check dams, and injection wells. Such recharge would provide opportunities for underground storage of the water to absorb differences between supply and demand for water, and to obtain soil-aquifer treatment benefits so that the water can be used for drinking. The detention basins would then also serve as pre-sedimentation basins to remove suspended solids and minimize clogging of infiltration systems for groundwater recharge. A detailed discussion of these alternatives is presented in a separate paper on aquifer storage and recovery (DBS&A, 2002a).

2. Technical Feasibility

The detention basins described in Option 1 for recharge enhancement are different from traditional flood control detention ponds, which are used by most municipalities to attenuate large flows such as 100-year events. Thus most existing detention ponds in the Jemez y Sangre region have large outlets designed only to reduce major (100-year) flood peaks. However, much of the annual water comes in the form of routine, frequent storm flows (WEF and ASCE, 1992), which are routed undiminished through the detention ponds designed solely for 100-year flows. In many cases, it is feasible to modify the outlets of existing storm water detention ponds to moderate the flows from the more frequent small storms as well as large storms.

Sediment management is needed to periodically remove accumulated sediment from detention ponds and infiltration systems. Mechanical removal and disposal of sediment represents the main operational cost of detention basins. To minimize these costs it is prudent to employ erosion control best management practices in the watershed areas above the detention ponds.

It has been shown that detention ponds can be designed to enhance water quality as well as reduce flood peaks (Denver Urban Drainage and Flood Control District, 1992). Conventional dry detention ponds can be very effective at capturing excess sediment in storm water. With the addition of small "water quality" pools, additional reduction of total suspended solids (TSS) and soluble pollutants can be achieved.

When choosing locations for detention ponds, it is necessary to identify favorable recharge reaches within the capture zone of existing or proposed supply wells. Those reaches would then be stabilized to maximize infiltration. Detention basins and infiltration check dams would typically be constructed within drainage easements and would be maintained by the local water supply entity.

Designs of infiltration basins vary with channel geometry and slope. Numerous low-height check dams (drop structures) can be constructed in degraded sections of the river and arroyo channels to reduce water velocity and increase infiltration. In addition, check dams reverse channel degradation by accumulating sediment that would otherwise be transported downstream.

Injection wells may be required where impermeable layers cause infiltrated water to perch above the local supply aquifer, as in the case of some Los Alamos sub basin streams. Injection wells are subject to physical clogging or chemical encrustation at the well screen and typically require some form of pretreatment. Therefore injection wells tend to be more costly than infiltration basins. They should be equipped with dedicated pumps to allow frequent short duration pumping to "backwash" clogging material. A variety of other types of infiltration systems, including storm water siphons and buried infiltration galleries, are being investigated by designers, but are not yet proven technologies. Where permeable alluvial fill with good infiltration characteristics exists, it is generally preferable to use surface infiltration basins due to their ease of maintenance as compared with subsurface systems. A more detailed discussion of methods for storing surface water is provided in a separate white paper on aquifer storage and recovery (DBS&A, 2002a).

Catchment facilities for roof harvesting of storm water are generally installed and maintained by property owners. The amount of water available for harvesting is a function of catchment surface (roof or pavement) area and weather. To effectively use the harvested water, the storage volume must be adequate to balance inflow and irrigation uses. A storage volume in the range of 1,000 to 1,500 gallons per home is typically needed to optimize capture. Larger volumes are required to serve larger commercial or institutional water harvesting arrangements.

Roof harvesting of storm water is currently practiced by individual property owners in the planning region, using both aboveground and buried cistern tanks. Aboveground cisterns require no pump to water nearby landscaping. Underground tanks usually require a pump or sloped terrain plus piping to deliver the irrigation water to landscaping.

Rainwater harvesting systems can be constructed by individual homeowners in many cases. If the terrain permits, shallow earthen basins can make very inexpensive alternatives to cisterns. Landowners can plant trees, grass, and ornamental landscaping that otherwise would require irrigation directly in the basins. Infiltration pits with pumice wicks have also been successfully placed under individual roof spouts to promote infiltration and irrigate landscaping near the house.

Catchment water quality depends on dust and contaminants in roofing, pavement, or other contact surface. These potential pollutants are not of concern with irrigation use, but do make potable use of roof harvest water less feasible without treatment.

Closely related to the alternatives discussed above are land reclamation treatments employed on upland areas to reduce flooding and sediment discharges. Many years of research by the Natural Resource Conservation Service (NRCS) has shown that enhancing upland area vegetation and soils will reduce watershed curve numbers (runoff coefficients) and, as a result, make flood and sediment control easier. In the Jemez y Sangre planning region, land reclamation has been applied for wildfire recovery and agricultural purposes but has not been systematically employed in urban areas for flood and sediment control since the Civilian Conservation Corps (CCC) projects of the 1930s. In the Santa Fe area, however, hundreds of CCC rock check dams have endured without maintenance for more than 60 years and still provide valuable erosion control. Urbanization obviously has not stopped since the CCC programs were active, and large-scale land stabilization programs are needed now at least as much as they were in the 1930s.

In the context of water supply, the desired effect of land reclamation is to slow runoff and increase infiltration. Many watersheds in the planning area have been historically overgrazed or over-logged. Most Jemez y Sangre watersheds would benefit from land reclamation measures to increase the density of native grasses, promote infiltration, and control gully formation. Applicable reclamation measures are very site-specific but may include soil amendment, seeding, mulching, thinning of piñon-juniper stands, and construction of check dams to control gullies. Typical reclamation efforts include enhancement of native grass communities, construction of contour swales, and sediment reduction. These have been ordinarily employed as a means of reducing erosion for grazing improvements or environmental goals, but are also applicable for managing water and sediment in recharge systems and for flood control. Additional discussion of land management is presented in the white paper on forest management (DBS&A, 2002c).

3. Financial Feasibility

For new construction, the cost of detention ponds and related in-stream facilities such as infiltration basins and check dams would probably be paid by developers if these facilities are required by local ordinance. Where communities already require storm water detention for flood control, the additional requirement to design and construct low-flow outlets and downstream infiltration measures would be relatively minor additions to storm water management costs already borne by developers or local government. Since the 1970s, Santa Fe terrain management regulations have required detention designed to reduce 100-year storms. However, the regulations have not been consistently enforced, and many areas developed since the 1970s still lack significant detention storage.

The main operational cost of detention basins would be for sediment management to periodically remove accumulated sediment from detention ponds and infiltration systems. These costs can be minimized by implementing erosion control best management practices in the watershed areas above the detention ponds.

For roof water harvesting, the cistern tank is typically the most expensive component of the system and costs on the order of $1 per gallon of storage. If landscaping within a shallow earthen basin is feasible, the storage and distribution costs are essentially eliminated. Roof water harvesting is generally feasible for homeowners and may easily be implemented with new development. However, government subsidies, regulatory requirements, or water rate incentives may be necessary to encourage retrofitting existing development for water harvesting.

Costs for banking water are discussed in a separate white paper (DBS&A, 2002a).

4. Legal Feasibility

4.1 Option 1: Short-Term Retention

Dams are regulated by the State Engineer (NMSA §72-5-32). Before constructing most dams, one must obtain a permit from the State Engineer (and meet the statutory criteria, that is, not cause impairment of any existing water rights, not be detrimental to the public welfare, and not be contrary to the conservation of water) (NMSA §72-5-6). Dams that are exempted from State Engineer permitting are stock dams, “erosion control structures whose maximum storage capacity does not exceed ten acre-feet,” and “dam[s] constructed for the sole purpose of sediment and flood control under the supervision of the United States army corps of engineers.” (Until 1997, no dams that were less than 10 feet in height and that impounded less than 10 acre-feet were subject to State Engineer regulation. In 1997, the legislature amended §72-5-32 to greatly restrict that exemption). The State Engineer’s primary concern in reviewing catchment dam applications would be to be sure that such dams do not increase net depletions to the surface water-groundwater system by increasing evapotranspiration. The State Engineer would likely require that any net depletions be offset by acquiring and retiring an equivalent amount of water rights.

Structures such as swales that do not completely dam a watercourse (defined in the State Water Code as “any river, creek, arroyo, canyon, draw or wash, or any other channel having definite banks and bed with visible evidence of the occasional flow of water” [NMSA 1978, §72-1-1) but merely slow down the water flow would not be considered “dams” and thus would not be subject to State Engineer permitting requirements.

(Unlike some other states, New Mexico does not define “dam” in the State Water Code or State Engineer regulations. One definition used by the U.S. Department of Agriculture is “an artificial barrier, with any associated spillways and appurtenant works, that does or may impound or divert water” [USDA Directive 650.1, Dam Safety (1980)]. Another definition that has been used in the Clean Water Act (CWA) context is “any structure which impounds waters” [NWF v. Gorsuch, 530 F. Supp. 1291 (D.D.C. 1982)]. Swales or other structures that only partially block or slow down water flows would not meet either of these definitions, as long as they do not have the capability of impounding water.)

The CWA also comes into play for catchment basins. Dams or dikes or any diversions that are constructed in arroyos or streams, which are considered “waters of the United States,” are subject to CWA jurisdiction and will require a permit from the Army Corps of Engineers under §404 (33 U.S.C. §1344). The bigger the land disturbance, the more onerous the permit conditions will be. At the same time, for municipalities and others that must obtain National Pollutant Discharge Elimination System (NPDES) permits from the U.S. Environmental Protection Agency (EPA) under the CWA for their storm water discharges (33 U.S.C. §1342(p)), EPA will be looking favorably on catchment systems that slow down and reduce pollution in storm water discharge.

4.2 Option 3: Roof Water Harvesting

Nothing in the State Water Code prevents individuals from harvesting runoff from roofs or property. Surface water does not become public and subject to State Engineer permitting until it enters a natural stream or watercourse (§72-5-27). Local governments are free to regulate and/or encourage this type of water management (see Section 4.1 in relation to harvesting water from property, where construction of dikes, swales, and/or dams is involved. Like catchment basins, from a CWA perspective, roof or property water harvest systems generally would improve storm water runoff quality and thus help compliance with the CWA.

4.3 Option 4: Surface Water Injection

For the legal feasibility of storing harvested water aboveground, see Section 4.1. Until the Ground Water Storage and Recovery Act (§72-5A-1 *et seq.*) was enacted in 1999, it was not possible to store water underground without it becoming public water subject to appropriation. Of course, simply increasing underground water supplies, without permitting and private ownership of the increased water, may be sufficient to meet the region's goals. In addition, however, water may be stored underground just as it may be stored aboveground, upon compliance with the Ground Water Storage and Recovery Act and after obtaining a permit from the State Engineer.

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

The yield available from enhancement of recharge in urbanized areas is dependent on a number of site-specific characteristics, especially the connected impervious area and characteristics of the receiving channel. Recent stream gaging data for the urbanized reach of the Santa Fe River provides an empirical basis to estimate yield for that system as an example of potential yields available from these measures.

The watershed of the Arroyo Mascaras is urbanized, relatively steep, and severely affected by erosion. Large impervious areas, including the De Vargas shopping mall, discharge through the arroyo to the Santa Fe River without any significant detention storage that mitigates flooding. The bulk of the annual discharge at this location comes in the form of summer thunderstorm events. A flood modeling study estimated the 100-year discharge rate for the Arroyo Mascaras at its confluence with the Santa Fe River to be 2,488 cubic feet per second (cfs) (Bohannan Huston, 1993). During summer thunderstorms it is very common for flood peaks of several hundred cfs or more to flow from the Arroyo Mascaras into the Santa Fe River.

The existing Santa Fe City well field is distributed in the urban area generally west of St Francis Drive and downstream of the Arroyo Mascaras confluence. A number of studies have shown that the Santa Fe River has very high natural infiltration rates west of St Francis (DE&S, 2001), and this reach is thus an active recharge zone for the aquifer serving the City wells.

A current study is measuring the interaction of the stream and the alluvial aquifer serving the City wells (DBS&A and Watershed West, 2002). Records from a stream gage installed in 1998 on the Santa Fe River at Ricardo Road indicate that this reach is strongly affected by urbanization, with large surges of runoff in response to summer rainfall. During dry weather, surface flows in the upper reaches of the river infiltrate into the sandy channel rapidly, usually considerably above the Ricardo Road gage. However, storm flows from the Arroyo Mascaras frequently overwhelm the infiltrative capacity of the wide sandy receiving channel and produce flashy peaks at the Ricardo Road gage.

In water year 1999 approximately 207 acre-feet flowed past the Ricardo Road gage (Ortiz and Lange, 2001). Complete records are not available for water year 2000. In water year 2001 the recorded discharge was approximately 184 acre-feet (DBS&A and Watershed West, 2002). Examination of the gage records indicates that the bulk of this water came during summer rainfall events.

The location of the Ricardo Road gage is near the downstream margin of the capture zone for the City well field. Large flows that surge past this gage are essentially lost to the well field, although they do contribute to recharge downstream. If flood peaks were attenuated by detention basins placed upstream (for example, in the Arroyo Mascaras basin), much more of the flow would infiltrate to the aquifer before reaching the Ricardo Road gage. Thus the Ricardo Road annual flows provide a very rough estimate that effective management of the tributary arroyo storm flows could result in additional recharge to the City well field of approximately 200 acre-feet per year, more in years with wet summers.

The yield available from roof water harvesting depends on the impervious area which is used as well as the capacity of the individual storage tanks or ponds. A 1,500-square-foot roof area in Los Alamos could yield a total of about 7,500 gallons of water during a typical summer with 8 inches of precipitation. Assuming that approximately 7,000 homes harvested runoff in Los Alamos, this source could supply approximately 160 additional acre-feet per year. For Santa

Fe, with 6 inches of precipitation during a typical summer (DE&S, 2001), the annual harvest would be about 5,600 gallons for a 1,500-square-foot roof area. Assuming that approximately 24,000 homes in Santa Fe (or an equivalent area of commercial development) harvested runoff, this source could supply approximately 410 additional acre-feet per year.

6. Environmental Implications

The options discussed here will generally have positive environmental impacts. The measures will increase recharge and contribute to raising local water tables, while decreasing peak rates of runoff and flood risk in urban areas. The measures discussed here also contribute to river restoration action strategies by improving surface water quality, reducing channel erosion, and contributing to ecologically healthy streams. To the extent that these measures stabilize and increase soil moisture in riparian areas, they also improve native aquatic and riparian wildlife habitat.

If captured storm flows will infiltrate or be injected into the subsurface, however, it is important to identify chemical or radiological contamination that may be present in the recharge zones. If recharge basins are placed over contaminated sites, transport of contaminants can be accelerated. This potential may limit the application of methods to enhance recharge in some areas, including some canyons draining Los Alamos National Laboratory.

The effect of increased recharge on downstream communities should also be considered, although increased upstream groundwater storage is generally considered beneficial to downstream communities. In the planning region, increased upstream recharge is not judged to be detrimental to downstream users. However, available streamflow for downstream water right owners may be reduced depending on how catchment basins are managed, how this “new” water is legally recognized, and to how and to where it is conveyed.

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 acequia 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.

All four options discussed herein for managing storm water using catchment basins in urban areas would have no significant direct socioeconomic or cultural impacts. 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. A possible detrimental impact that must be carefully considered, depending on how catchment basins are managed and how any “new” water is legally recognized, might be a reduction of available streamflow for downstream water right owners.

Other indirect benefits would include the aesthetics of more vegetation and greater opportunities for personal or community gardens from the outdoor application of rooftop harvesting. In general, increasing available water would probably reduce the cost for all water users.

8. Actions Needed to Implement/Ease of Implementation

Municipalities should conduct a thorough review of drainage in urban areas to identify recharge areas for their supply wells and feasible locations for detention ponds, infiltration basins, or in-stream measures. In many cases existing detention ponds can be upgraded at modest cost with the addition of low-flow outlets. In addition, opportunities often exist to convert culverted road crossings into low-flow detention ponds. Check dams and in-stream measures to increase infiltration in natural channels should be designed and constructed in accordance with local river corridor master plans where they exist.

Infiltration enhancement, watershed reclamation, and sediment management should be considered integral components of local water supply programs and should be funded as such. Major detention and recharge facilities, in particular, should be operated by a public entity. Drainage easements should be defined to permit ongoing maintenance of the facilities. Municipalities should develop formal goals for aquifer recharge enhancement and monitor the effectiveness of the measures adopted though stream gaging and groundwater studies.

Residents and business should be encouraged or required by ordinance to harvest roof water, to the extent practical, prior to discharge of runoff to the municipal drainage network. Land owners would build and maintain the roof water harvesting tanks or ponds according to requirements of the municipality. In 2001 Santa Fe adopted a landscape site design ordinance that offers incentives for water harvesting, and an amendment is currently under consideration that would require installation of water harvesting tanks for all new development except within the Business Capitol District.

Land reclamation measures need to be organized with the consent and cooperation of landowners and developers. An initial step is to formalize municipal planning goals that embody water supply objectives to justify future regulatory requirements on development.

9. Summary of Advantages and Disadvantages

Apart from increasing available local water resources, urbanized areas within the planning area generally need flashy runoff reduction, erosion control, and water quality improvement. Urban riparian areas also generally require channel stabilization and protection of recharge zones.

These measures also can be designed to significantly:

- Reduce peak rates of flow for urban flood reduction
- Raise the local water table to revive desiccated riparian bosques
- Convert ephemeral reaches to perennially flowing reaches
- Increase the usable volume of groundwater for drought protection
- Reduce channel erosion and restore degraded urban arroyo channels
- Improve storm water runoff quality
- Achieve river restoration goals for improving aquatic and riparian habitat

No adverse effects of these programs are anticipated. But to achieve the desired improvement, the water supply and environmental goals for these measures must be clearly stated and required by local engineering, planning, and land use ordinances.

References

Bohannan Huston, Inc. 1993. *Santa Fe drainage management plan.* December 1993.

Briggs, M.K. 1996. *Riparian ecosystem recovery in arid lands*: Strategies and references. University of Arizona Press, Tucson, Arizona. 159 p.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002a. *Alternative: Aquifer storage and recovery.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002b. *Alternative: Optimize reservoir management / increase allowable storage.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002c. *Alternative: Restore and manage forests, piñon-juniper woodlands, and riparian systems.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Daniel B. Stephens & Associates, Inc. (DBS&A) and Watershed West, Ltd Co. 2002. *Santa Fe stream aquifer interaction study*. Anticipated publication date March 2002.

Denver Urban Drainage and Flood Control District. 1992. *Urban storm drainage criteria manual.*

Duke Engineering & Services (DE&S). 2001. *Water supply study, Jemez y Sangre water planning region, New Mexico.* Prepared for Jemez y Sangre Water Planning Council, Sangre de Cristo Water, and City of Santa Fe, Santa Fe, New Mexico. January 2001.

Ortiz, David, and Lange, K.M. 2000. Water resources data, New Mexico, water year 1999, v. 1, Rio Grande Basin, Mimbres River Basin, and Tularosa Valley Basin. U.S. Geological Survey Water-Data Report NM-99-1. 402 p.

Riley, A.L. 1998. *Restoring streams in cities: A guide for planners, policymakers and citizens.* Island Press, Washington, D.C. 450 p.

Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE). 1992. *Design and construction of urban stormwater management systems.* American Society of Civil Engineers, New York. 724 p.

White Paper 4a

Alternative: Groundwater Desalination

Alternative: Groundwater Desalination

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Jeffrey Forbes (primary author), Susan C. Kery (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

Desalination is a water treatment process that converts brackish or saline water to fresh water by removing dissolved minerals (e.g., sodium and chloride ions) from the water. Where supplies of brackish or saline water exist, desalination can be used to yield potable fresh water. However, because of its relatively high cost, desalination is generally only chosen when supplies of fresher water are not available.

Groundwater within the Jemez y Sangre study area is generally of excellent quality and is obtained primarily from sand and gravel aquifers of the Tertiary Santa Fe Group (Wilson and Jenkins, 1979). However, brackish groundwater does exist in some parts of the study area. For example, total dissolved solids (TDS) concentrations in groundwater in much of the South Galisteo Creek sub-basin exceed the New Mexico Water Quality Control Commission (NMWQCC) groundwater standard of 1,000 mg/L (DE&S, 2001). These high TDS concentrations are associated with groundwater from the Paleozoic and Mesozoic bedrock aquifers that underlie the area, and groundwater from these aquifers is simply too salty to be used without desalination treatment. Other locations within the Jemez y Sangre study area where slightly to moderately elevated TDS concentrations occur in groundwater include (1) portions of the Los Alamos well field (Blake et al., 1995), (2) isolated wells within the City of Santa Fe's Buckman well field (DE&S, 2001), and (3) the western side of San Ildefonso Pueblo near the boundary between the Tesuque and Los Alamos sub-basins (DE&S, 2001).

However, water rights would be required to divert the brackish water in these areas, and therefore, desalination would not create more water, unless water is piped in from other regions. Desalination can be used to treat existing water supplies, but is not considered an alternative for meeting new demands in the region.

In addition to treating naturally brackish groundwater, desalination processes may be an important tool in the reuse of treated wastewater effluent. Wastewater typically contains higher TDS concentrations than the source water, and repeated reuse results in a buildup of dissolved salts. Desalination can be used to counter this salt buildup. Desalination may offer additional benefits such as removal of organic compounds and pharmaceuticals from reclaimed water.

2. Technical Feasibility

Desalination plants are used commercially to provide fresh water for many communities around the world; thus the technical feasibility of desalination has been proven. Approximately 13,600 desalination units in 120 different countries currently produce 26 million cubic meters of fresh water each day (Reuters ENN, 2001). The Middle East region has approximately 50 percent of the desalination capacity because fresh water supplies are scarce in that region (Gleick, 1998; Buros, 1999). The United States has approximately 10 percent of world desalination capacity (U.S. Congress, 1988).

Two main types of desalination processes are currently in use: (1) membrane methods and (2) thermal methods. The most common membrane process is reverse osmosis (RO), whereby pure water passes through a semipermeable membrane under pressure, leaving the dissolved salts (minerals) behind in a more concentrated brine solution. A related technology is electrodialysis (ED), which uses charged electrodes to cause dissolved ions to pass through semipermeable membranes, leaving behind water of lower salinity. Nanofiltration membranes have also been demonstrated to remove salts, though not as completely as RO. The most well known thermal process is distillation, where saline water is heated to increase its vapor pressure, and subsequent condensation of the resulting water vapor yields fresh water.

Existing desalination plants consist primarily of RO, ED, and multistage flash distillation units (Table 1). The production capacity of membrane and thermal process plants is presently nearly equal, but most older plants are distillation units, so the total operating capacity of membrane plants will likely increasingly exceed that of thermal units (Buros, 1999). Where brackish water containing less than 10,000 parts per million (ppm) dissolved salts is available, membrane

Table 1. Selected Membrane Desalination Plants Operating in the Western United States

City/Name	State	Startup Year	Plant Capacity (mgd)	Process Type [a]	Recovery Rate [b] (%)	Feedwater Type [c]	Product Water Type [d]
Buckeye	AZ	1989	0.9	EDR	80	BW	DW
Chandler	AZ	1997	2.3	NF / RO	88	WW	GWI
Bolinas	CA	1996	0.2	MF	80	IW	DW
El Segundo	CA	1996	20.0	MF / RO	70	WW	IRR / IND
Marina	CA	1996	0.3	RO	40	SW	DW
Oceanside	CA	1994	2.0	RO	75	BW	DW
Riverside	CA	1990	5.4	RO	76	BW	GWI
Saratoga	CA	1994	5.0	MF	93	IW	DW
Torrance	CA	1993	1.3	RO	80	BW	IRR / IND
Tustin	CA	1996	3.0	RO	84	BW	GWI
Water Factory 21	CA	1977	5.0	RO	85	BW / WW	GWI / DW
Las Animas	CO	1996	1.0	RO	50	BW	DW
Washington	IA	1993	1.9	EDR	88	BW	DW
Wallace	ID	1998	1.2	UF	80	IW	DW
Froid	MT	1995	0.1	RO	88	BW	DW
Sherman	TX	1993	6.0	EDR	85	IW	DW

Source: http://www2.hawaii.edu/~nabil/mdpow.htm#state

mgd = Million gallons per day

[a] EDR = Electrodialysis reversal
MF = Microfiltration
NF = Nanofiltration
RO = Reverse osmosis
UF = Ultrafiltration

[b] Product water/feed water

[c] BW = Brackish water
GW = Groundwater
IW = Impaired water
SUR = Surface water
SW = Seawater
WW = Wastewater

[d] DW = Drinking water (potable water)
GWI = Groundwater injection
IND = Industrial water
IRR = Irrigation water

processes (RO or ED) are generally the preferred technologies for desalination. ED tends to be more economical at salinities less than about 3,000 ppm, whereas RO is preferred at salinities between 5,000 and 10,000 ppm (U.S. Congress, 1988).

Historically, desalination has suffered from a non-technical bias against technologies that are perceived as innovative or unproven (U.S. Congress, 1988). Engineers charged with designing water treatment plants tend to favor "tried and true" conventional water treatment techniques. However, with increasing numbers of desalination plants coming online worldwide, this perception is changing.

3. Financial Feasibility

Several considerations influence the cost of desalination per volume of freshwater produced, including (1) feed water salinity, (2) energy costs, and (3) economies of size. The major categories are capital costs and operation and maintenance (O&M) costs. In addition, any economic evaluation of the total cost of water delivered to a customer must include costs for water distribution and costs for compliance with environmental regulations (Section 6).

Costs rise significantly with increasing salinity of the feed water, and the cost of desalting seawater (TDS=35,000 mg/L) is three to five times higher than the cost of desalting lower-salinity brackish water from the same size plant (Buros, 1999). Therefore, it is advantageous to make use of the freshest feed water available. Reverse osmosis plants appear to be the preferred choice for desalting brackish water in most small to medium-size communities in the United States. This is due to their simpler operation, lower energy consumption, and resulting lower fresh water unit costs as compared with other desalination methods (Glueckstern, 1999). The overall cost of fresh water from a reverse osmosis plant is often less than half of that produced by means of distillation, although the process has higher up-front investment costs compared to thermal processes. As technical advancements of membrane processes improve their cost and efficiency, they will continue to be the preferred choice for new desalination plants. Given that the groundwater underlying parts of the Jemez y Sangre study area only marginally exceeds water quality TDS standards, it appears that ED or RO would most likely be the preferred desalination technologies. Depending on feedwater quality, some pretreatment may be required prior to desalination by RO or ED.

All desalination processes require large amounts of thermal or electric energy. A finite minimum amount of energy is required to separate pure water from a saline solution. For seawater, for example, this minimum energy is approximately 2.65 kilowatt hours (KWH) per 1,000 gallons of fresh water produced (Cordes and Shaeffer, 1973). However, because of inefficiencies that exist in any real process, the actual energy requirements for desalination systems are substantially higher than this theoretical minimum value. In practice, energy costs often represent 50 to 75 percent of operating costs (Mesa et al., 1996). With generally the lowest energy requirements, membrane processes are more attractive in many instances, compared to distillation plants (Sackinger, 1982; Glueckstern, 1999), and rising energy prices tend to increasingly favor RO or ED.

Economies of scale arise when increases in the plant size (gallons of water produced per day) bring decreases in the unit fresh water cost. Economies of size are evident in all desalination processes, but to different extents. RO exhibits the smallest economies due to size, while distillation processes show the greatest economies of size. O&M costs are not subject to economies of size, but are directly affected by the quality of the feed water (Morin, 1999).

Costs (in 1985 dollars) for desalination of brackish water (<10,000 ppm) using RO or ED are in the range of $1.50 to $2.50 per 1,000 gallons of water produced, or approximately $500 to $830 per acre-foot (U.S. Congress, 1988). These costs do not include distribution costs or the cost of brine disposal. Because of economies of scale, costs are higher for small-capacity plants. At present, costs for traditional water supplies generally remain lower than the total cost of desalinating water. However, the gap between the two might be reduced by (1) reductions in the cost of desalination (e.g., by reducing energy costs or increasing energy efficiency), and/or (2) increases in the cost of traditional water sources.

Increasing demands for fresh water worldwide should result in continued improvements in desalination technology. Improved desalination technologies will increase the performance ratio (the ratio of fresh water to the amount of energy consumed) and hence lower the unit costs of producing potable water. Reduced energy costs would likewise make desalination relatively more attractive. Recent investigations have focused on the use of renewable energy to provide the required power for the desalination process, with the most popular renewable source being solar energy. Another approach is the use of dual-purpose plants, where the desalination plant is connected to an electric power generating station and uses the waste heat from that station as an energy source (Buros, 1999; Goosen et al., 2000).

Solar desalination systems are simple and easy to operate and maintain, and also reduce pollution by not using fossil fuels (Voivontas et al., 1999; Chaibi, 2000). In locations with abundant sunshine, such as New Mexico, solar desalination is a potentially viable option, especially for small-scale plants in remote locations. Indeed, RO of brackish water (if available) using solar energy is potentially the cheapest way to provide new fresh water resources in remote areas (McCarthy & Leigh, 1979; Voivontas et al., 1999). At present, solar desalination worldwide is restricted to remote areas needing smaller desalination systems.

Increases in the cost of traditional water sources will make desalination increasingly attractive. Costs of traditional water sources may rise in the future for a number of reasons:

- Increasing levels of treatment being required to meet more stringent water quality standards
- Demand for fresh water outpacing supply
- Environmental concerns reducing quantities of traditional water sources available to communities
- Alteration of existing pricing schedules to reflect true costs of water

Determining the true cost of water can be difficult, and if known, true costs would often be significantly higher than the costs charged to consumers. When compared with true costs of traditional water supplies, desalination would immediately become more competitive than it appears based on prices currently charged for water from conventional sources.

4. Legal Feasibility

The legal restraints arising in the context of the groundwater desalination are minimal. In New Mexico, the State Engineer has no jurisdiction over aquifers that are 2,500 feet or more below the surface of the ground and contain nonpotable water (defined as water containing more than 10,000 parts per million TDS) (NMSA 1978, §72-12-25). Thus one way to acquire new, unappropriated water is to tap nonpotable water.

Before a well can be drilled in such an aquifer, a “notice of intent” to drill such a well must be filed with the State Engineer and published in a newspaper in the county in which the well will be located. Such notice must state the location and depth of the proposed well, the purpose for which the water will be used, and the estimated amount of water that will be used. The proposed well can be drilled 10 days after publication of the notice (NMSA 1978, §72-12-26).

Any person claiming impairment of existing water rights due to an appropriation of nonpotable water may bring an action in state court (NMSA 1978, §72-12-28). Such impairment may be subject to a plan of replacement pursuant to state law (NMSA 1978, §72-12A-4). Once acquired, nonpotable water that will be used for municipal purposes must be treated to comply with Safe Drinking Water Act standards (42 U.S.C. 300f *et seq.)* and New Mexico’s drinking water regulations found at 20 NMAC 7.1.

Since the majority of the water in the region contains less than 10,000 TDS, it falls under OSE jurisdiction. New appropriations for groundwater require submission of an application for a permit to the OSE (NMSA 72-12-1). However, the groundwater in the region is generally considered to be connected to surface water, which means that no unappropriated water is available for new permits. In such cases, the State Engineer allows only the transfer of perfected consumptive water rights. Consequently, the acquisition of water rights in a basin where all surface water effects of groundwater pumping must be offset can only occur through the marketplace between a willing seller and a willing buyer. In addition, such a transfer can occur only after publication and notice and after a determination that the proposed appropriation and its point of diversion and place and purpose of use will not impair existing water rights, will not be contrary to the conservation of water, and will not be detrimental to the public welfare.

The legal restraints associated with the disposal of brine include the necessity of obtaining either a groundwater discharge permit pursuant to the state Underground Injection Control Program or, if discharge is to surface water, a federal National Pollutant Discharge Elimination System (NPDES) permit.

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

Desalination technology is well proven and could effectively be used to lower salinity levels to produce potable water. However, the quantity of brackish water potentially available for desalination within the study area is presently unknown. Detailed hydrogeologic studies would be required for each location where desalination is contemplated. Based on a preliminary review of available information (DE&S, 2001), it appears that most of the brackish groundwater underlying the study area contains only slightly elevated TDS concentrations, mostly in the range of 1,000 to 5,000 mg/L TDS. The New Mexico State Engineer has defined “protectable underground water” as all waters in the State of New Mexico containing 10,000 mg/L TDS or less. Therefore, the brackish water within the study area would likely be classified as potentially potable under the State Engineer’s criteria. This in turn suggests that most of this brackish water would be subject to the same New Mexico water law governing the use of fresh water.

6. Environmental Implications

For desalination, the major environmental concern involves disposal of brine (highly concentrated saline water), which is a byproduct of all desalination processes. Alternatives for disposal of brine include (1) deep subsurface injection, (2) discharge to surface water stream or lake, (3) discharge to sanitary sewer, (4) disposal of brine in evaporation ponds, and (5) evaporation, crystallization, and disposal of solid salt in a special landfill (Winter et al., 2001).

- Deep subsurface injection wells would be considered Class V wells under the New Mexico Environment Department's (NMED) Underground Injection Control (UIC) Program. Obtaining permits for such wells could be costly and would require a hydrogeologic study to ensure that the proposed injection well(s) would not impact freshwater aquifers. Furthermore, drilling and maintenance of deep injection wells would also prove costly. For these reasons, deep injection of brines may not prove cost-effective.

- Likewise, direct discharge of desalination brine to surface water bodies would require an approved NPDES permit from NMED, and in all likelihood this option would not be permitted because it would result in degradation of surface water quality.

- Brine disposal to sanitary sewers probably would not require a permit providing the quantities were small enough to not cause significant salinity change in total flow to the wastewater treatment plant. For small desalination plants in communities served by sewers, this could prove the most economical option for brine disposal.

- Disposal of brine in lined evaporation ponds can be relatively inexpensive, especially where land is readily available. Brine evaporation ponds operating in Texas add costs of $0.05 to $0.25 per 1,000 gallons of fresh water produced (U.S. Congress, 1988).

- Crystallization and disposal of desalination salts in an approved landfill has become increasingly popular nationwide, in part due to the high technical and regulatory costs of surface or subsurface brine disposal. Salt crystallization can result in additional costs of $1.15 to $1.85 per 1,000 gallons of fresh water produced (U.S. Congress, 1988).

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 acequia 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.

Treating groundwater will have no greater socioeconomic or cultural impacts than the impacts that are occurring from the existing use of water. However, the acquisition of water rights to indirectly divert brackish water could put pressure on traditional communities. If saline water was piped in from outside the region, thereby making more groundwater available to more populous areas, this alternative would have the 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. Depending on how and by whom treatment expenses are financed, this alternative may or may not reduce the cost of water for all users.

8. Actions Needed to Implement/Ease of Implementation

In general, implementation of desalination within a given sub-basin of the study area will require the following steps for the planning, design, and construction process:

- Hydrogeologic study to define water source (adequate quantity and quality)
- Legal study to assess water rights and permitting issues

- Conceptual design/feasibility study
  - Well field development
  - Pipeline/conveyance study
  - Treatability, blending, and wastewater disposal assessment
  - O&M considerations (e.g., workforce requirements)
  - Capital and annual cost estimates
  - Assessment of changes to distribution system and user rates
- Review and approval of selected design
  - Local, state, and federal approval
  - Public participation
  - Investigation of funding options
- Engineering design
  - Bench studies of water compatibility
  - Development of plans and specifications
  - Compilation of bid documents for approved alternative
- Construction (phased)
- Preliminary O&M
- System integration

For small-capacity plants that would serve smaller communities, many steps in the design process could be streamlined considerably by working directly with a vendor that offers off-the-shelf membrane filtration systems.

9. Summary of Advantages and Disadvantages

Advantages of desalination include:

- An increased quantity of potable water is available for use.
- Use of brackish water does not compete with other fresh water users.
- Technology is proven.

Disadvantages of desalination as a water management alternative include:

- The unit water costs are higher than the cost of traditional water sources.
- Costly disposal of waste brine or salt (e.g., landfill or deep injection) is required.
- Disposal of waste brine must comply with permitting requirements (UIC, NPDES, or New Mexico Discharge Plan)

References

Blake, W.D., F. Goff, A.I. Adams, and D. Counce. 1995. *Environmental geochemistry for surface and subsurface waters in the Pajarito Plateau and outlying areas, New Mexico.* LA-12912-MS, Los Alamos National Laboratory.

Buros, O.K. 1999. *The ABCs of Desalting.* International Desalination Association, New York, Massachusetts, USA.

Chaibi, M.T. 2000. An overview of solar desalination for domestic and agriculture water needs in remote arid areas. *Desalination* 127:119-133.

Cordes, Eugene H., and R. Schaeffer. 1973. *Chemistry.* Harper and Row, -New York.

Duke Engineering & Services (DE&S). 2001. *Water Supply Study Jemez y Sangre Water Planning Region, New Mexico.* January 2001.

Gleick, P.H. 1998. *The World's Water.* Biennial report of fresh water resources, 1998-99. Island Press, USA.

Glueckstern, P. 1999. Design and operation of medium- and small-size desalination plants in remote areas: New perspective for improved reliability, durability and lower costs. *Desalination* 122:123-140.

Goosen, M.F.A., S.S. Sablani, W.H. Shayya, C. Paton, and H. Al-Hinai. 2000. Thermodynamic and economic considerations in solar desalination. *Desalination* 129:63-89.

McCarthy, J.V. and J.M. Leigh. 1979. *The prospects of desalination using solar energy.* BHP Melbourne Research Laboratories, Australia.

Mesa, A.A., C.M. Gómez, and R.U. Azpitarte. 1996. Energy saving and desalination of water. *Desalination* 108:43-50.

Morin, P.E. 1999. *Desalting plant cost update: 2000.* International Desalination Association.

Reuters Environmental News Network (ENN). 2001. Thirst for water drives desalination boom. www.enn.com/news. Wednesday, March 21, 2001

Sackinger, C.T. 1982. Energy advantages of reverse osmosis in seawater desalination. *Desalination* 40:271-281.

U.S. Congress, Office of Technology Assessment. 1988. *Using desalination technologies for water treatment*. OTA-BP-O-46. Washington, DC: U.S. Government Printing Office. March 1988.

Voivontas, D., K. Yannopoulas, K. Rados, A. Zervos, and D. Assimacopoulos. 1999. Market potential of renewable energy powered desalination systems in Greece. *Desalination* 121:159-172.

Wilson, L. and D.N. Jenkins, 1979. Ground-water resources of Santa Fe Country. pp. 293-298. *In New Mexico Geological Society Guidebook, 30th Field Conference, Santa Fe Country*.

Winter, Tennille, D.J. Pannell, and Laura McCann. 2000. *The economics of desalination and its potential application in Australia.* SEA Working Paper 01/02, Agricultural and Resource Economics Department, University of Western Australia, Perth. http://www.general.uwa.edu.au/u/dpannell/dpap0102.htm.

White Paper 4b

Alternative: Removal of Trace Constituents from Groundwater

Alternative: Removal of Trace Constituents from Groundwater

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Jeffrey Forbes (primary author) and Susan C. Kery (legal).

1. Summary of the Alternative

Groundwater that would otherwise be potable may require removal of trace constituents prior to consumption. Some such constituents (e.g., arsenic) may occur naturally in the groundwater, while others (e.g., trichloroethylene [TCE]) may be of anthropogenic origin. Trace constituents that commonly occur in New Mexico groundwater at concentrations that exceed drinking water standards include arsenic, iron, manganese, nitrate, radium, and uranium. EPA’s primary maximum contaminant levels (MCLs), which must be met by all public water supplies, for these constituents are listed in Table 1.

Table 1. Drinking Water Standards for Selected Trace Constituents

Constituent	EPA MCL [a]
Arsenic	10 µg/L [b]
Iron	0.3 mg/L [c]
Manganese	0.05 mg/L [c]
Nitrate (as N)	10 mg/L
Radium	5 pCi/L
Uranium	30 µg/L [d]
Gross alpha radiation	15 pCi/L

[a] Pursuant to the Safe Drinking Water Act, 42 U.S.C. 300f *et seq.*
[b] New arsenic MCL becomes effective in January 2006.
[c] Secondary (non-enforceable) standard established for aesthetic reasons.
[d] New uranium MCL takes effect December 8, 2003.

According to the Jemez y Sangre water planning study (DE&S, 2001), elevated concentrations of each of the above constituents can be found in groundwater at isolated locations within the study area. Additional constituents reportedly found at elevated concentrations in particular wells include barium, fluoride, and sulfate, plus miscellaneous organic compounds associated with leaking underground storage tanks and spills, such as benzene, toluene, TCE, and perchloroethylene (PCE) (DE&S, 2001).

DBS&A used a northern New Mexico water quality database compiled by Los Alamos National Laboratories to determine which constituents are most often present in groundwater at concentrations above their respective MCLs. Figure 1 shows the wells within the study area that have exceeded drinking water MCLs for one or more constituents. As shown in the figure, arsenic appears to be the constituent that most commonly exceeds MCLs within the study area. Therefore, the focus of the remainder of this paper is on arsenic treatment to meet the new MCL of 10 µg/L. Many of the same technologies used for arsenic treatment are also applicable to the removal of the other constituents, such as dissolved iron, manganese, and uranium.

Because of the regulatory requirements, particularly for arsenic, the removal of trace constituents is necessary to use existing supplies and does not provide new water to meet growing demand.

2. Technical Feasibility

In January 2001, the U.S. Environmental Protection Agency (EPA) lowered the arsenic drinking water standard from 50 µg/L to 10 µg/L. The new standard applies to both community water systems and non-transient, non-community water systems. Public drinking water supplies must comply with the new 10-ppb arsenic MCL within five years of promulgation of the new rule, that is, on or before January 22, 2006. However, certain provisions for extensions due to technical or economic hardship are available.

It is well known that elevated concentrations of naturally occurring arsenic are present in groundwater throughout much of northern New Mexico (DE&S, 2001). The previous arsenic MCL of 50 µg/L is exceeded in numerous wells in northern New Mexico (Figure 1), and many more wells exceed the new arsenic standard of 10 µg/L (Figure 1). Therefore, at some locations within the study area, arsenic removal will be required prior to serving groundwater to consumers.

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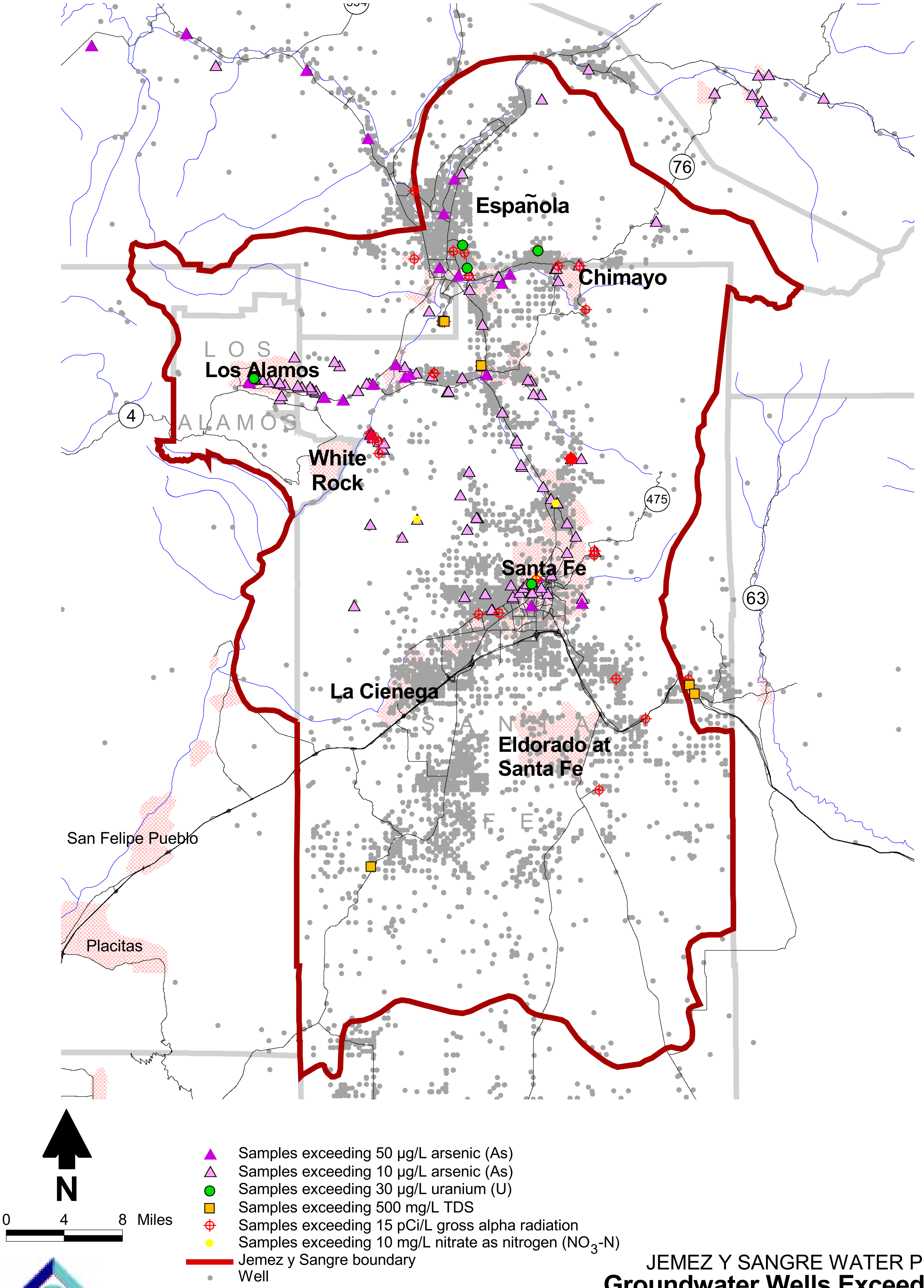

▲ Samples exceeding 50 µg/L arsenic (As)
△ Samples exceeding 10 µg/L arsenic (As)
● Samples exceeding 30 µg/L uranium (U)
■ Samples exceeding 500 mg/L TDS
⊕ Samples exceeding 15 pCi/L gross alpha radiation
• Samples exceeding 10 mg/L nitrate as nitrogen (NO_3-N)
— Jemez y Sangre boundary
• Well

JEMEZ Y SANGRE WATER PLAN

Groundwater Wells Exceeding Drinking Water Standards

Daniel B. Stephens & Associates, Inc.

2-11-02

JN 9419

Figure 1

Unlike desalination, treatment of water to reduce arsenic concentrations is relatively new. The technologies for arsenic removal are still evolving rapidly, and technology breakthroughs are likely over the coming years. Both EPA and the American Water Works Association Research Foundation (AWWARF) have investigated the technologies available for removal of arsenic from groundwater and are supporting the development of new technologies.

EPA identified the following types of processes as being applicable to the removal of arsenic from drinking water (U.S. EPA, 2000):

- Precipitation processes (e.g., coagulation/filtration, lime softening, etc.)
- Sorption processes (e.g., activated alumina)
- Ion exchange processes
- Membrane processes (e.g., nanofiltration, reverse osmosis [RO])
- Alternative technologies

AWWARF (Amy et al., 2000) identified the following technologies as most promising for aboveground arsenic removal: (1) sorption on activated alumina or other solid media, (2) ion exchange, (3) coagulation/microfiltration, and (4) nanofiltration/reverse osmosis. One of these technologies may prove superior to the others in any particular situation, depending largely on the size of the treatment system and flow rate.

2.1 Activated Alumina

The activated alumina process involves adsorption of arsenic on a filter bed of oxidized alumina (Al_2O_3). When the alumina surface becomes exhausted, it must be regenerated using a strong base solution, such as sodium hydroxide. The alumina is then rinsed with water, and the high pH is neutralized using an acid solution. The strong base regenerant solution must be disposed of, and eventually the alumina bed must be replaced. As an alternative, the alumina is not regenerated but rather disposed of directly when spent ("throwaway activated alumina").

2.2 Ion Exchange

Ion exchange is an adsorption process in which dissolved arsenic in the water becomes adsorbed to a synthetic-coated plastic resin. For each negatively charged arsenate anion that becomes adsorbed, one chloride ion is liberated, thus the name ion exchange. Ion exchange can continue until the resin is exhausted, at which point it must be regenerated by passing a concentrated chloride salt solution (brine) over the resin, which displaces the arsenate ions and replenishes the chloride ions on the resin (CH2M-Hill, 1999). The brine can be reused many times prior to disposal, but will then contain appreciable concentrations of dissolved arsenic.

Because sulfate is adsorbed preferentially over arsenate, elevated sulfate concentrations in the feedwater will result in shorter times before the ion exchange resin becomes exhausted. Another potential drawback of ion exchange is the possibility of “chromatographic breakthrough,” which could result in rapid release of the sorbed arsenic from the ion exchange resin back to the treated water.

2.3 Coagulation/Microfiltration

This technology involves the addition to the feedwater of a chemical (e.g., ferric chloride), which then precipitates (as ferric hydroxide) and causes co-precipitation of dissolved arsenic. The precipitate with adsorbed arsenic is then removed by flocculation and gravity settling, or by filtration. Because of the high affinity of the dissolved arsenate anion for the ferric hydroxide surface, coagulation/microfiltration can achieve very high removal efficiencies. Pentavalent arsenic (As V) is removed more effectively than trivalent arsenic (As III) species. Microfiltration is necessary to remove the fine ferric hydroxide particles quickly.

The process uses significant amounts of chemical reagents to remove the arsenic from the water, and these chemicals accumulate as an arsenic-bearing sludge that must be disposed of in a permitted landfill. The transportation of chemicals and sludge to and from the treatment plant is an important cost consideration for this technology.

2.4 Reverse Osmosis

RO involves forcing water through a semipermeable membrane. The white paper on desalination (DBS&A, 2002) provides more information on the RO technology. RO not only removes arsenic from the water, but most other dissolved ions as well. Thus RO reduces both the arsenic concentration and the total dissolved solids (TDS) content of the water. Because of the high energy demand, RO would in most cases not be the most cost-effective means of arsenic removal. An exception would be if the water supply also required treatment to reduce salinity levels, in which case, RO could be used to simultaneously effect both salinity reduction and arsenic removal. A potential drawback of RO is its inability to remove uncharged As III species without prior oxidation to As V.

2.5 Subsurface Arsenic Treatment

Subsurface arsenic treatment is an innovative and potentially cost-effective technology for arsenic treatment at the wellhead (Miller, 2001). The concept is to create a geochemical barrier composed of iron hydroxide in the aquifer surrounding the well. The iron hydroxide surfaces will adsorb dissolved arsenic as it approaches the well screen, thereby removing it from solution. The geochemical barrier can be created either by injection of a ferric solution followed by oxygenated water or by alternating injection and withdrawal of oxygenated water to and from the well. While subsurface arsenic removal has not yet been demonstrated on a large scale, it offers the significant advantages that the arsenic in the groundwater is left below ground, no arsenic-bearing waste sludges or waste chemical solutions requiring disposal are generated, and minimal operator training is required.

2.6 Selection of Preferred Arsenic Treatment Technology

Many factors must be considered in selecting the most appropriate arsenic treatment technology for a given site, including feedwater arsenic concentration, total flow rate, general water chemistry, and proximity to an approved disposal site for waste sludge. Another consideration is whether the situation requires numerous separate treatment facilities or a single large facility. In Albuquerque, for example, the dispersed locations of City supply wells, coupled with the large elevation difference between them, requires that arsenic treatment systems be installed at each wellhead or storage tank, as opposed to a single large treatment plant (Chwirka et al., 2000). Because this restriction limits the possibility of economy of scale, certain technologies are more favorable than others.

Small communities (fewer than 3,000 persons) may be able to use point-of-use, ion exchange, or RO systems to remove arsenic within the home. However, treatment costs for small systems will always be higher per household served (Gurian and Small, 2002). Therefore, where feasible, "regionalization" of water treatment systems is to the consumer's benefit.

A further consideration in selecting the preferred technology for a given site is water waste. Some technologies, such as RO, result in a large wastewater stream whereas others, such as activated alumina adsorption or coagulation/microfiltration, waste very little water (Chwirka et al., 2000). Last but not least, waste management of residuals (e.g., sludge, spent filter media) is a significant cost consideration for some of the technologies, such as coagulation/ microfiltration and ion exchange.

3. Financial Feasibility

Over the past few years, many New Mexico communities that rely on groundwater have been concerned about the costs of future arsenic treatment when the new MCL goes into effect. While federal funding may become available to assist communities in complying with the new drinking water standard, operation and maintenance costs for arsenic treatment plants will ultimately be passed on to customers. Bitner (2001) has investigated anticipated arsenic treatment costs in New Mexico and found that in addition to the other variables mentioned in Section 2.6, the most cost-effective technology for arsenic treatment at a particular location will depend largely on system capacity. For example, RO may prove the most cost-effective for small point-of-use systems, whereas large public water supplies may find the coagulation/ microfiltration technology most economical.

The American Water Works Association (AWWA) arsenic work group developed an *Arsenic Treatment Cost Estimating Tool* to help communities estimate their costs to comply with the new drinking water standard (AWWARF, 2000; Chwirka and Narasimhan, 2000). The tool consists of an Excel spreadsheet into which are entered the raw water arsenic concentration and flow rate, interest rate, and other variables. The tool permits calculation of capital and operations and maintenance (O&M) costs, as well as monthly rate increases that can be expected by customers. An updated cost tool is expected to be released by AWWA by Summer 2002.

CH2M-Hill (1999) has investigated arsenic treatment costs for the City of Albuquerque. This evaluation ranked three technologies (activated alumina, ion exchange, and coagulation/ microfiltration) in terms of costs and ease of implementation in Albuquerque. The report concluded that coagulation/microfiltration is the preferred technology for Albuquerque. Ion exchange was rejected because of the large volumes of generated waste brine and salt that would require disposal.

4. Legal Feasibility

All water to be used for municipal supplies must be treated to comply with Safe Drinking Water Act standards (42 U.S.C. 300f *et seq.*) and New Mexico's drinking water regulations found at 20 NMAC 7.1. The legal restraints associated with the disposal of any brine generated through the process of treating water include the permitting requirements necessitated by discharge to groundwater, surface water, or landfills (Section 6).

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

All of the technologies described above are very effective in removing dissolved arsenic to levels well below the new MCL of 10 µg/L. Typically only a portion of the water supply would be treated, but the resulting arsenic concentrations would be very low (e.g., <1 µg/L). This essentially "arsenic free" treated water would then be blended with untreated groundwater in proportions that would ensure that the resulting blend would still be below the arsenic MCL. Blending in this way reduces overall treatment costs.

No new supply would actually be created by this alternative, but treatment would allow water users to exercise their water rights. The City of Española has several wells off-line due to high fluoride and other trace constituents. If the communities create a regional water system, the ability to cost-effectively remove arsenic nitrate, uranium, and other trace constituents would be vastly improved.

6. Environmental Implications

The primary environmental concern for arsenic treatment (and treatment to remove other trace constituents) involves the management of waste residuals, such as RO brine, coagulation/ microfiltration sludge, or spent ion exchange resins. Generation and disposal of RO brine (highly concentrated saline water) may be undesirable, both from an economic perspective (permitting costs), as well as a public perception standpoint. Alternatives for disposal of brine include (1) deep subsurface injection, (2) discharge to surface water stream or lake, (3) discharge to sanitary sewer, (4) discharge to evaporation ponds, and (5) evaporation, crystallization, and disposal of solid salt in a special landfill:

- Deep subsurface injection would require a Class V well permit from the NMED Underground Injection Control (UIC) Program, which could be costly to obtain. Furthermore, deep injection wells would have to be drilled and maintained, which would also prove costly.

- Direct discharge of brine to surface water bodies would require an approved National Pollutant Discharge Elimination System (NPDES) permit, and in all likelihood this option would not be permitted because it would result in degradation of surface water quality.

- Brine disposal to sanitary sewers probably would not require a permit providing the quantities were small enough to not cause significant salinity change in total flow to the wastewater treatment plant. For small desalination plants in communities served by sewers, this could prove the most economical option for brine disposal.

- Disposal of brine in lined evaporation ponds can be relatively inexpensive, especially where land is readily available. Brine evaporation ponds operating in Texas add costs of $0.05 to $0.25 per 1,000 gallons of fresh water produced (U.S. Congress, 1988).
- Crystallization and disposal of salts in an approved landfill may be the preferred option, in part due to the high technical and regulatory costs of surface or subsurface brine disposal.

Solid wastes generated by the alumina absorption, coagulation/microfiltration, or ion exchange processes would require disposal in a permitted landfill. The most important consideration would be whether the waste sludge or solids would be classified as a hazardous waste under RCRA regulations. This determination would be based on the results of laboratory testing using the Toxicity Characteristic Leaching Procedure (TCLP). This test involves leaching of the waste material in a weak acid solution and subsequent testing of the TCLP extract to determine if the arsenic concentration exceeds the TCLP limit of 5 mg/L. If the waste fails the TCLP test, then that waste would be classified as a RCRA hazardous waste based on the toxicity characteristic for arsenic. Whether a particular waste material passes or fails the TCLP test would thus depend both on the concentration of arsenic it contains and the extent to which the arsenic is soluble in the TCLP test. This regulation would also apply to waste products generated from treatment processes to remove trace constituents other than arsenic.

Wastes that pass the TCLP test would be classified as non-hazardous municipal waste and could potentially be disposed of at any Subtitle D municipal landfill at costs of approximately $25 per ton tipping fee. However, such wastes might be considered to be “special waste” under the New Mexico solid waste management regulations, requiring segregation in a separate designated portion of the landfill. This determination would be made by the NMED Solid Waste Bureau.

If the waste failed the TCLP test, it would be classified as a RCRA hazardous waste based on the toxicity characteristic for arsenic, which would in turn radically increase disposal costs. Such a classification would require that the waste be disposed at an out-of-state RCRA hazardous waste landfill at a cost that could exceed $1,000 per ton, not including transportation costs. For obvious reasons, generation of RCRA hazardous waste should be avoided if at all possible.

The preceding discussion makes it clear that disposal of waste sludge or spent reagents generated from conventional aboveground water treatment plants can constitute a large fraction of the total O&M costs. The innovative subsurface arsenic treatment technology may potentially offer large cost savings because little or no waste requiring disposal is generated. Although the feasibility of subsurface arsenic treatment at the wellhead has not yet been demonstrated, the possibility of avoiding waste disposal costs makes this alternative very attractive.

7. Socioeconomic Impacts

Treating groundwater will have no significant direct socioeconomic or cultural impacts. By making more groundwater available to more populous areas, this alternative would have the 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.

Removal of trace constituents from all water used in the region would require the regionalization of water systems. The treatment technology is expensive and complex and therefore best effected by hiring and training skilled operators. To effectively protect all users, individual domestic well use would need to be replaced by regional wells with treatment facilities. Such regionalization could impact the independent, rural lifestyle of many water users, but could also bring in new higher paying jobs. Depending on how and by whom treatment expenses are financed, this alternative may or may not reduce the cost of water for all users.

8. Actions Needed to Implement/Ease of Implementation

Assuming that a purveyor of water has water rights, permits, and infrastructure, implementation of water treatment to remove arsenic (or other trace constituents) using aboveground treatment plants would proceed along the following general steps for planning, design, and construction:

1. Conceptual design/feasibility study, including:
    - Assessment of treatability, blending, and waste residuals disposal
    - O&M considerations (e.g., workforce requirements)
    - Capital and annual cost estimates
    - Assessment of changes to distribution system and user rates

2. Review and approval of selected design
    - Local, state, and federal approval
    - Public participation
    - Identification of potential funding options

3. Engineering design
    - Bench studies of water compatibility
    - Development of plans and specifications
    - Preparation of bid documents for approved alternative

4. Construction (phased)

5. Preliminary O&M

6. System integration

If pilot testing indicates that this alternative is feasible, selection of the subsurface arsenic treatment technology could substantially simplify the above process because it avoids most of the design and construction steps associated with aboveground treatment plants.

The public is generally unaware of the cost implications of the new arsenic MCL. Water users in affected communities need to be educated about the new regulations and associated costs.

9. Summary of Advantages and Disadvantages

Advantages of groundwater treatment to remove trace constituents such as arsenic are:

- Enables continued use of existing well fields under new arsenic MCL, thereby maximizing community return on investment
- Increases quantity of potable water available for use through use of lower-quality water not otherwise usable without treatment
- Takes advantage of federal funding sources for arsenic treatment that are expected to become available for affected communities (e.g., SB 1299, Domenici)
- Reduces demand for low-arsenic surface water

Disadvantages of trace constituent removal from groundwater may include:

- Unit water costs are higher as compared with traditional (untreated) water sources.
- Pretreatment may be required.
- Some technologies require certified operator.
- Disposal costs for waste brine or sludge from aboveground treatment plants are likely to be high.
- Permitting requirements may be significant.
- Some innovative technologies require further testing.
- Public perception problems resulting from use of “arsenic-bearing” water may arise.

References

American Water Works Association Research Foundation (AWWARF). 2000. *Cost implications of a lower arsenic MCL.* AWWARF project 2635. October 10, 2000.

Amy, G.L., M. Edwards, M. Benjamin, K. Carlson, J. Chwirka, P. Brandhuber, L. McNeill, and F. Vagliasindi. 2000. Arsenic *Treatability Options and Evaluation of Residuals Management Issues.* American Water Works Association Research Foundation, Denver, Colorado.

Bitner, Kelly A. 2001. *Cost of compliance with a lower arsenic drinking water standard in New Mexico.* Report submitted in partial fulfillment of the requirements of the degree of Master of Water Resources, Water Resources Program, University of New Mexico. January 2001.

Chwirka, Joseph, and R. Narasimhan. 2000. *Arsenic treatment cost estimating tool.* Developed for American Water Works Association Research Foundation arsenic workgroup. Presented at the American Water Works Association Inorganic Contaminants Workshop, Albuquerque, New Mexico, February 27-29, 2000.

Chwirka, Joseph, B.M. Thomson, and J.M. Stomp III. 2000. Removing arsenic from groundwater. *Journal of American Water Works Association,* March 2000, pp. 79-88.

CH2M-Hill. 1999. *Arsenic treatment evaluation report.* Prepared for the City of Albuquerque. April 1999.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Groundwater desalination.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Duke Engineering & Services (DE&S). 2001. *Water supply study, Jemez y Sangre water planning region, New Mexico.* Prepared for Jemez y Sangre Water Planning Council, Sangre de Cristo Water, and City of Santa Fe, Santa Fe, New Mexico. January 2001.

Gurian, P.L. and M.J. Small. 2002. Point-of-use treatment and the revised arsenic MCL. *Journal of the American Water Works Association* 94(3):101-108. March 2002.

Miller, Gregory P. 2001. *Surface complexation of arsenic in natural water and sediment systems.* PhD dissertation, New Mexico Institute of Mining and Technology. May 2001.

U.S. Congress, Office of Technology Assessment. 1988. *Using desalination Technologies for water treatment*. OTA-BP-O-46. Washington, DC: U.S. Government Printing Office. March 1988.

U.S. Environmental Protection Agency (U.S. EPA). 2000. *Technologies and costs for removal of arsenic from drinking water.* EPA 815-R-00-028 (www.epa.gov/safewater). December 2000. 284 p.

White Paper 5

Alternative: Optimize Reservoir Management/Increase Allowable Storage

Alternative: Optimize Reservoir Management / Increase Allowable Storage

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Rob Leutheuser, Leutheuser Consulting (primary author), and Craig Allen, U.S. Geological Survey, John W. Utton (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternatives

The usability of a given surface water supply is influenced by the management of its storage. The quality of storage management affects the timing of water delivery and associated storage and conveyance losses. This white paper discusses methods of optimizing the regional water supply through effective management of its storage in reservoirs.

The regional surface water supply in the Jemez y Sangre region is directly influenced by the three major reservoirs in the Rio Chama drainage, Heron, El Vado, and Abiquiu, and the smaller water storage reservoirs in the region, which include McClure, Nichols, Nambe Falls, and Santa Cruz. Management of the Rio Chama reservoirs is affected by San Juan-Chama (SJ-C) Project water. SJ-C Project contractors in the Jemez y Sangre planning region include:

- City of Española: 1,000 acre-feet
- City and County of Santa Fe: 5,605 acre-feet
- Los Alamos County: 1,200 acre-feet
- Pojoaque Valley Irrigation District: 1,030 acre-feet
- San Juan Pueblo: 2,000 acre-feet

The Jemez y Sangre Regional Water Planning Council identified three areas of surface water management for consideration in the development of the regional water plan.

- *Alter management of reservoir storage/release to optimize water supply through limiting losses such as evapotranspiration.* In addition to the existing reservoirs within the region, potential management options could also be developed with the conjunctive use of Cochiti Lake and Elephant Butte Reservoir. Through securing additional storage from other parties it is possible to store water (particularly SJ-C water) that would otherwise be "lost," reduce reservoir-related water losses, further manage the timing of releases of water, and/or store additional water.

- *Improve existing holding capacity through dredging of reservoirs.* A reservoir's water capacity diminishes over time due to the entrapment of sediments. The reduction of water storage volume is dependent upon the age of the reservoir and the rate of sediment deposition. Effective water storage can be increased by removing sediments from the reservoir.

- *Construct new large reservoirs.* Where there are ample supplies of surface water and favorable site conditions, new reservoirs (both large and small) can be constructed. Water storage can be seasonal (for annual needs such as irrigation) or multi-year (for drought cycle water supplies.) The "water cost" of storing water is incurred through surface water evaporation, associated evapotranspiration by vegetation, and seepage.

Optimizing reservoir management could increase the amount of water in storage, thus increasing flexibility for water managers and providing added protection during short-term droughts. New water that could be used to meet growing demand will not be created under this alternative unless it is coupled with other alternatives, such as appropriating flood flows during spill years.

2. Technical Feasibility

2.1 Alter Reservoir Management

Altering the management of water within the existing Rio Chama system of dams is very feasible and has been implemented by some SJ-C contractors. This has had the effect of increasing upstream reservoir storage for individual contractors in the Jemez y Sangre planning area.

As dictated by federal law, contracts, and operating agreements, SJ-C water must be delivered annually from Heron Reservoir, and SJ-C contractors must take delivery of the water or lose that year's contracted amount. If they take delivery from Heron Reservoir, the water has to be beneficially used above Elephant Butte Dam (authorized storage is considered a beneficial use). If the contractor does not have a need for the water or a means to divert the water, the water can either be formally or informally marketed or stored in one of the downstream reservoirs (El Vado and/or Abiquiu). If the quantity needed to be stored is in excess of a contractor's allocated storage space, the contractor can attempt to enter into an agreement with the managing entity of the reservoir storage space (for El Vado, Middle Rio Grande Conservancy District [MRGCD]; for Abiquiu, City of Albuquerque). One-on-one arrangements are negotiated between the parties. Provisions that have been included in some of the past agreements with MRGCD are:

- The MRGCD has the first right to use the water, should it need it.
- A storage fee of $2 to $5 per acre-foot per year is charged plus 10 to 20 percent of the stored water, with the other party absorbing the evaporative losses for its water on a prorated basis.

If a holder of a native water right is unable to exercise its full water right due to a lack of storage capacity, it could also attempt to enter into an agreement with an entity who had excess storage capacity (i.e., El Vado and Abiquiu.) This would have to be accomplished in accordance with state water law, the paramount consideration being that such an "exchange" of water would not impair downstream water right holders nor New Mexico's ability to make deliveries under the terms of the Rio Grande Compact.

When the City of Albuquerque begins direct use of its SJ-C allocation (currently scheduled for 2006), it is anticipated that more of its New Mexico State Engineer-permitted 170,900 acre-feet of conservation space in Abiquiu Reservoir will be available for use by other SJ-C contractors. However, in the interim period before the proposed diversion project comes on line, the City will be storing greater quantities of its SJ-C project water in Abiquiu, thereby reducing the amount of space available to other water users. Space in the Abiquiu Reservoir allocated in 2001 to SJ-C contractors above the City of Albuquerque's 170,900 acre-feet, but within the easements owned by the City, consists of:

- City of Española: 1,275 acre-feet
- City of Santa Fe: 7,147 acre-feet
- Los Alamos County: 1,530 acre-feet

Directly storing water further downstream in Cochiti Lake and Elephant Butte Reservoir would be theoretically possible. Additional federal legislation and approval by the U.S. Army Corps of Engineer, New Mexico Office of the State Engineer, Cochiti Pueblo, Bandelier National Park, and the U.S. Forest Service would be required for storing water in Cochiti Lake. The storing entity would store SJ-C water in Cochiti Lake, store or use native water at an upstream location, and then release equivalent volumes from Cochiti to be beneficially used above Elephant Butte. The State Engineer would have to determine that water rights between the point of native water storage and diversion and Cochiti Lake would not be impaired, as well as calculate differential transit losses. For Elephant Butte, SJ-C contractors could enter into an agreement with the City of Albuquerque to store water in its 50,000-acre-foot pool. However, complicated exchanges would have to be negotiated for the contractor to recoup its use of the stored water.

Altering reservoir management on the tributaries is not considered likely because of limited storage capacity (approximately 2,680 acre-feet in Santa Cruz, 1,940 acre-feet in Nambe Falls, 3,260 acre-feet in McClure, and 680 acre-feet in Nichols). Storage space in these reservoirs is already used to maximum capacity by current water right holders.

The principle of reducing evaporation losses by storing water at higher elevations is sound. If choices are available, water users seek opportunities to store their water as high in the system as possible. Based on pan evaporation data, surface evaporation as compared to El Vado Reservoir is 135 percent greater at Elephant Butte, 65 percent greater at Cochiti, and 45 percent greater at Abiquiu. The ratio of surface area to volume also greatly affects the calculated per-acre-foot evaporation. For example, a reservoir holding 1,000 acre-feet with a surface area of 10 acres would have a smaller per-acre-foot evaporative loss than a reservoir storing the same 1,000 acre-feet that has a surface area of 50 surface acres.

2.2 Remove Sediment

There are no technological barriers to removing sediment from a reservoir basin. Several methods of removal are possible:

- The water could be drained to expose the sediments, which would then be excavated using conventional heavy equipment. The sediment would be hauled away and disposed in an upland area. Access roads to the removal and disposal sites would likely have to be constructed.

- It is also technologically feasible to dredge sediment "in the wet," that is, with water still in the reservoir.

- Sediments could be sluiced through the dam's outlet works. This method requires partially or completely draining the reservoir, then passing large quantities of water through the exposed sediments at velocities necessary to transport the sediment. This method would remove a relative small proportion of the total sediments in the reservoir basin.

Any drainage of a reservoir to facilitate the removal of sediments could be scheduled when the reservoirs are low, thereby reducing water losses.

2.3 Construct New Large Reservoirs

From an engineering standpoint, there are inevitable technological challenges to constructing new reservoirs, but few absolute barriers that cannot be overcome through investments of additional funds. The engineering barriers to any given dam site are dictated by geologic conditions, such as the lack of stable abutments and footings for the dam, high seismic risk, or unfavorable geology in the reservoir area that would result in excessive seepage losses.

In addition to building new reservoirs, it is possible that existing dams could be modified to increase the storage capacity of their associated reservoirs. A 1981 Bureau of Reclamation appraisal-level study (USBR, 1983) concluded that it was "engineeringly feasible" to raise the crest of the Santa Cruz Dam. In 1995, concurrent with completing safety of dams work, the City of Santa Fe increased the capacity of McClure Reservoir by modifying the dam's spillway (personal communication with Frank Bailey, City of Santa Fe, January 7, 2002).

Also, whereas Abiquiu Reservoir has a total potential capacity of about 1.5 million acre-feet, the current federal authorization limits conservation storage to only 200,000 acre-feet (which includes the sediment pool), and all the existing easements for allowable storage (183,246 acre-feet) are owned by the City of Albuquerque (170,900 acre-feet) and the U.S. Army Corps of Engineers (12,346 acre-feet). It is physically possible to store more water in the existing reservoir, but easements must be obtained. The Corps of Engineers has congressional authorization for approximately 17,000 additional acre-feet of storage in Abiquiu Reservoir if an easement can be secured. This increased storage capacity could help the region over the short term until SJ-C water is fully diverted. Storage in amounts above the 200,000 acre-feet approved by Congress would result in the inundation of homes and roads and would require congressional authorization. The added storage would be beneficial during high flow years, but could have negative ecological and scenic consequences.

3. Financial Feasibility

3.1 Alter Reservoir Management

Altering reservoir management is financially feasible on the Rio Chama mainstem. As a hypothetical example, a SJ-C contractor wishing to store 1,000 acre-feet of SJ-C water in El Vado Reservoir (assuming the space is available) might pay the MRGCD 150 acre-feet (15 percent water charge) and $3,500 ($3.50 per acre-foot) for one year's storage, plus a prorated share of evaporative losses.

For Abiquiu, SJ-C contractors with temporary allocations of storage space in the City of Albuquerque-owned space currently pay a prorated share of operation and maintenance (about 30 cents per acre-foot) to the U.S. Army Corps of Engineers. Terms of using *additional* storage space in Abiquiu within Albuquerque's 170,900-acre-foot pool would have to be negotiated with the City of Albuquerque. It is expected that there would be a monetary cost per acre-foot, a proportional share of evaporative losses, and possibly a water charge.

When considering evaporative loss charges, the differences among reservoirs need to be taken into account, as they will have a direct impact on the storage cost per acre-foot of water recovered from storage.

3.2 Remove Sediment

Based upon the Bureau of Reclamation's aforementioned study of the Santa Cruz dam and reservoir, in Year 2000 dollars, sediment removal would cost about $14,500 per acre-foot (e.g., removal of 1,000 acre-feet of sediment would cost about $14.5 million). At that time, the Bureau of Reclamation determined sediment removal was not a financially practical solution (USBR, 1983).

A 2001 study performed under contract to the U.S. Army Corps of Engineers concluded that two canyons at the upper end of Santa Cruz Reservoir had the capacity for the disposal of 367 acre-feet of sediment. This removal and disposal would cost about $2.75 million, or about $7,500 per acre-foot. The presumed difference in estimated costs is due to on-site disposal (Resource Technology, Inc., 2002).

3.3 Construct New Large Reservoirs

Because the construction costs for a dam are determined by its specific site, it is impossible to estimate the costs of constructing new dams. However, as points of reference, the original construction costs of Nambe Falls Dam and Reservoir and Heron Dam and Reservoir, indexed to Year 2000, were about $30 million and $50 million, respectively.

In terms of benefits, a 2001 study addressing Rio Grande Basin water management during prolonged droughts concluded that the construction of a 100,000–acre foot reservoir above Cochiti Reservoir would produce long-run average annual *collective* benefits to New Mexico water users of only $134,000 (Ward et al., 2001).

The Bureau of Reclamation study for Santa Cruz Dam determined that to raise the dam 13 feet (increasing storage by 1,310 acre-feet), appraisal-level estimates (indexed to Year 2000 dollars) were about $11.5 million; to raise the dam 23 feet (increasing storage 2,600 acre-feet) was estimated to cost about $12.8 million (USBR, 1983). However, the modification of the McClure Dam spillway, increasing storage by 500 acre-feet, cost the city of Santa Fe about $1 million (personal communication with Frank Bailey, City of Santa Fe, January 7, 2002).

The primary costs for storing additional water in Abiquiu Reservoir, beyond the planning and compliance expenses, would be acquiring land easements. No estimates of costs are available.

3.4 Financing

Because of the high costs associated with sediment removal, dam modification, or dam construction, project beneficiaries would likely need federal and/or state funding, which would require repayment contracts. Local repayment could be accomplished through increasing water user fees and issuing bonds. Grants, which normally require local cost-sharing, could be pursued for planning studies and compliance activities.

Costs to local beneficiaries could theoretically be reduced or eliminated by entering into contracts with third parties (municipal and industrial water users) whereby the third party would pay for some or all of the construction and operation and maintenance costs in exchange for some portion of the developed water.

4. Legal Feasibility

Of the three alternatives, changes in storage/release management in general would require less demanding legal authorization (Section 4.1). The second alternative, restoring reservoir capacity through dredging likewise involves a less demanding legal process (Section 4.2). The third alternative, expansion of existing reservoirs and/or construction of new reservoirs is more legally demanding, requiring multiple authorizations at state and federal levels and would be subject to the Rio Grande Compact’s post-1929 storage restrictions on native water.

4.1 Alter Reservoir Management

Altering management of existing reservoirs to optimize water supply presents a relatively moderate level of legal restraint, as long as the change in use does not increase depletions beyond the recognized right. Any proposed increase in depletions above existing rights would require acquisition and approval of additional rights, as discussed in Section 4.3.

The first legal authorization needed for changes in reservoir operations will be from the owner/operator of the reservoir. On the Chama/Rio Grande main stem, rights to excess storage capacity could be obtained by agreement with the managing entity, MRGCD, with respect to El Vado Reservoir and with the City of Albuquerque with respect to Abiquiu Reservoir. Although Abiquiu Reservoir has a capacity of 1.5 million acre-feet, federal legislation would be required to store water in Abiquiu above the total authorized storage amount of 200,000 acre-feet. Likewise, in addition to needing approval by the U.S. Army Corps of Engineer, Office of the State Engineer, Cochiti Pueblo, Bandelier National Park, and the U.S. Forest Service, storage in Cochiti Reservoir would require federal legislation allowing the storage. Storage in Cochiti of a native right vested above the Otowi gage would also have to comply with transfer requirements imposed by the Rio Grande Compact, as discussed in another white paper (DBS&A, 2002c).

In addition to owner/operator approval, one seeking increased storage in tributary reservoirs (i.e., Santa Cruz, Nambe Falls, McClure and Nichols) would have to contend with impairment of water rights holders on the tributary below the reservoir dam, even where SJ-C is the source of supply, because, in effect, tributary storage of SJ-C water would most likely be achieved through an exchange, thereby diminishing tributary native flows.

In order to protect other water rights holders and to assure deliveries under the Rio Grande Compact, the State Engineer will only permit storage of a native right if the change does not increase the total depletion beyond that allowed by the right. In addition, the State Engineer would require a no-injury analysis demonstrating that storage does not impair intervening water right holders, that is, those diverting between the point of storage and the established point of diversion or the point that exchange water (i.e., SJ-C) is introduced in replacement.

Finally, although management modifications are the least likely of the three alternatives discussed on this topic to affect the environment, changes in the hydrograph would have to be considered, as discussed in Section 4.3. In addition, new storage would be subject to the post-1929 restrictions of the Rio Grande Compact, also as discussed in Section 4.3.

4.2 Removal of Sediment

Restoring reservoir capacity should not require acquisition and transfer of additional water rights, as long valid rights exist for the larger capacity. Nonetheless, increased storage capacity and with it full use of a recently dormant right will result in more water being depleted. On water-short tributaries in particular, full exercise even of a valid right could result in the curtailment of that right by priority administration if senior rights do not get their full historical supply.

The main legal obstacle to reservoir dredging is environmental effects. The environmental requirements applying to reservoir construction and expansion, as discussed in Section 4.3, would generally apply to dredging; however, maintenance of an existing reservoir should pose far less of an environmental concern in terms of on-site effects. The primary environmental issue would be disposal of dredged material and/or downstream water quality and siltation effects, especially if sluicing is used as a dredging method.

4.3 Construct New Large Reservoirs.

Construction of new reservoirs and major expansion of existing reservoirs would present the most legal hurdles of the three alternatives. Any increase in the amount of water already permitted to be stored would require a new permit from the State Engineer. If storage results in increased depletions, the party proposing to increase storage would either have to use SJ-C water or transfer native water rights to offset the new depletions or would have to obtain a State Engineer permit to appropriate water in the amount of the new depletions. To transfer (i.e., to change its point of diversion and/or place and/or purpose of use) a water right, an applicant must show that the transfer (1) will not impair other water rights, (2) is not contrary to conservation, and (3) is not detrimental to public welfare (§§72-5-23, 72-12-7 NMSA 1978 (1997

Repl.)). Generally, the surface waters of the planning region are considered to be fully appropriated, and therefore the State Engineer is not likely to issue a permit to appropriate additional amounts of water, except perhaps for potentially available flood flows, as discussed in the white papers on appropriating above-average runoff flows (DBS&A, 2002a) and potentially available water above the Otowi gage (DBS&A, 2002b).

Construction of dams is also regulated by the State Engineer (§72-5-32). Before constructing a dam, one must obtain a permit from the State Engineer (and meet the statutory criteria: not cause impairment of any existing water rights, not be detrimental to the public welfare, and not be contrary to the conservation of water) (§72-5-6). Dams that are exempted from State Engineer permitting include "erosion control structures whose maximum storage capacity does not exceed ten acre-feet," and "dam[s] constructed for the sole purpose of sediment and flood control under the supervision of the United States army corps of engineers." (Until 1997, no dams that were less than 10 feet in height and that impounded less than 10 acre-feet were subject to State Engineer regulation. In 1997, the legislature amended §72-5-32 to greatly restrict that exemption).

A new reservoir or an expanded reservoir would require authorization from the affected landowner, which in most cases would be the federal government. In the national forests, dam construction and reservoir expansion or creation must comply with the National Forest Management Act, 16 U.S.C. §1600, *et seq.* (NFMA). In addition, other federal laws would apply: the National Environmental Policy Act, 42 U.S.C. §4321 *et seq.* (NEPA), the Clean Water Act, 33 U.S.C. §1251 *et seq.* (CWA), the Endangered Species Act, 16 U.S.C. §1531 *et seq.* (ESA), and possibly the National Historic Preservation Act, 16 U.S.C. §470 *et seq.* (NHPA) and the American Indian Religious Freedom Act, 42 U.S.C. §1996 (AIRFA). Most of the constraints placed by these laws relate to process, studies, and planning that must be done before significant surface-disturbing work is done. There will, however, also be substantive constraints on how much earthmoving, logging, and road-building can be done. NFMA places limits on methods and locations of earthmoving, logging, and road-building (e.g., limiting clear-cuts and similarly extreme methods of logging, prohibiting logging on very steep slopes, limiting logging adjacent to rivers). The ESA may limit these actions where species listed as threatened or endangered are located. The CWA will come in to play because dams or dikes or any diversions that are constructed in arroyos or streams, which are considered “waters of the United States,” are subject to CWA jurisdiction and will require a permit from the Army Corps of Engineers under §404 (33 U.S.C. §1344). The bigger the land disturbance, the more onerous the permit conditions will be. AIRFA and NFMA may limit land disturbance near sites of religious, cultural, or historical significance. In addition, some local governments, such as Santa Fe County, impose environmental and land use constraints on logging and road-building in national forests within the county’s jurisdiction (e.g., no land disturbance on very steep slopes, no logging or road-building on ridgelines).

Finally, the Rio Grande Compact of 1938 places restrictions on storage of water (§72-15-23 NMSA 1978 (1997 Repl.)). Under Article VI of the Compact, New Mexico’s accrued debit shall not exceed 200,000 acre-feet at any time, except as such debit may be caused by holdover storage of water in reservoirs constructed after 1929; however, New Mexico shall retain water in storage at all times to the extent of its accrued debit. This means that the water could not be released for any local use, but must be held for release to Texas if called upon. Under Article VII, New Mexico in general shall not increase the amount of water in storage in reservoirs constructed after 1929 whenever there is less than 400,000 acre-feet of usable water in project storage in Elephant Butte and Caballo Reservoirs. Finally, under Article VIII, Texas may demand release of water from storage reservoirs constructed after 1929 to the amount of the accrued debits of New Mexico and Colorado, sufficient to bring the quantity of usable water in project storage to its regular annualized amount of 790,000 acre-feet. This affects El Vado, Abiquiu, Nambe Falls, and McClure Reservoirs, all of which were constructed after 1929; Nichols (1946), Two Mile (1894), and Santa Cruz (1929) Reservoirs are not regulated by the Compact. To avoid a Texas call on water stored in a post-1929 reservoir, the party storing the called water may leave the water in storage by substituting other water, such as SJ-C water.

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

5.1 Alter Reservoir Management

The system of reservoirs in or impacting the Jemez y Sangre planning region is currently well managed. Water users are expected to continue to exploit opportunities to store water in El Vado and Abiquiu as the needs and opportunities arise. Non-monetary storage fees associated with storing water in El Vado versus Abiquiu would likely negate the savings in evaporative losses associated with moving storage from Abiquiu to El Vado. The evaporative losses realized in storing water in Cochiti Lake, and especially Elephant Butte Reservoir, would have to be considered carefully before pursuing these potentials. This option has the potential to affect the annual management of the 10,835 acre-feet of annually contracted water, as well as any other SJ-C water being held in upstream storage.

5.2 Remove Sediment

For the larger reservoirs (i.e., Heron and Abiquiu), sedimentation is not an issue because of its small proportion relative to the total storage volume of the reservoir. Sediment accumulations in smaller reservoirs, however, can significantly reduce the available storage capacity. For every acre-foot of sediment removed from a reservoir, there would be an acre-foot of additional water storage space. Therefore, this option must be considered technically effective. The approximate current sediment accumulations in the smaller reservoirs are:

- Santa Cruz: 1,800 acre-feet
- McClure: negligible
- Nambe Falls: 100 acre-feet

Although additional hydrologic analyses would be required, a review of reservoir hydrographs and relevant stream gages indicates that there are adequate inflows into both Santa Cruz and Nambe Falls reservoirs to take advantage of recouped storage space (inflow data are not available for McClure).

5.3 Construct New Large Reservoirs

The construction of new large reservoirs would be effective in increasing storage space, which could replace space lost to sedimentation and/or store additional water. The storage of additional water would be limited to those periods when spring runoff or precipitation events generated water in excess of current storage capacity, and when such storage would not negatively impact New Mexico's ability to comply with its Rio Grande Compact water delivery obligations. The location of the reservoir(s) would affect both the amount of water lost during storage and the transit losses from the reservoir to the point(s) of diversion.

6. Environmental Implications

6.1 Alter Reservoir Management

The environmental issues associated with modifying reservoir management are the least burdensome of the three categories of options. The principal issue would be the modification of the shape of the hydrograph downstream from the points of storage and release. This would affect the fisheries, including the brown trout fishery between El Vado Dam and Abiquiu Reservoir, and the long-term health of riparian community. There could also be effects on endangered species, most notably the Rio Grande silvery minnow and the Southwestern willow flycatcher. In the past, water managers have found enough latitude to minimize environmental impacts associated with modifications to Rio Chama operations resulting from SJ-C contractors' storage agreements.

Multiple adverse in-reservoir environmental impacts from water storage were observed at Cochiti Reservoir in the 1980s, prompting changes in operation. The ecosystem disruptions associated with long-term but fluctuating water levels were not consistent with productive ecosystems or the land management objectives of Cochiti Pueblo, Bandelier National Park, and the Santa Fe National Forest. The operation of Cochiti reservoir has focused on providing temporary water storage consistent with the flood and sediment control authorization. Careful management can meet these temporary storage goals with minimal disruption of the natural ecological river system where temporary flooding occurs (less than a few weeks in duration) by releasing water in a manner that more closely mimics natural conditions.

6.2 Remove Sediment

There are numerous environmental considerations associated with the mechanical removal of sediments from reservoirs. These include, but are not limited to, mobilization of potential contaminants, physical destruction of riparian vegetation and habitats, construction of access and haul roads, and environmental impacts to disposal sites.

If sluicing the sediment through the dam's outlet works was pursued, the impacts of the increased sediment load on the downstream waterway would be significant and would likely prove to be unacceptable.

6.3 Construct New Large Reservoirs

A wide range of environmental issues are associated with the construction of a new dam. Beyond the immediate effects of the dam and reservoir on the environment, a new dam would affect downstream conditions such as hydrograph, sediment, water temperature, water quality, and river morphology. These effects would also occur if an existing dam was modified, or if additional storage was secured in Abiquiu Reservoir. For this, and all alternatives, the cost of mitigating adverse environmental impacts would be included in the construction and operation and maintenance costs.

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 acequia 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.

Optimizing reservoir management to limit evaporative losses would have the direct benefit of increasing streamflow for downstream water right owners, including acequias and other traditional uses, thus benefiting the associated socioeconomic and cultural values.

Increasing allowable reservoir storage would negatively impact downstream water users by creating a larger water surface area that would increase evaporative losses. Indirect impacts would involve mostly issues of public perception and, therefore, public acceptance. Local communities are likely to look with suspicion on increased reservoir capacity unless they reap a direct benefit in the form of more water.

With growing environmental sensibilities among the public, new large reservoirs would likely encounter significant public opinion hurdles and probably strident opposition. In addition, the cost of new reservoirs would likely be passed on to consumers, increasing the cost of water.

8. Actions Needed to Implement/Ease of Implementation

8.1 Alter Reservoir Management

The water right holders would continue to enter into individual or collective agreements with the managers of the storage space. If agreements were pursued that were outside of the existing New Mexico water rights permits, formal approval of the New Mexico Office of the State

Engineer would be required. The U.S. Army Corps of Engineers would have to be consulted regarding the steps required to initiate consideration of storage in Cochiti Lake.

8.2 Remove Sediment

Feasibility-level studies would have to be completed to review the inflow hydrology to the reservoir in question in order to calculate project costs, identify and quantify the benefits of the increased water supply, evaluate funding sources, and identify related issues. A feasibility study would cost in the neighborhood of $100,000 to $250,000 and take one year to complete.

8.3 Construct New Large Reservoirs

Any effort to actually construct a new large reservoir would first require an appraisal-level study to review possible dam and reservoir sites, determine possible sizes based on hydrology and water rights, and identify and quantify potential project beneficiaries. Assuming the results were positive, the next step would be a feasibility study of the favorable option(s) identified in the appraisal study. In total, this could take 3 to 5 years, with a cost of up to $1 million.

If the region is interested in increasing storage capacity by using Abiquiu Reservoir, the first step would be to secure the 17,000 acre-feet of storage easements in Abiquiu that are within the authorized amount. If an even greater amount of storage capacity is desired, the region should seek authorization from Congress. Increased storage capacity is desirable in the short term for the purpose of increasing the pool of water available to offset the impacts of past well pumping when the City and County of Santa Fe begin diverting water directly from the Rio Grande, rather than through the Buckman Well Field.

9. Summary of Advantages and Disadvantages

Table 1 summarizes the advantages and disadvantages of the three reservoir-related options.

Table 1. Advantages and Disadvantages of Reservoir Options

Alternative	Pros	Cons
Alter reservoir management	• Few, if any, institutional barriers exist. • Depending on availability of storage space, option can be implemented immediately. • Costs are low. • Environmental issues are comparatively minor.	• For next 5 years, available storage space could be very limited. • As entities develop methods to divert surface water, amount of water needing storage space would be reduced. • Opportunities are unlikely to be available for tributary reservoirs, and if available, would accommodate only small amounts of water.
Remove sediment	• All or a portion of storage lost to sediment deposition can be restored. • Adequate water supply likely exists.	• Costs are high. • Significant environmental issues exist.
Construct new large reservoirs	• Water in excess of New Mexico's Rio Grande Compact delivery obligations could periodically be captured without harming downstream water right holders.	• Costs are high. • Significant environmental issues exist. • There are likely few hydrologic opportunities to store water. • Institutional considerations exist. • Difficulty in finding suitable location(s

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002a. *Alternative: Appropriate flood flows during spill years.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002b. *Alternative: Reappropriate water above Otowi Gage up to 1929 conditions*. White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002c. *Alternative: Transfer water across Otowi Gage.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Duke Engineering & Services. 2001. *Water supply study, Jemez y Sangre water planning region, New Mexico.* Prepared for Jemez y Sangre Water Planning Council, Sangre de Cristo Water, and City of Santa Fe, Santa Fe, New Mexico. January 2001.

New Mexico State University. *New Mexico Climate Center.* http://weather.nmsu.edu

Resource Technology, Inc. 2002. *Santa Cruz Dam sedimentation study, causes and possible solutions.* Prepared for U.S. Army Corps of Engineers, Albuquerque District Office.

U.S. Bureau of Reclamation. 1983. Technical memorandum, Santa Cruz Dam and Reservoir Study New Mexico. Southwest Region, Amarillo, Texas. April 1983.

Ward, F.A., Robert Young, Ronald Lacewell, J. Philip King, Marshall Frasier, J. Thomas McGuckin, Charles DuMars, James Booker, John Ellis, Raghavan Srinivasan. 2001. *Institutional adjustments for coping with prolonged drought and severe drought in the Rio Grande Basin*. Technical Completion Report, Account Number 01323937, New Mexico Water Resource Research Institute. February 2001.

White Paper 6

Alternative: Efficiently Convey Water to Reduce Loss

Alternative: Efficiently Convey Water to Reduce Loss

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Mike McGovern, P.E. (primary author), Alletta Belin (legal), and Bonnie Colby (socioeconomic).

1. Summary of the Alternative

As a major component of a water delivery system, conveyance (or carriage) is the action of moving water from one point to another. Beginning at some water source and ending in some consumptive activity, large and small quantities of water are conveyed for irrigation, livestock watering, domestic, and/or commercial/industrial uses. Water conveyance requires energy and physical structures. Typically, water is conveyed in some sort of open or closed conduit, such as a channel, tunnel, canal and/or pipe, and is moved by some driver, typically gravity and/or an energized pump.

For a variety of reasons, conveyance facilities and systems, when in use, are often a source of water loss. Pipes and canals leak. Water escapes from channels through evapotranspiration processes. To the extent desired or required, leakage and evapotranspiration can be minimized in manmade or modified natural conveyance structures and systems through appropriate facility planning, design, construction, and operation/maintenance activities.

Some conveyance facilities leak more than others do. The amount of conveyance system and/or facility leakage is commonly interpreted as an appraisal of its efficiency: the less a conveyance system leaks or loses water, the more efficient it is.

This white paper briefly examines the following four alternative conveyance systems or possible modifications to conveyance systems to determine if they might represent an increase in conveyance efficiency and, therefore, a potential water savings (from the reduction of perceived water losses):

- Construction of lined canal and/or installation of pipe irrigation delivery systems

- Transport or delivery of water from the San Juan-Chama Project through a regional pipeline

- Repair and maintenance of public water supply systems to reduce levels of unaccounted-for water that are above and beyond acceptable industry standards

- Use of regionally managed and operated systems to optimize water distribution/ management

These alternatives focus primarily on methods to use existing resources (water and energy) more wisely and reduce risk during times of drought. It is unlikely that any of these alternatives could result in new water to meet growing demand. The lining of an acequia, for instance, may improve the ability to deliver water to end users on a ditch, which is particularly crucial during periods of low flow. However, the reduced amount of seepage does not necessarily mean that more water is available for new uses, particularly when flows are low. In some situations it may be possible to prove that the lining of a ditch will actually save water that was not otherwise put to beneficial use. For the most part, however, the alternatives discussed in this paper focus on improving the system efficiency rather than providing new supplies for growing demand.

1.1 Linings and Pipes for Unlined Irrigation Channels

Approximately 62,000 acre-feet of water flows from wells and surface diversions for irrigation within the limits of the Jemez y Sangre planning region (DE&S, 2001). This water is conveyed through canals, ditches, and pipes to agricultural fields. In much of the conveyance system, some water is lost through evapotranspiration and infiltration. In 1999, off- and on-farm conveyance losses in canals and laterals in New Mexico were estimated to be about 36 percent of the total surface withdrawals for irrigation (NM SEO, 1992).

The main contributor to these losses was reported as seepage and excessive vegetative growth. Installation of canal lining systems such as impervious soils, soil-cement, concrete, blocks, and piping systems can decrease up to 95 percent of this total loss.

Water that evaporates while it is in the irrigation canal is lost to the atmosphere. Some water that seeps into the ground through unlined canals is used for transpiration by peripheral vegetation and is therefore lost to vegetation. The balance of the water that seeps into the ground through unlined canals to some extent recharges the existing groundwater aquifer. These losses are part of the overall water balance that exists in an irrigation system where diverted or withdrawn water is primarily used for crop transpiration. The two major components of these losses are seepage of water from agricultural fields into the ground and drainage of water off agricultural fields to some surface watercourse.

The main difference between piped delivery systems and lined canals is that evaporation losses that occur in canals are virtually eliminated in a closed conduit system. However, piped irrigation conduits are difficult to keep clean and operating as irrigation water typically carries solids and debris that can choke pipes.

1.2 San Juan-Chama Water Regional Pipeline

The Bureau of Reclamation's San Juan-Chama Project is a transbasin diversion system that imports water from tributaries of the San Juan River into the Rio Grande Basin. The water is delivered through the Azotea Tunnel, which runs under the Continental Divide to Willow Creek and then to the Rio Grande via Heron Reservoir and the Rio Chama. Since initiation of diversions in 1970, the San Juan-Chama Project has imported an average of 94,200 acre-feet of water into the Rio Grande Basin annually. Water users such as the City of Albuquerque, Middle Rio Grande Conservancy District (MRGCD), U.S. Department of Energy, and other municipalities and irrigation districts contract with the Bureau Reclamation for San Juan-Chama Project water (U.S. Army Corps of Engineers, 2001).

In the planning region, 10,835 acre-feet of water are allocated to municipal and irrigation entities. This water now flows from Heron Dam along the Rio Chama and the Rio Grande to and through the planning region, where withdrawals can be made as required. Beginning at Heron, which is close to 53 miles north of the City of Santa Fe, some of this water flowing in the Rio Chama and Rio Grande is lost through open water evaporation and through transpiration by non-crop vegetation along the river channels. Transporting this water from Heron through a closed conduit such as a tunnel or large-diameter pipe would eliminate virtually all of these losses and result in a corresponding increase of delivered water to the planning area equal to the amount lost. This paper briefly examines the piping of only the San Juan-Chama water that is allocated to the planning area.

1.3 Water Distribution System Repair and Maintenance

Water intended for municipal and industrial uses is conveyed from groundwater and surface water points of withdrawal to points of use through transmission and distribution piping systems. These pressurized piping systems typically exhibit some leakage due to a variety of reasons. Chiefly, poor initial planning and design, poor materials, poor construction, poor operations and maintenance (O&M), and finally, age and normal wear and tear can each, alone or in combination, be the cause. In most potable water systems, leakage from pipelines is probably the largest component of what is known as “unaccounted-for water.”

The elimination of unaccounted-for water in potable water systems should be an O&M goal in all municipal/industrial water systems. Currently an acceptable level of unaccounted-for water is considered to be around 15 percent of the total water produced in a system (Mays, 2000). Every water system is different, however, and this figure is at best a rule of thumb to be viewed with caution depending on actual system configuration, size, customer types and distribution, and age.

In the planning region, approximately 18,500 acre-feet of groundwater and surface water is withdrawn and diverted into large and small municipal potable water systems (DE&S, 2001). Currently, it is estimated that just over 13 percent of this water is unaccounted for. A leak detection and repair program could reduce this percentage to some agreed upon level beyond the “reportedly acceptable” 15 percent; however, all leakage could never be eliminated. For the purpose of discussion, an achievable figure of 7 percent will be used as a goal.

1.4 Regional Water System(s)/Authority(ies)

Regional water authorities are established to manage regional water resources in areas where federal, state, municipal, irrigation, institutional, and other agencies determine there is a need to plan and coordinate water-related activities on a cooperative basis. Their formation can also be mandated through state or federal direction. No regional water authorities currently exist in the planning area, although one has been studied and planned in the Española-Pojoaque area. It is difficult to quantify and characterize the effects of such agencies on water quality and quantity management; however, their formation would most likely have several region-wide effects:

- Professional and improved planning, management, operations and maintenance
- Improved metering, permitting, record keeping, and standards monitoring and enforcement
- Improved ability to prioritize and efficiently implement infrastructure enhancements, planned initiatives such a conservation programs, and equitable and effective cost reimbursement strategies
- Improved ability to draw and use internal and external funds

Such actions would obviously contribute to overall region-wide efficiency in water use in the planning area. Region-wide authorities could be established for sub-areas within the planning area or for the entire area. They could also be instituted for irrigation system water uses and/or municipal and industrial system uses. Such regional entities require vested and delegated legal authorities from the joined parties that allow them to manage their responsibilities. They also require medium time frames for establishment and development of efficient operations on the order of three to five years.

2. Technical Feasibility

All of the options described in the previous section are technically feasible, as discussed in Sections 2.1 through 2.4.

2.1 Linings and Pipes for Unlined Irrigation Channels

Irrigation conveyance systems can be broken down into three classes: main, distributory, and field canals, with each conveying a correspondingly smaller flow. *Main canals* take water for entire irrigated command areas from some source and carry it to *distributory canals,* which issue water to *field canals,* which deposit water onto agricultural fields. Each of these canal types lends itself to lining or piping of some sort. The canal lining and pipe replacement necessary to reduce water loss is well understood and practiced worldwide. Available technology includes linings made from compacted impervious earthen material, gunite, soil-cement, concrete, and plastics. Various types of pipe materials and systems are also used for the same application.

The issue is complicated by the effects of channel lining or piping, such as reduction or elimination of useful and aesthetic vegetation and trees now found growing along canal alignments that use seepage water for nourishment. Some amount of this seepage water may also be a meaningful component of shallow groundwater recharge. Lining canals also must be done thoughtfully so as to minimize the future destruction or breaking of linings by farmers who might want to install new or change the location of existing farm turn-outs, for example.

2.2 San Juan-Chama Water Regional Pipeline

Large-diameter and long (more than 50 miles) closed conduit water conveyance systems are in use today all over the world carrying raw or treated water from some source to some point of use. Complicating factors for using a closed conduit to carry San Juan-Chama project water include right-of-way acquisition, routing to avoid pump stations, compliance with the Clean Water Act, requirements of the National Environmental Policy Act (NEPA), and the need to build in possible future needed capacity for the delivery of water volumes in excess of those now allocated. Future water rights purchases, leases, and or assignments might one day augment the existing level of San Juan-Chama project water past its total current allocation.

2.3 Water Distribution System Repair and Maintenance

Three main steps are essential in repairing water distribution systems: (1) leak detection, (2) determination of the exact location of each individual leak, and (3) repair of leaks determined to be an issue. The technology exists to carry out very sophisticated and effective computer and geographic information system (GIS) assisted leak detection and location surveys in water supply systems. The technology to repair water line leaks is also available and is in use in public water systems throughout the world. Complicating factors involve the locations of some of the water lines that are now on private property, the age of some of the pipe materials and the difficulty in effectively repairing them, and the need to conduct repair operations on a recurring annual basis.

The definition of unaccounted-for water also will differ somewhat for each locality, and the inability of small systems to perform this work with in-house resources will be an issue.

2.4 Regional Water System(s)

Few technical issues are associated with forming a regional authority. However, sophisticated managerial skill is required to plan and establish an effective entity that would be poised to achieve its goals. Complicating factors include establishment of rules and regulations, procurement of required equipment and materials, staffing with experienced technicians, locating and using “as-built” facility drawings, and developing experience with systems.

Regional authorities can be a board of several members, each from a constituent entity that mandates system direction to members. Alternatively, regional authorities can be formed to manage, operate, and maintain certain member system infrastructure such as the relatively larger source withdrawal, treatment, and transmission facilities that are deeded to them. Authorities formed under the latter scenario have significantly more control of their members’ activities and are more able to accomplish the objectives for which the authority was formed.

Regional water systems are defined here as authorities that are formed by amalgamating the areas and responsibilities of numerous systems, whether they are rural systems or systems managed by a county, municipality, city, or other entity. An existing or new municipal water system is not a regionally managed system in itself.

3. Financial Feasibility

Each of the four options examined have financial feasibility issues that relate to capital costs, recurring annual costs, and the existing or possible future pricing of water that are beyond the scope of this white paper to address; however, the expected order of magnitude of costs to implement each option are discussed in Sections 3.1 through 3.4.

3.1 Linings and Pipes for Unlined Irrigation Channels

Agriculture is an economic activity. It is normal to invest funds in such projects if they can be shown to have a positive rate of economic return. Some agricultural projects, however, do depend on publicly dispersed funds, and this option might be one of those cases. Most of the irrigated acreage in the study area is not commercial-scale agriculture and does not generate cash flows sufficient to justify investments in water delivery system improvements. Consequently, funding from sources other than the owners of irrigated land is likely to be necessary.

The following example attempts to shed some light on the magnitude of savings that might be realized if some meaningful percentage of canals in the planning area were lined (assuming that they are now all unlined). Assume that unlined canals lose 36 percent of the water that they convey and that 60 percent of all lost water could be saved by lining 75 percent of all canals. If 62,000 acre-feet of water were withdrawn for irrigation in 1999, lining those canals would equate to savings of 13,392 acre-feet. Assuming that this “lost” water provides no benefit and that the sale price per acre-foot of water is $5,000, then this savings equals more than $66 million.

To estimate the cost of lining the canals (and saving the $66 million), assume that 10,333 acres of irrigated land exist in the planning area (irrigation duty = 6 acre-feet per acre) and that for each acre, 206 feet of some type and size canal is needed to deliver water to fields, for a total of more than 2.1 million feet of unlined canal. To line 75 percent of this total footage at an average lining cost of $40 per foot would cost more than $63 million.

The above cost-estimating exercise does not include the annual recurring maintenance cost or any other costs for planning and managing such a program. Additional capital costs would also be necessary to address non-channel construction required to improve irrigation delivery systems under such a program.

For the purposes of this study, therefore, lining ditches in the planning area is roughly estimated to cost between $50 and 100 million. However, there would be a significant return of saved water.

The use of pipes in irrigation systems in lieu of lined canals saves even more water as it virtually eliminates evaporation. To the extent that water that seeps into the ground through unlined canals reaches the regional groundwater system, it is not lost to evapotranspiration and is available for other uses in the planning area. When using pipes in irrigation water conveyance, however, complicating operational issues are introduced, including increased potential for system clogging, reduced infrastructure flexibility, and increased headworks infrastructure (bars, screens) and maintenance. The costs for planning, designing, and installing a piped irrigation system can be generally compared to a lining project in magnitude. The additional amount of water saved would be equal to the amount of evaporation prevented. In the planning area this amount is estimated to be an additional 670 acre-feet or approximately 5 percent of the total estimated losses from unlined canals.

3.2 San Juan-Chama Water Regional Pipeline

The cost of planning, designing, building, and then operating and maintaining a pipeline for transporting water from the San Juan-Chama Project would be large. For a rough estimate of the cost, several assumptions were made:

- A regional pipeline would only include those waters allocated to the planning area.

- A 53-mile (straight line distance from Santa Fe to Lake Heron), 48-inch-diameter pipeline could be used to transport the water.
- No pump stations would be required.
- The linear foot construction cost would be $300
- The right of way cost would be $0.20 per foot
- Planning, design, and project management costs would be 40 percent of the total cost of the job.

Based on these assumptions, the total project cost would be more than $117 million.

To calculate potential savings, assume the following:

- The planning area has 10,835 acre-feet of allocated San Juan-Chama water and it loses 10 percent, or 1,084 acre-feet, of this water in conveyance while in the Rio Chama and the Rio Grande.
- All of this water can be saved if the planning area's allocation was piped from Heron.
- Water to replace losses is purchased at $5,000 per acre-foot

Based on these assumptions, a cost savings of just over $5.1 million would be realized.

An additional cost would be the feasibility and environmental studies that would be required prior to building a regional pipeline. These studies would cost at least several million dollars. Other costs would include those related to community involvement, such as public notice of construction activities near a community, public meetings, and inter-jurisdictional coordination when construction involves federal or tribal land.

3.3 Water Distribution System Repair and Maintenance

The three largest municipal water systems in the planning area (Santa Fe, Los Alamos, and Española) serve a total estimated population of just over 89,000. Each of these systems is managed, operated, and maintained by a full-time professional staff, and each has an ongoing leak repair program to help reduce unaccounted-for water. While the amounts of unaccounted-for water in these systems (12 percent in Santa Fe [estimated], 10 percent in Los Alamos, and 14.5 percent in Española) are within industry-standard acceptable levels, they are above the 7 percent achievable goal proposed in Section 1.

The planning region also includes 76 other small public water systems that serve 50 to 1,500 people each. Experience with these systems indicates that unaccounted-for water ranges from 15 to 50 percent. To estimate costs savings possible through this option, it was assumed that the 76 smaller systems serve a combined population of just over 22,500 people and that 25 percent of the total withdrawals in these systems is unaccounted for.

Water withdrawals in 2001 from each of the three large systems are known and total 11,304 acre-feet. The other smaller 76 systems are estimated to have withdrawn 1,222 acre-feet. Current losses throughout the region can therefore be estimated at 2,397 acre-feet. Reducing unaccounted-for water through a leak detection and repair program to 7 percent would save 1,078 acre-feet or, at $5,000 per acre-foot, $5,300,000.

The basic cost of the program to carry out these leak detection and repair activities in the three major municipalities and the 76 smaller systems can be estimated at about $12,000,000 in its first year.

3.4 Regional Water System(s)

Regional authorities can effect real and significant improvements in water delivery, quality, customer service, conservation, and environmental management; however, they do so at a price. While they add technical and managerial value, they can be viewed as just an added layer of government, and adding this regional capability arguably reduces the need for those capabilities in existing member service organizations. Downsizing existing service organizations when a regional authority is established does sometimes (but not always) take place. Existing organizations, especially smaller ones, will sometimes take the opportunity to reorganize management, operations and maintenance responsibilities to be more efficient, instead of downsizing.

An effective regional authority could provide economies of scale in managing facilities and in using technology and information, and may thus be able to provide services at a lower cost than each individual entity could achieve on their own. Such additional efficiencies, however, cost additional money. The planning and establishment of a regional authority can sometimes draw external funding assistance in a similar fashion to a capital improvement project. But any annual recurring costs of the regional authority that are not offset by reductions in annual recurring cost for member organizations must be recouped by water user charges. An increase in monthly water rates to all types of users might be 10 to 40 percent of existing rates, depending on the size and type of authority formed. Such a cost increase may well lead to an increase in water withdrawal and consumption efficiency commensurate with the additional costs.

4. Legal Feasibility

There are no legal barriers to improving water delivery systems to reduce leakage and evaporation. The legal issues arise in considering how much of the “saved” water is available for use and by whom. Currently, any municipal or mutual domestic water entity that reduces leakage in its water delivery system increases its water supply correspondingly; such entities are free to use all of the “saved” water.

The situation gets complex if one considers, for example, whether a municipality could pay an acequia or irrigation district to line its canals in return for the municipality receiving some or all of the “saved” water. Such a transaction would require State Engineer approval, as it would be a change in location and purpose of use. Approval would be given only if it could be conclusively demonstrated that no net increase in water depletions would result. In other words, the State Engineer does not view stopping leakage of water from ditches into the aquifer as “saving” water because that water remains in the hydrological system one way or the other (either on the surface or underground). The only true savings, according to the State Engineer, come when evapotranspiration is reduced or waters otherwise lost to the system are retained. Moreover, since the State Engineer allows water rights owners to transfer only their consumptive irrigation right (CIR) rather than their diversion right, any increase in delivery efficiencies would not be part of the CIR and thus could not be transferred by the farmer to the city, according to the State Engineer's current interpretation of the law. Finally, a reduction in depletion at one place of use may simply increase the supply for other users along an acequia, with no net savings that can be transferred.

Any proposal to pipe San Juan-Chama water from either Heron or Abiquiu Reservoir would be a major construction project requiring compliance with the National Environmental Policy Act (42 U.S.C. Section 4321 *et seq.*), the Endangered Species Act (16 U.S.C. Section 1531 *et seq.*), the Clean Water Act (33 U.S.C. Section 1251 *et seq.*) (permit needed for the diversion from Heron or Abiquiu and for any arroyo or river crossings), and possibly other statutes, such as the National Historic Preservation Act (16 U.S.C. Section 470 *et seq.*) and any applicable local land use and environmental requirements. Removal of the water from the river system much higher in the Rio Grande/Chama watershed than would occur under other plans under consideration could make obtaining necessary approvals from the U.S. Fish & Wildlife Service under the Endangered Species Act more problematic than alternate San Juan-Chama diversion schemes, if any endangered southwestern willow flycatchers or other listed species are located between the proposed pipeline diversion and the alternate proposed place of diversion. In addition, if San Juan-Chama contractors in this region follow the Albuquerque model and propose to divert both their full amount of contracted San Juan-Chama water plus an equivalent amount of native Rio Grande water, it would be far more difficult to get State Engineer approval for such diversion from Heron or Abiquiu than if the diversion were further down the system and closer to the place where return flows rejoin the river. In general, compliance with federal, state, and local laws would be significantly more onerous for a pipeline taking the water from Heron or Abiquiu than they would be for a diversion and pipeline significantly further down the river system (such as near Otowi) because the pipeline would be far longer and thus its environmental impacts more significant, and because the water would be removed from the river system far upstream from where it would be used and where return flows would rejoin the river.

In addition, rights of way would have to be negotiated with all landowners along the route of the pipeline, which would likely include Pueblos, other governmental entities, and private landowners.

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

The four options vary in their anticipated effectiveness:

- *Linings and pipes for unlined irrigation channels:* If planned and carried out well, a project that resulted in lined canals and/or piped irrigation delivery systems in the planning area could provide more water to agriculture, thus reducing demand at the diversion structure, and/or increasing system return flows, and in turn, providing more water for downstream uses. While the conceptual costs seem high, the cost of “saved” water appears to be large in comparison to the investment. A project that focused on this activity could also be implemented over a period of time (e.g., 10 years), thereby lessening the impact of a major one-time capital outlay. As discussed in Section 3, if 60 percent of all lost water could be saved by lining 75 percent of all canals, approximately 13,000 acre-feet per year could be saved (based on 1999 irrigation withdrawals) in years with a full supply. Reappropriation of this “saved” water and transfer to domestic use is highly uncertain, but improved efficiency for the existing users could extend the supply in dryer years.

- *San Juan-Chama water regional pipeline:* While there is water to be saved by using such a facility, its conceptual cost appears to be significantly higher than the apparent value of the water that will be lost through conveyance of San Juan-Chama water in the Rio Chama and the Rio Grande. As discussed in Section 3, this option would potentially save 884 acre-feet of water per year.

- *Water distribution system repair and maintenance:* Again, while there is water to be saved by adopting and implementing such a program in the planning area, the cost of the activities to achieve some desired goal are high in comparison to the possible value of water saved. However, smaller projects in the smaller systems with large amounts of unaccounted-for water would be worthwhile.

- *Regional water system(s):* While comparisons of establishment and recurring costs to the value of water savings are difficult, this option will likely be beneficial and cost-effective. The degree of effectiveness will also increase as the size of the regional system and its associated responsibilities and authorities increase. This is likely a worthwhile first step in addressing any water issues in the planning area.

6. Environmental Implications

The environmental implications of the four options vary:

- *Linings and pipes for unlined irrigation channels:* Any such project must be planned and designed to account for groundwater recharge requirements if it is determined that such recharge does occur and is beneficial. Clean Water Act and NEPA regulations must be addressed. As there will be impacts to flora, fauna, water, and soil, any such project warrants and will be required to undergo, at a minimum, an environmental assessment. In particular, lining or piping community acequias would reduce water available for acequia-fed riparian vegetation and habitat. Nevertheless, all of the issues related to the environment can be easily addressed if these projects are properly designed.

- *San Juan-Chama water regional pipeline:* This option would entail major impacts to the river ecosystems, the flora and fauna of the river and its environs, and some endangered and threatened species, because water now in the pipeline will drastically reduce seasonal in-river flows that are required to sustain these species. These possibly huge impacts would become a major focus of public scrutiny and would most probably preclude such a project.

- *Water distribution system repair and maintenance:* No significant environmental implications are associated with this option.

- *Regional water system(s):* Establishment of a regional water authority would most probably benefit the environment due to improved water quality in rivers and streams as a result of, for instance, more efficient wastewater treatment.

7. Socioeconomic Impacts

Each of these options will have socioeconomic impacts of varying degrees that mainly relate to increased charges for water for all customers. Those who can afford such cost increases absorb them, while those who can't must consider and/or make changes in lifestyles. Threats to established rural lifestyles are perceived by many in New Mexico as a threat to their culture. The rural and less affluent population in the planning area will view increased water charges as additional pressure that makes their lives more difficult and as additional proof that those who are more affluent than they and who practice a more urban and less traditional lifestyle are negatively affecting them.

Potential opposition as a result of these viewpoints can be mitigated by implementing a cost structure other than the traditional system of charging each customer similarly for the same unit quantity of water. Other water pricing and reimbursement strategies exist that result in cost apportionment based on uses and ability to pay. Such systems might offer some relief from certain negative socioeconomic effects.

Other specific socioeconomic impacts include:

- *Linings and pipes for unlined irrigation channels:* If planned and designed properly, such a program would have little impact. Participation of irrigators from start to finish in such a project will also ameliorate any negative impacts. Some negative impacts may, however, occur. Lining or piping community acequias, in particular, could reduce groundwater recharge in areas where residents rely on shallow domestic wells. Such a program might also result in an increase in maintenance costs. Resistance to change on the part of irrigators may be an issue to overcome. Unless such a project addresses agricultural sustainability issues, no increase in agricultural income would be expected from such a project. However, some irrigators at the ends of some irrigation canals will probably receive more water and therefore will economically benefit from the program.

- *San Juan-Chama water regional pipeline:* The socioeconomic impacts of this option are difficult to predict. During construction, there would be a great deal of disruption in areas where large-scale heavy construction activities occur.

- *Water distribution system repair and maintenance:* No socioeconomic impacts are associated with this option except for higher customer water rates due to the cost of carrying out these activities on annual basis.

- *Regional water system(s):* This option has few real socioeconomic impacts. Customer water rates would be higher due to increased overall system recurring annual management and O&M costs. In addition, there would be major hurdles to overcome in terms of trust between potential member entities, and voluntary regional authority formation is often difficult.

8. Actions Needed to Implement/Ease of Implementation

The ease of implementation and actions needed to do so are as follows:

- *Linings and pipes for unlined irrigation channels:* Considering the cost of this initiative, an existing and or new external funding program would need to be established that would be devoted to assisting farmers and acequia organizations in this endeavor. An alternative to developing and providing an external funding program might involve legislating the activity through a requirement that farmers reduce seepage and evapotranspiration from their canals by some percentage. Tax breaks and subsidies could also be legislated for farmers who comply with such legislation. A program to carry out such activities can be designed, can work, and can be fairly easy to implement. Major involvement of irrigators in planning, design, and construction is required to ensure project viability over a useful facility design life. Such programs have been successfully carried out on small irrigation systems throughout Africa and Asia for the last 40 years.

- *San Juan-Chama water regional pipeline:* This option would require extensive feasibility studies as well as environmental impact assessments, particularly with regard to threatened and endangered species. In addition, the high cost of this option would require considerable financing and/or funding from outside sources.

- *Water distribution system repair and maintenance:* Implementation of a planning-area-wide program to carry out this goal would have to be the result of an agreed upon objective by all 79 water system governmental entities. Then all 79 entities would either need to obtain external funding to pay for this program or raise user charges to do so, and the external funding or user charge increases would have to be sustained over time, as this is an annual program with ongoing costs. This option would be easy to implement although it would result in temporary construction activities on private property in some cases where water lines run in public easements on private land.

- *Regional water system(s):* The formation of regional authorities to administer and manage water resources is a political decision. Community-wide trust and understanding of the logic of and need for regional authorities can sometimes drive the needed agreement by neighboring entities. In other cases, the formation of such authorities is the result of a court or federally ordered action. In either case, major detailed cost and technical studies are required to justify and demonstrate the efficacy of such decisions.

9. Summary of Advantages and Disadvantages

The advantages and disadvantages of each of the four options are outlined in Table 1 and summarized below:

Table 1. Advantages and Disadvantages of Water Conveyance Options

Water Conveyance Option	Advantages	Disadvantages
Linings and pipes for unlined irrigation channels	• Increased available supplies • Value of water saved high • Improved irrigation coverage • Increased return flows • Minimum environmental issues • Minimum cultural impact • More crops, more farmer income • Legally feasible	• Must be done right • Cost high • External funding probably required • Additional studies required • Decreases aquifer recharge • Impacts riparian vegetation • Accurate assumptions difficult due to water supply fluctuations
San-Juan Chama water regional pipeline	• Increased available supplies • Minimum cultural impact	• Difficult to design, build • Cost high • Value of water saved low • Major negative environmental impacts • Major right-of-way issues • Legal hurdles • Politically difficult
Water distribution system repair and maintenance	• Increased available supplies • Cost-effective for small systems • Minimum environmental issues	• Not cost-effective for major cities • Cost high • Value of water saved low • High annual pass-on cost to customers • Additional costs to low income families
Regional water system(s)	• Increased available supplies • Reduced projected demand • Medium costs • Value of water saved high • Better financial management • More external funding available • Improved water quality • Positive environmental impacts • Improved water systems efficiencies • Water conservation programs	• Politically difficult • Pass-on costs to customers • Additional costs to low income families • Scarcity of qualified staff

- *Linings and pipes for unlined irrigation channels:* This option is expensive, but significantly increases supply for the water users, particularly during drought periods. Implementation will not be easy but is feasible.

- *San Juan-Chama water regional pipeline:* This option comes with too many environmental issues to overcome and too high a cost for the small potential return in value.

- *Water distribution system repair and maintenance:* A region-wide program may not make sense in the Jemez y Sangre planning region, but small systems that experience high unaccounted-for water levels should address this issue.

- *Regional water system(s):* This option is politically difficult if not impossible, but could ensure that long-term water delivery efficiencies and improvements occur. Quantification of the benefits of any potential regionalization requires a cost-benefit analysis.

References

Duke Engineering & Services. 2001. *Water supply study, Jemez y Sangre water planning region.*

Mays, L. 2000. *Water distribution system handbook.* American Water Works Association.

New Mexico State Engineer Office. 1992. *Water use by categories in New Mexico counties and river basins, and irrigated acreage in 1990.* Technical report 47. July 1992.

U.S. Army Corps of Engineers. 2001. *Upper Rio Grande water operations model.*

White Paper 7

Alternative: Wastewater Reuse

Alternative: Wastewater Reuse

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Frederick W. Pontius, Pontius Water Consultants, Inc. (primary author), Susan C. Kery (legal), and Bonnie Colby (socioeconomic).

1. Summary of the Alternative

Wastewater reclamation and reuse is being practiced successfully in several locations in the western United States as a means of increasing or supplementing the available supply of water and preserving potable water for drinking water uses. Nonpotable reuse is already widely practiced in the United States. It involves treating wastewater generated by the community to a level suitable for non-drinking water uses such as irrigation or discharge for return flow credit. Reuse of reclaimed wastewater for direct potable purposes may be technically feasible, but it imposes additional public health risks and is currently not practiced in the United States.

There are several options possible for using treated wastewater, including:

- Discharge treated wastewater for return flow credits.
- Inject treated wastewater as artificial recharge.
- Use treated wastewater for irrigation, turf, construction, and other outdoor uses.
- Use treated wastewater in manufacturing and industry (e.g., cooling towers).

Each of these alternatives requires that the wastewater be treated prior to use. The degree of treatment and the standards to be met depend upon the end use of the reclaimed water. In each case, reclaimed water must be conveyed and distributed through a piped distribution system that is separate from the drinking water transmission and distribution system.

Wastewater reuse is most effective in urban areas where the wastewater is collected in a central treatment plant and, following treatment, available for redistribution from that plant. Where the wastewater can be used to obtain return-flow credits for new water supplies, this alternative provides an additional source of supply to meet the region's growing demands.

Where the wastewater is used to replace potable uses of water, it can reduce the demand on the system, but may result in the exchange of one use of the effluent (i.e., discharge to downstream users) for another (i.e., watering of parks, golf courses, etc.). Therefore, the use of effluent, while efficient, may not increase the supply available to the region. Careful study of individual water/wastewater systems is necessary to determine if the supply is increased.

2. Technical Feasibility

Treatment of wastewater for reuse has been practiced at some locations within the U.S. for more than 25 years. Secondary treatment of wastewater is generally required in order to meet State of New Mexico Environment Department (NMED) discharge standards. A higher-quality effluent can be provided by applying tertiary treatment with additional treatment processes. The effectiveness of tertiary processes for treating wastewater to a high quality is well documented.

The degree of wastewater treatment necessary beyond secondary treatment (and thus the cost of the treatment) depends on the quality standards required for various end uses. While the technological feasibility of treating wastewater for reuse is well known, the applicable standards that would have to be met for any given reuse application are not well defined. In the absence of firm reuse standards from the NMED, this white paper can provide only a general discussion concerning reuse options and costs.

Current NMED guidelines are unclear or are relatively lenient in comparison to guidelines that exist elsewhere. NMED has an existing policy issued in 1985 covering irrigation use of treated wastewater effluent and is currently in the process of revising this policy. The guidelines are intended to be used in conjunction with a permit for discharge of the reuse water. A discharge permit that describes the reuse application (use, flows, etc.) and specifies a water quality monitoring program must be filed with NMED for each reuse site. NMED guidelines do not allow for potable reuse applications.

To date, no federal regulations have been proposed for either nonpotable or potable reuse. In 1992, the U.S. Environmental Protection Agency (EPA) published guidelines for water reuse, defining a broad range of reuse applications and presenting guidelines for treatment water quality and implementation; however, these guidelines are not legally binding. Generally, where overlap occurs, EPA's guidelines are similar to or more conservative than NMED's.

In 1998, Camp Dresser & McKee (CDM) developed a treated effluent management plan for the City of Santa Fe (CDM, 1998). The final report provides a review of the significant reuse standards current at that time. The most extensive of those are of the State of California, who since 1978 has regulated nonpotable reuse under Title 22 of the California Administrative Code. In 1993, California drafted proposed regulations for intentional recharge of potable aquifers with treated wastewater. There is still considerable disagreement within the water industry on how indirect potable reuse should be regulated.

In 2000, NMED in conjunction with the New Mexico Department of Health (NMDH) issued a revised draft of its guidelines for reuse, following the approach of California Title 22. Significant adverse comment was received on this proposed revision. Stakeholders thought that following the approach of Title 22 was not appropriate, in particular because changes would be imposed on existing New Mexico reuse practices without providing needed financial support. Reuse of wastewater for irrigating parks, school yards, and certain other areas is currently practiced throughout New Mexico, and objections were raised concerning additional treatment and monitoring that might be required for these activities.

NMED and NMDH are reviewing the comments received on the draft revisions and are considering options. At this point, only concepts are being explored and no firm proposal has been developed by NMED. NMED has reviewed the approaches taken by other states and is considering regulation based on classes of reuse. A workgroup has been formed to address this issue.

Tables 1 through 3 summarize possible classes of reuse and associated treatment standards and monitoring requirements that might constitute nonpotable reuse regulations in the future. These tables were developed based on discussions with NMED; however, NMED and NMDH are still formulating draft reuse standards for public comment, and at this point, it is unknown what the actual draft or final reuse standards will be. For this white paper, however, the

Table 1. Conceptual Use Classes for Reclaimed Wastewater

Use	Reuse Class		
	A	B	C
Irrigation uses			
Residential landscape	■		
Parks and playgrounds	■		
School yards	■		
Unrestricted access golf course	■		
Unrestricted access landscape	■		
Orchard or vineyard spray irrigation	■		
Restricted access golf course	■	■	
Freeway landscape	■	■	
Orchard or vineyard flood irrigation	■	■	
Pasture for milking cows	■	■	
Pasture for non-dairy animals	■	■	
Sod farms	■	■	■
Fiber, seed, forage, and similar crops	■	■	■
Silviculture	■	■	■
Construction uses			
Dust control	■	■	
Backfill consolidation around portable water pipes	■		
Backfill consolidation around non-potable piping	■	■	
Soil compaction	■	■	
Mixing concrete	■	■	
Other uses			
Toilet and urinal flushing	■		
Fire protection systems	■		
Street cleaning	■	■	
Snowmaking	■		
Commercial laundries	■		
Landscape impoundment	■	■	
Recreational impoundment (no significant dilution)	■		
Vehicle and equipment washing (does not include self-service vehicle washes)	■		
Livestock watering (non-dairy animals)	■	■	■
Livestock watering (dairy animals)	■	■	
Irrigation and other non-potable uses at wastewater treatment plants	■	■	

Table 2. Conceptual Reuse Treatment Standards

Category	Reuse Class		
	A	B	C
Treatment required	Secondary, filtration, and disinfection	Secondary with disinfection	Secondary with disinfection
Turbidity limit	3 NTU monthly average, not to exceed 5 NTU in more than 5 percent of monthly samples	None	None
Disinfection limit	Nondetection of fecal coliform in 4 of last 6 daily samples; maximum 23 cfu/100 mL in any single sample	*E. coli* of 126 cfu/100 mL monthly geometric mean; maximum 235 cfu/100 mL in any single sample	Fecal coliform less than or equal to 1000 CFU/100mL at all times.
Other	---	BOD 30 mg/L; TSS 45 mg/L	BOD 30 mg/L; TSS 45 mg/L

NTU = Nephelometric turbidity units
cfu/100 mL = Colony-forming units per 100 milliliters
BOD = Biological oxygen demand
TSS = Total suspended solids

provisions for the classes of reuse outlined in Tables 1 through 3 for nonpotable uses will be assumed.

Table 3. Conceptual Reuse Monitoring Requirements

Parameter	Reuse Class		
	A	B	C
Turbidity	Continuous	None	None
Pathogen	Fecal coliform, daily	*E. coli,* weekly	Fecal coliform, monthly
BOD5	None	Monthly	Monthly
TSS	None	Monthly	Monthly

BOD5 = Biological oxygen demand (5-day)
TSS = Total suspended solids

Reuse classes A, B, and C are arbitrary designations put forth as possibilities by NMED, and are defined by the quality limits indicated in Tables 1 through 3. The classes are intended to make a distinction between uses of reclaimed water that require a higher quality, and therefore a higher degree of tertiary treatment.

Because of the technical challenges involved, in most cases only the larger municipalities will have adequate staff and resources to treat wastewater for reuse without incurring unacceptable environmental or public health impacts. The technical feasibility of the various wastewater reuse options outlined in Section 1 is discussed in Sections 2.1 through 2.4.

2.1 Discharge Treated Wastewater for Return Flow Credit

Discharging treated wastewater effluent for return flow credits is one way that effluent can be used to indirectly augment water resources. Secondary wastewater treatment to the State of New Mexico standards would be required prior to surface water discharge. A National Pollutant Discharge Elimination System (NPDES) permit would also be required, and discharges could be limited by any total maximum daily load (TMDL) limits set for the Rio Grande.

In New Mexico, return flow credits are granted on a one-for-one basis, that is, for every gallon of treated effluent returned to the Rio Grande, one additional gallon of Rio Grande water can be diverted for use without the purchase or lease of additional water rights. For example, the City of Santa Fe could pump a portion of the City's effluent from the wastewater treatment plant back to its original source at the Rio Grande, and proportionally increase the amount of Rio Grande water diverted for treatment and subsequent potable use (CDM, 1998). Return flow credits are granted by the State of New Mexico on an annual basis, making this option very flexible. For example, the majority of return flow credit effluent could be sent to the Rio Grande during winter months, when irrigation and other demands on treated effluent supplies are lowest, while the resulting credited water could be diverted at a later date when demand is greater.

Primary costs associated with this option are the cost of pumping the reclaimed water to the Rio Grande and the cost for the infrastructure (piping) required to do so. This option is only practical if the point from which the treated wastewater is being pumped is within a reasonable distance of the point of return. Long return pipelines are generally costly and may not always be feasible because of terrain, permits, or other considerations. For Santa Fe, this option is possible and is part of City's long-term plan.

2.2 Inject Treated Wastewater as Artificial Recharge

Treating wastewater and injecting it as artificial recharge is straightforward technologically. The required treatment processes and technology are readily available, but depending upon the degree of treatment required, they can be expensive. Treated effluent may be recharged to the ground by pumping into the ground or by percolation from the surface, as discussed in the artificial recharge white paper (DBS&A, 2002).

This section addresses requirements for treatment prior to injection. (Technological considerations regarding artificial recharge, including mechanisms for injection, are discussed in the artificial recharge white paper [DBS&A, 2002].) Unfortunately, determining treatment requirements is difficult, because the State of New Mexico has not enacted guidelines or regulations regarding acceptable quality for effluent recharge for indirect potable reuse. Because groundwater is widely used as a drinking water source in New Mexico, injection or percolation of treated wastewater into the ground is considered indirect potable reuse. NMED requirements would typically be expected for recharge effluent quality, depth to groundwater, and minimum setback distance from existing drinking water wells. Any discharge of effluent to an aquifer will require a groundwater discharge plan permit to ensure that groundwater standards are not violated.

The New Mexico Water Quality Control Commission (NMWQCC) groundwater regulations specify maximum concentrations for many constituents. Degradation of the groundwater quality up to these limits is allowed. Thus, if ambient concentrations were below the specified concentrations, treated wastewater concentrations could be higher than the specified in-ground concentrations. If the existing concentration of any constituent in groundwater already exceeds the specified maximum, no degradation beyond the existing concentration would be allowed. At a minimum, however, the quality of any treated effluent being used for groundwater recharge should be equal to or less than the standard specified in the NMWQCC groundwater regulations.

Application of water to streambeds may fall under the jurisdiction of the NMWQCC in-stream water quality regulations. Discharge to any stream would require a case-by-case comparison of effluent quality to the water quality regulations for the body of water in question.

EPA's water quality guidelines on groundwater recharge through surface application state that after percolation through the vadose zone, all Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs) must be met and fecal coliforms must be nondetectable. Ensuring that this will be the case is difficult, unless an underdrain system is constructed.

The most conservative and most publicly acceptable approach to indirect potable reuse involves treatment of wastewater to potable standards using advanced water treatment (AWT). This might require application of one or more of the following processes beyond secondary wastewater treatment: chemical clarification, reverse osmosis (RO), granular activated carbon (GAC) adsorption, air stripping, filtration, and ion exchange. Advanced treatment should be sufficient to remove pharmaceuticals and other trace constituents that may be of concern to the public. Soil-aquifer treatment (SAT) is a technology that has been demonstrated in Tucson, Arizona and other areas to be effective in treating wastewater for groundwater recharge. The use of SAT requires particular geological conditions and the availability of considerable land; however, if feasible, SAT may be the most economical option for groundwater recharge in the Jemez y Sangre region.

The primary cost associated with this option is the increased cost of wastewater treatment, most likely to drinking water quality. Piping of the effluent to the recharge area and, if injected, injection wells and pumping costs will also be necessary. Thus groundwater recharge is more feasible when the wastewater can be treated at a location close to an area suitable for recharge. Groundwater provides a source of supply at many locations throughout the Jemez y Sangre region (Table 4) where augmenting that supply through recharge would be beneficial.

2.3 Use Treated Wastewater for Irrigation, Turf, Construction, and Other Outdoor Uses

Reusing wastewater for irrigation, turf, construction, and other such uses is feasible if the source of treated wastewater is within a reasonable distance of the reuse point. Small acreages are not usually economically practical for irrigation with reused wastewater if long pipelines must be constructed, especially in urban areas. For this option to be feasible, wastewater would require treatment to conceptual reuse class A standards (Table 2), which would likely consist of secondary treatment, filtration, and disinfection.

Santa Fe already includes irrigation with reused wastewater as part of its long-term plan. The CDM study (1998) discusses irrigation using effluent at the Santa Fe Municipal Recreation Center and at the Santa Fe Landfill. Irrigation of Santa Fe parks with treated effluent proved cost-prohibitive and was screened out in the CDM study as not cost-competitive with respect to other potential uses, because building new pipelines through urban areas to numerous parks was not feasible. Typically, reuse of treated effluent for irrigation of parks, medians, and other public areas is only feasible in new developments where treated effluent piping is constructed at the same time as roads, water lines, and other infrastructure.

A dispensing station for treated effluent could be constructed for construction water. However, such use does not constitute a significant demand. Given that 10 daily truckloads at 5,000

Table 4. Summary of Sub-Basins in Jemez y Sangre Water Planning Region

Sub-Basin	Size (sq. mi.)	Elevation (ft msl)		Current Uses	Population			2060 Shortfall (afy)	Comments
		High	Low		1970	2000	2060		
Velarde	167	12,300	6,730	Irrigation: 26,400 afy SW 46 afy GW Municipal: 667 afy GW	2,459	4,446	6,617	~325	Could acquire new water rights and develop new wells
Los Alamos	173	10,423	5,360	Municipal, domestic, industrial: ~4,000 afy combined	15,646	19,758	23,137	None	Primary concern is sustainability
Santa Clara	84	11,525	5,523	Agriculture: 679 acres SW Domestic: 1120 afy GW	2,655	4,857	7,184	~357	Groundwater supplies appear adequate
Santa Cruz	200	12,980	5,490	Agriculture: 9890 acres SW Domestic and municipal: Unknown amount of GW	10,487	19,907	40,253	~3,000	San Juan-Chama to provide sustainable supply (~2000 afy)
Pojoaque-Nambe	123	12,621	5,494	Agriculture: 2,250 acres Domestic: 943 afy GW	1,731	6,280	22,383	~3,357	Could develop groundwater and surface water sources
Tesuque	77	11,850	5,750	Agriculture: 475 acres SW (2,110 afy in 2000) Domestic/industrial: 310 afy GW	1,048	4,859	30,422	~3,834	Current supply adequate until about 2050
Santa Fe River	284	11,700	5,250	GW and SW used for municipal and irrigation purposes	45,057	87,709	157,092	~13,200	San Juan-Chama water and other water rights proposed for diversion directly from the Rio Grande will meet regional needs until 2010.
Caja del Rio	158	7,400	5,150	Domestic: 88 afy Livestock SW and GW	101	554	2,476	~290	Could acquire new water rights and develop new wells
North Galisteo	93	8,230	5,720	Domestic: Unknown amount of GW	898	11,072	49,449		Could develop groundwater and surface water sources
South Galisteo	527	10,500	5,400	Domestic: Unknown amount of GW	685	2,903	15,273	~1,856	Could develop new ground-water wells

[a] GW = Groundwater
SW = Surface water

[b] 2,110 afy of surface water in 2000

ft msl = Feet above mean sea level
afy = Acre feet per year

gallons each would be considered heavy use, the rate of use is likely to be insignificant relative to total drinking water demand.

Because of the large number of acres of irrigated farm land within the sub-basins of the Jemez y Sangre Water Planning Area, the potential may exist on a case-by-case basis to exchange existing agricultural water for treated reuse class A wastewater. In other words, reuse class A wastewater might be offered for agricultural use, in exchange for existing agricultural water that could then be used for drinking water supply.

2.4 Reuse Treated Wastewater in Manufacturing and Industry

Reusing wastewater effluent in manufacturing and industry is feasible only if such industries are located within the service area. Wastewater treatment to conceptual reuse class A standards (Table 2) or higher (tertiary treatment) may be required for such uses.

If industries exist that could use recycled water, then a distribution system for reused water could be constructed to serve those industries. For example, the City of San Antonio, Texas is planning a 64-mile pipeline around the entire city to deliver recycled water to customers for non-drinking purposes. Industries could be attracted to certain areas if reuse effluent was made available. Within the Jemez y Sangre sub-basins, special industrial parks could be created where reuse effluent would be available for industries and manufacturing at a lower cost compared to other water sources.

Use of reclaimed wastewater for cooling purposes is one example of an industrial use of treated wastewater, but again, is possible only if industries are present or located within the service area that require cooling water. A special example this use is the Palo Verde Nuclear Generating Station in Arizona, which is believed to be the only nuclear facility in the world using treated sewage effluent as a source of water for cooling tower operation. Industrial uses also include boiler feed water, reactor coolant, and water for steam generation, but very high-quality water is needed for these uses, and effluent reuse water would not be appropriate without additional treatment.

3. Financial Feasibility

The cost of wastewater reuse alternatives will depend upon the standards to be met, the volume treated, the end use, the distance the treated effluent must be pumped and/or piped, and the cost of permitting. The costs of effluent reuse fall into several categories:

- Raw wastewater supply acquisition
- Construction and operation of treatment facilities needed to meet standards for planned end uses
- Construction and operation of storage facilities needed to ensure a reliable supply on a day-to-day basis, accounting for seasonal differences in supply of effluent and use (for instance, turf facilities have peak demand in the summer, and effluent produced in the winter may need to be stored for summer use on these facilities)
- Construction and operation of the transmission and distribution system
- Diminished return flows for downstream users who have relied upon effluent discharges, along with costs of resolving these return flow issues
- End-user adaptation costs, which can include:
  - On site hookup and re-plumbing to connect to the non-potable system
  - Special equipment, such as corrosion resistant devices
  - Additional on-site treatment for water-quality sensitive end uses
  - Idling other water supply facilities (e.g., groundwater wells) that no longer be used
  - Worker safety and public health practices, as applicable
  - Higher maintenance costs (cleaning, reducing clogging) compared to other water sources
  - More frequent leaching and higher volume of leaching water to control salt buildup in irrigation uses

Costs for treatment and reuse of wastewater effluent have differed substantially from one area to another across the U.S. The cost of reuse in the Jemez y Sangre region is expected to differ from one sub-basin to another because of local conditions, and a separate assessment of the cost feasibility for each sub-basin will therefore need to be made. Reuse options away from municipalities typically are limited due to a lack of locally generated wastewater and the high cost of conveying wastewater from cities. In general, wastewater reuse is an economically viable option only in areas where sewer lines are already in place.

In addition, the most desirable wastewater treatment process differs depending upon the reuse application. Although now somewhat dated, the cost estimates in Tables 5 and 6 give an idea of the range in treatment costs for different reuse options. Though the costs in Tables 5 and 6 would be expected to be higher today, technology has been changing rapidly and specific cost estimates would need to be prepared based on the characteristics and conditions of each sub-basin.

Table 5. Estimated Reclamation Treatment Process Costs, 1996 Dollars

Reuse Alternative	Treatment Process	Annual Cost [a] ($/ac-ft)
Agricultural irrigation	Activated sludge	245 – 682
Livestock and wildlife watering	Trickling filter	268 – 711
Power plant and industrial cooling, once through	Rotating biological contactors	379 – 728
Urban landscape irrigation	Activated sludge, filtration	291 – 903
Power plant and industrial cooling-recirculation	Tertiary lime treatment	404 – 1334
Groundwater recharge, spreading basins	Infiltration-percolation	108 – 260
Groundwater recharge, injection wells	Activated sludge, filtration, carbon adsorption, reverse osmosis	1166 – 3271

Source: Richard, 1998
[a] 1 ac-ft = 325,851 gallons

ac-ft = Acre-foot
RO = Reverse osmosis

El Paso, Texas, is an example of a large-scale reuse application. Two wastewater plants provide reuse water that is treated to advanced secondary wastewater quality using conventional secondary treatment (aeration) and sand filters to meet an average of 5 mg/L carbonaceous biochemical oxygen demand (CBOD), fecal coliform maximum of 75 colony-forming units per 100 milliliters (cfu/100 mL), fecal coliform geometric mean of 20 cfu/100 mL, and turbidity average of 3 nephelometric turbidity units (NTU). This effluent quality, based on monthly averages, meets Texas standards for unrestricted use in irrigation of landscapes at facilities such as golf courses, schools, and parks.

A third El Paso plant (the Fred Hervey Plant) provides tertiary treatment and injects the effluent into the aquifer at drinking water standards. This 10-million-gallon-per-day (mgd) plant uses primary treatment, a two-stage biophysical powdered activated carbon treatment (PACT) process, lime treatment, recarbonation, sand filtration, ozonation, granular activated carbon adsorption, and clearwell storage prior to aquifer injection. This plant was completed in 1984 at a cost of $26 million.

The amount of reclaimed water El Paso sells to customers for use is 1700 million gallons per year. The price of secondary treated reclaimed water is $0.49 per 100 cubic feet (60 percent of the lowest El Paso potable block 1 rate of $0.82 per 100 cubic feet). The price of tertiary treated reclaimed water is $0.66 per 100 cubic feet (80 percent of the lowest El Paso potable block 1 rate). These prices are based on what people are generally willing to pay for reclaimed water.

In contrast, smaller-scale reuse facilities will be expected to have a higher unit cost because of the lack of economy of scale, as demonstrated in Table 6.

There are essentially two sources of funds for planning, design, and implementation of wastewater reuse: federal programs and local funding. Several federal programs exist that can provide grants or loans. A detailed discussion of these programs is beyond the scope of this white paper, but the principal federal funding mechanisms are listed below:

- *Title XVI, Reclamation, Recycling and Water Conservation, through the U.S. Bureau of Reclamation (USBR).* Eligible projects include reclamation and reuse of municipal and other wastewaters and naturally impaired waters. The maximum federal cost share is 50 percent for planning, 25 percent for design, and 25 percent for construction. The

Table 6. Estimate of Reclamation Facility Life Cycle Costs, 1996 Dollars

Wastewater Treatment	Life Cycle Costs ($/ac-ft[a])		
	1 mgd	5 mgd	10 mgd
Secondary treatment, plus full Calif. Title 22 facility			
Capital	886	388	371
Operation and maintenance	465	351	342
Total	1,351	739	713
Secondary treatment, direct filtration			
Capital	726	331	316
Operation and maintenance	314	215	206
Total	1,040	546	522
Secondary treatment, contact filtration			
Capital	742	350	326
Operation and maintenance	310	215	205
Total	1,052	565	531
Secondary treatment, contact filtration, phosphorus removal			
Capital	748	382	363
Operation and maintenance	594	489	479
Total	1,342	871	842
Secondary treatment, contact filtration, carbon adsorption			
Capital	953	539	529
Operation and maintenance	731	610	600
Total	1,684	1,149	1,129
Secondary treatment, contact filtration, carbon adsorption, reverse osmosis			
Capital	1,415	922	886
Operation and maintenance	1,109	889	859
Total	2,218	1,811	1,745
Secondary treatment, lime treatment, reverse osmosis			
Capital	1,273	745	690
Operation and maintenance	945	757	726
Total	2,218	1,502	1,416

Source: Richard, 1998
[a] 1 ac-ft = 325,851 gallons

ac-ft = Acre-foot
mgd = Million gallons per day

maximum federal share amount for construction is $20 million for a single project, regardless of total cost. In most cases, the federal share is non-reimbursable, resulting in a de facto grant to the local project sponsors. Projects are funded by congressional appropriations.

- *Water Supply Act projects, through the U.S. Army Corps of Engineers.* In the past, Congress has authorized the Corps to assist specific local communities with municipal water supply and treatment needs not necessarily associated with other Corps projects. These special projects are funded individually through congressional appropriations.

- *Environmental Programs and Management, through the U.S. EPA.* Eligible projects are environmental infrastructure. Maximum federal cost share varies, with the maximum funding for a single project approximately $4 million.

- *State and Tribal Assistance Grants, through the U.S. EPA.* Eligible projects are environmental programs and infrastructure projects for water, drinking water, and wastewater.

- *Clean Water Act State Revolving Loan Fund, through the U.S. EPA/States.* Eligible projects are wastewater treatment.

- *Safe Drinking Water Act State Revolving Loan Fund.* Eligible projects include drinking water facilities to provide a safe supply and quality improvement.

- *USBR Loan Program.* Eligible projects include conservation, improvement of water quality, enhancement of fish and wildlife, and support of Native American self-sufficiency.

- *Rural Utilities Services (RUS) funding, through the Department of Agriculture.* Grants and loans for communities of 10,000 or less are available. Grants may be available up to 75 percent of the development cost of a project to reduce user costs to a reasonable level.

Local funding mechanisms include:

- *Bonds.* Bonding capacity is a function of the amount and type of revenue available, bond rates, and other factors.

- *Treated effluent sales.* Contract users of treated effluent could be charged for the quantities of effluent used. Selling treated effluent, rather than providing it at no charge, is standard practice in most communities in the southwest U.S. Examples of treated effluent rate structures are listed in Table 7. In general, rates charged for treated effluent are below the costs of treating and conveying it and must be subsidized to encourage its acceptability and use by consumers.

- *Government partnerships/private funding sources.* Entities interested in using reclaimed water could be approached to help fund the costs associated with treatment and reuse.

- *Expansion/impact fees.* Expansion fees, also known as tap fees, are typically paid to a municipality by those responsible for the development of new areas or construction of new dwelling units.

- *Water/wastewater rates.* Rate increases could be used to provide needed funds.

It is likely that a funding package using several of the above mechanisms will be needed to implement effluent reuse within the Jemez y Sangre regional sub-basins.

4. Legal Feasibility

As outlined above, reuse of water can occur under a number of scenarios. First, reuse can occur when a water user seeks to increase its diversions based upon the amount of return flows it makes to the river system. Diversions may be increased by approval by the State Engineer of a return flow plan that has the effect of crediting the water user with the return flows and allowing diversions to increase in the same amount. Discharges will have to comply with applicable environmental regulations. Alternatively, the water supplier may wish to inject treated wastewater to recharge the groundwater for future use. Finally, the water supplier may wish to reuse or recycle effluent directly for immediate use. These latter two types of reuse, by aquifer storage or by direct use, will result in less water returning to the river system for use by other users and, consequently, raises questions of whether State Engineer approval is necessary and whether other users may oppose the reuse.

Table 7. Examples of Treated Effluent Rates

Utility/Municipality	Treated Effluent Rate ($/kgal)	Treated Effluent Rate as Percentage of Comparable Potable Rate (%)
Clark County, NV	2.00	100
Henderson, NV	0.80	57
Tucson, AZ	1.42	60
Phoenix, AZ	1.42 - 2.12 [a]	80
San Diego, CA	Varies	90
Irvine Ranch Water District, CA	Varies	90
Santa Barbara, CA	Varies	80
El Paso, TX (secondary) [b]	0.65	60
El Paso, TX (tertiary) [b]	0.88	80

Source: CDM, 1998, except as noted.
$/kgal = Dollars per kilogallon

[a] Varies seasonally.
[b] Source: Personal communication, December 2001.

4.1 Return Flow Credits

A right to divert water provides its user with two types of water: the diversion portion, which equals the total amount withdrawn from the stream system, and the consumptive use portion, which is the portion that is consumed. Any amount left over that returns to the stream system by seepage, discharge, or even injection is a return flow.

A water supplier whose permitted diversions are insufficient to use up the full amount of its consumptive right may seek to increase its diversions by demonstrating that it is returning some of the water to the stream system, thereby obtaining return flow credits. A return flow credit would allow the supplier to offset the effects of increased diversions for use elsewhere in its water system. Such offsets could allow additional pumping from municipal wells. For approval, the State Engineer would require a return flow plan as evidence of the amount of flows returning to the system.

Because of the amount of San Juan-Chama water contracted to members of the planning region, it is important to note that this imported supply of water is entirely consumptive. As a result, if a return flow plan demonstrates that after diversion and use some of the water is returning to the system, the State Engineer will approve increased diversions by that amount. For example, if a local entity with a contract for 1,000 acre-feet per annum of San Juan-Chama water could demonstrate with a return flow plan that its consumptive use averaged only 400 acre feet per annum and that the rest returned to the system, the entity could seek return flow credits for 60 percent of its diversions. Under this example the State Engineer would authorize diversions of up to 2,500 acre-feet per annum, thereby allowing the diverter to consume 40 percent or 1,000 acre-feet per annum of the total, with the balance returning to the system. In the planning region, what makes the approval of such a return flow plan somewhat uncertain is the distance from the place of use back to the river. A successful plan may have to show that return flows are actually getting back to the main stem of the river, as opposed to the tributary basins.

In general, the plan must demonstrate the return flow actually reaches the stream system, either by direct flow into the surface waters or by seepage to groundwater. As a rule of thumb, the State Engineer assumes that water returned more than 100 feet above the water table does not reach the groundwater. Also, the State Engineer will not issue a permit if the increased diversions would cause impairment to other users between the point of diversion and the point at which return flows are introduced into the system. Finally, discharges to public waters will require regulatory approval, either through the issuance of a federal National Pollution Discharge Elimination System (NPDES) permit for discharges to surface water (33 U.S.C. §1342) or a state-issued groundwater discharge permit for discharges to groundwater (NMSA 1978 §74-6-5).

4.2 Aquifer Storage and Recovery

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 groundwater 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 underground injection control wells to protect groundwater which 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 NMED prior to use of a groundwater management injection well. (Section 2 discusses some of the treatment issues associated with lack of clear guidance from the NMED regarding the acceptable quality for wastewater recharge.)

4.3 Reuse and Recycling

Alternatively, a water supplier may wish to go to a reduced or no-discharge system, where treated effluent is reused and consumed for either turf irrigation or manufacturing/industrial purposes. Where the State Engineer has already issued a permit to divert a specified quantity of water with no return flow requirement, the permittee may proceed to reuse treated effluent.

Other than the power to prohibit a user from using more water than permitted, the State Engineer's authority is restricted to evaluating proposed new uses or new points of diversion to determine whether the change would impair other users or be contrary to public welfare or conservation. Accordingly, the State Engineer lacks jurisdiction to regulate the implementation of a reduced discharge system, as long as the system would not result in a use of municipal water in a place, for a purpose, or in an amount not already allowed by the city's permit.

In the case of *Reynolds v. City of Roswell* (99 N.M. 84, 654 P.2d 537 (1982)), the New Mexico Supreme Court addressed the issue of the State Engineer's imposition of a return flow requirement on a city permit that previously contained no condition. The court held that the requirement was unlawful, concluding that all of the water appropriated under the permit could be used and consumed by the city, as the water was “artificial” water belonging to the city (99 N.M. 87-88, 654 P.2d at 540-1 (1982)).

A more complex question concerns a municipality's ability to reuse waters when some or all of its permits contain discharge requirements. A return flow condition will typically require a city to return all measurable return flow to the river, including sewage effluent, or may state a percentage of pumping, such as 30 percent, that must be returned to the river system. Under these circumstances, the municipality may not use more than its consumptive use right. But it could reuse some or all of its effluent if it reduced its pumping correspondingly, so that the total consumptive use did not increase. In other words, by limiting diversions under a permit to the consumptive right and replacing any consequent shortfall in municipal supply with effluent, the municipality could make use of its return flows within its legal authority. Again, as long as the substitution of effluent did not result in a change in the purpose or place of use of municipal water, no State Engineer approval would be necessary in most instances. The first use plus the reuse must stay within the total allowed consumptive right.

With respect to challenges by downstream users, the issue is one of title to water once it is released back into a public watercourse. New Mexico law contains an exemption for artificial waters from the general rule that waters returned to the river system are appropriable public waters. The fact that a city has discharged waters in the past does not extinguish the city's right to its use and consumption and, further, does not create a right to the waters in another, and a downstream user could not assert a claim against the city to the use of the discharged effluent, absent agreement by the city (§72-5-27 NMSA 1978). However, if the reduced discharge left less water for a downstream senior, replacement of the reduced discharge could be required in times of shortage.

From a water quality perspective, any use of treated effluent which results in a discharge to groundwater or surface water must be permitted through either a groundwater discharge permit or, for discharge to surface water, through an NPDES permit.

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

Estimating the potential for wastewater reuse is complicated, especially considering the historical uses of wastewater effluent. In particular, downstream users of streamflow provided by wastewater effluent discharges will protest diversion of the water for other uses. Several wastewater treatment facilities operate within the Jemez y Sangre region, including Santa Fe, Española, Los Alamos, Las Campanas, and Pojoaque. To estimate the maximum potential for water reuse, the population served by and flow treated by each wastewater plant must be determined. The maximum potential for reuse would be the wastewater effluent flow minus the effluent discharge required for minimum streamflow and downstream uses, adjusted for projected population.

Many homes within the sub-basins are not served by wastewater treatment plants, but use septic tanks and therefore have no reuse potential (except for on-site). In addition, only a portion of the drinking water delivered to customers with sewer connections will find its way to the wastewater treatment plant. For example, in Santa Fe, only about 60 percent of the water served to customers will be discharged as treated effluent, meaning that the only a portion of the overall water demand could be reduced through wastewater reuse.

Nevertheless, effluent reuse can play a role in each sub-basin water plan, even if only on a small scale. The effectiveness of effluent reuse in providing a substantial portion of future water demands is difficult to predict. Reuse could be a future option if planned, for example, with installation of dual distribution systems or piping to deliver treated effluent to certain areas. However, the reuse of existing wastewater may or may not provide new water to the region, depending on the current demands on wastewater. For example, the City of Santa Fe currently has contracted to lease more than 4,000 acre-feet per year of its wastewater; the remaining 2,000 to 3,000 acre-feet per year is currently discharged to the Santa Fe River, meeting senior water rights downstream and serving to recharge the aquifer. Diversion of all of this wastewater effluent would deplete these existing uses. Careful analysis is necessary to assess what amount of effluent is available to meet growing demand.

Although this white paper focuses on reuse as it pertains to central wastewater treatment, individual on-site wastewater reuse systems are also available. In areas where drinking water and lawn irrigation water are provided principally by individual on-site wells, reuse of gray water could be encouraged on an individual household basis to lower the water demand from the aquifer.

6. Environmental Implications

Implementing reuse has several environmental implications. Permitting associated with construction of necessary facilities and pipelines must be satisfied and, in some cases, may prove to be a difficult hurdle. Satisfying National Environmental Policy Act (NEPA) requirements will be necessary depending upon the funding source, and the Clean Water Act (CWA) Section 404 permitting (dredge and fill) can be time consuming.

Perhaps most importantly, there is currently considerable discussion in the U.S. at this time regarding the adequacy of guidelines and standards for wastewater reuse. For example, some regulators have lingering concerns about exposure to microbiological agents during nonpotable reuse, and there are new questions regarding exposure to endocrine-disrupting chemicals and pharmaceuticals present in treated wastewater. It is possible that any NMED standards set for nonpotable reuse in the near term may be considered inadequate years into the future. If scientific and health concerns cause reuse standards to become more strict 3, 5, or even 10 years into the future, the economics of reuse as a viable option may change dramatically. The financial risks associated with increasing stringency of standards should be carefully evaluated.

The other primary environmental implication is the impact of reusing wastewater that would otherwise be discharged and allowed to flow downstream. Planners should carefully evaluate and consider the cumulative environmental impact to downstream surface flows and associated habitat if less water is being discharged from wastewater treatment facilities as a result of treating and reusing some of that wastewater.

7. Socioeconomic Impacts

Wastewater reuse has the potential to provide a number of regional benefits, including:

- Shifting higher-quality water to potable needs by using effluent for uses with less stringent quality requirements, thus expanding a region’s potable supplies
- Assisting in compliance with water conservation goals and regulations
- Improving regional supply reliability during drought
- Postponing the capital expenses of developing new regional water supply capacity
- Reducing costs of complying with surface discharge regulations currently incurred for disposal of effluent
- Increasing property values near facilities (parks, golf courses, recharge ponds) that use effluent
- Decreasing fertilizer costs for end users applying effluent for irrigation

Wastewater reuse has the potential to contribute to a more stable, diverse and cost-effective regional water supply. The inter-jurisdictional arrangements necessary to manage wastewater acquisition, treatment, storage, and conveyance can give local jurisdictions experience coordinating with one another, reinforcing regional cooperation on water issues. Cooperative agreements involving effluent reuse could involve cities, counties, tribal governments, school districts, acequias, community ditch associations, irrigation districts, and private landowners.

End user adaptation costs and concerns are a significant factor to be addressed in planning for effluent reuse. Potential users include turf facilities (golf courses, parks, school yards, race courses, cemeteries), sand and gravel operations, power plants, mining operations, and irrigated agriculture. These users may either have known adaptation costs or face uncertainty about such costs. In either case, effluent may need to be priced below the cost of their next best alternative water source in order for them to be willing to adapt to effluent reuse.

If regional regulations require specific water users to use effluent, then they have a direct incentive to participate in reuse plans. If not, their use may need to be subsidized in recognition of wider regional benefits of effluent reuse. For instance, hookup costs may need to be waived, and any summer surcharges for potable water users may need to be waived (for effluent) as an incentive for effluent reuse. If subsidies are necessary, fees collected from effluent users will not cover the costs of the reuse system and other funding mechanisms will be necessary.

8. Actions Needed to Implement/Ease of Implementation

The following actions are recommended to examine the feasibility of implementing reuse of treated wastewater as a strategy for conserving potable water supplies in the Jemez y Sangre water planning region:

- Work with NMED and the NMDH to update and define needed regulations for nonpotable reuse and indirect potable reuse. Clearly defined rules from the State of New Mexico are needed before serious assessment and planning regarding the long-term potential of reuse options can be undertaken. Evaluate the suitability of these standards in light of current science, and assess the impact if these standards were to become more stringent in the future.

- Develop future projections of wastewater volumes for each sub-basin.

- Assess whether SAT would be a feasible treatment option within any of the sub-basins.

- Identify needed treatment processes for anticipated end-uses.

- Identify potential reuse options and sites (agriculture, industrial, lawn watering, etc.) within each sub-basin that are reasonably close to current and future wastewater discharge points.

- Evaluate the potential for reuse of wastewater for agricultural purposes in exchange for potable water from agricultural water rights.

- Once the potential for reuse within each sub-basin has been assessed and NMED standards have been established, evaluate and develop financing mechanisms for reuse options and projects.

- Approach decision making regarding reuse with an effective public involvement process to build public support for reuse within the sub-basins.

9. Summary of Advantages and Disadvantages

The advantages and disadvantages of wastewater reuse as an alternative for increasing the available water supply in the Jemez y Sangre water planning region are summarized in Table 8.

Table 8. Advantages and Disadvantages of Wastewater Reuse

Wastewater Reuse Option	Advantages	Disadvantages
Treat wastewater and discharge for return flow credits	• Easy to implement and operate • Currently accepted practice • No additional treatment beyond secondary treatment needed • One-for-one volume exchange	• Must be within reasonable distance to point of return • Piping/pumping costs possibly prohibitive over long distances
Treat wastewater and inject as artificial recharge	• Indirect potable reuse currently accepted practice in U.S. • May be achieved using either well injection or spreading basins • Can be done on a large or small scale • Simultaneous recharge and treatment if SAT is possible, • SAT inexpensive alternative depending upon local conditions.	• No definitive NMED regulations or guidelines • Possible changes in feasibility and costs due to any future enactment of or changes in NMED regulations • Treatment of effluent to potable water standards using tertiary processes a likely requirement • Higher O&M costs associated with a complex mechanical treatment plant, if needed
Treat wastewater and use for irrigation, turf, construction, etc.	• Easy to implement and operate • Currently accepted practice • Minimal additional treatment beyond secondary (filtration) likely to be required • Can be planned for in new developments • User charges for treated effluent offset portion of costs	• Current NMED regulations outdated, revisions uncertain • Point of irrigation must be within reasonable distance of effluent source • Piping/pumping costs potentially prohibitive over long distances • Requires willing users/purchasers of treated effluent • Irrigation of small areas possibly not cost-effective in urban areas • Construction uses typically consume a relatively small volume
Treat wastewater and reuse in manufacturing and industry (e.g., cooling towers).	• Currently accepted practice • Could be used to encourage industrial growth in certain areas • Can be planned for in new developments • User charges for treated effluent offset portion of costs	• Current NMED regulations outdated, revisions uncertain • Piping/pumping costs potentially prohibitive over long distances • Requires willing users/purchasers of treated effluent

NMED = New Mexico Environment Department
O&M = Operation and maintenance

References

Camp Dresser and McKee, Inc. 1998. *City of Santa Fe treated effluent management plan.* Prepared in association with Lee Wilson and Associates. May 1998.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Aquifer storage and recovery.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Richard, D. 1998. The cost of wastewater reclamation and reuse. *In* Asano, T. (ed.), *Wastewater reclamation and reuse.* Technomic Publishing Co., Lancaster, Pennsylvania.

White Paper 8

Alternative: Increase Precipitation, Runoff, and Infiltration Through Cloud Seeding

Alternative: Increase Precipitation, Runoff, and Infiltration Through Cloud Seeding

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Don A. Griffith, North American Weather Consultants (primary author), Susan C. Kery (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

Cloud seeding, sometimes referred to as weather modification, is a technology that has developed since some historic discoveries in the late 1940s. These discoveries demonstrated, first in the laboratory and later in the atmosphere, that clouds containing super-cooled water droplets (droplets colder than freezing) could be altered through seeding to produce tiny ice crystals that could grow into snowflakes. These discoveries opened the door to the possibility of modifying certain types of naturally occurring clouds to produce more precipitation. Such a possibility is important, not only because many types of clouds contain super-cooled water droplets, but because the presence of such droplets often means that these clouds will be inefficient in producing precipitation. Seeding that targets super-cooled water droplets is commonly known as glaciogenic seeding.

The initial optimism that followed these discoveries led to a flurry of both research and operational programs in the 1950s. Some skepticism developed when the perceived results of these programs were not as promising as hoped. Nevertheless, a considerable amount of additional research was conducted in this field in the United States and a number of other countries from the 1950s to the 1990s.

At the present time there is still some disagreement in the scientific community about the efficacy of cloud seeding. Professional societies do, however, have policy statements that are guardedly optimistic concerning this technology (i.e., American Meteorological Society, 1998). These statements all agree that the likelihood of success depends on the type of weather modification being considered:

- The most scientifically accepted capability of man to alter clouds is in the realm of cold (32°F or colder) fogs. Dry ice dropped through such clouds or compressed gases released into these fogs will create snowflakes that fall to the ground, resulting in an improvement in visibility. A typical application is at airports that experience disruption in flight landings due to dense fog.

- The next most accepted capability is that of treating winter clouds passing over mountain barriers (called orographic seeding programs). With some of these clouds, seeding can result in precipitation increases of 10 to 15 percent.

- The effectiveness of summer cloud (typically cumulus clouds) modification is less proven than that of winter mountain cloud modification. There is, however, considerable evidence that individual clouds can be seeded to produce additional precipitation. Less evidence exists that seeding summer clouds leads to area-wide increases in precipitation.

- The least scientifically accepted weather modification technique is that of hail mitigation or reduction.

In spite of the mixed scientific reviews, a large number of cloud seeding programs are being conducted in numerous locations and countries. For example, approximately 13 winter cloud seeding programs are typically conducted in California each winter. Texas had 7 large summer programs in 1999 (Bomar et al., 1999) and will have approximately 10 programs in operation next summer. China has a large number of active programs.

Perhaps one of the reasons for the number of operational programs is the willingness of program sponsors to accept some uncertainty given the potentially significant impact that a cloud seeding program may produce. While the scientific community requires a 95 percent confidence level (i.e., no more than a 5 percent likelihood that the observed result could occur by chance) to accept results from research programs, the public sector is apparently willing to accept lower confidence levels (i.e., 80 percent). Less scientifically rigorous evaluations of a number of these operational programs have indicated beneficial effects from precipitation enhancement programs (both winter and summer) and some hail mitigation programs.

An interesting parallel regarding the level of confidence necessary to proceed with a cloud seeding project can be drawn from the field of weather forecasting which, like cloud seeding, inherently has some inaccuracy due to the large number of variables that directly drive the weather. The accuracy in 1- to 3-day weather forecasts is on the order of 85 percent correct and, as would be expected, less for longer-range forecasts. Yet the National Weather Service (NWS) routinely provides weather forecasts for 1 to 3 days and beyond, despite the fact that they are not 95 percent accurate.

2. Technical Feasibility

Cloud seeding projects could be conducted in the Jemez y Sangre region in both winter and summer seasons. A study by Duke Engineering & Services (2001) indicates that a large majority of the surface streamflow in the various sub-basins of the study area is the result of melting snow that accumulates on the Jemez and Sangre de Cristo Mountains during winter. Hence, increasing winter snow pack through cloud seeding could be beneficial to the region. Groundwater recharge is also primarily derived from precipitation that falls on these two mountain barriers. Little groundwater recharge is derived from precipitation that falls over lower-elevation areas.

2.1 Winter Orographic Cloud Seeding

Winter cloud seeding projects have been conducted in the western United States for many years, with some ongoing projects in California dating back to the early 1950s. The primary targets of these projects have been mountainous areas for many reasons, including:

- High amounts of natural precipitation due to the orographic effect (the lifting of moist air over mountain barriers) result in maximization of condensation and precipitation.

- An excess of water (more water available than required to meet evapotranspiration requirements) in these areas results in surface and underground runoff into lower-elevation areas.

- The orographic lift generates very favorable conditions for seeding due to the production of zones of super-cooled water droplets over the upwind slopes of these barriers.

- The orographic lift favors the transport of seeding material released from the ground into these zones of super-cooled liquid water.

A 4-year research-oriented cloud seeding project was conducted from 1969 to 1972 in the Jemez and Sierra Nacimiento Mountains of northern New Mexico (Keyes et al., 1972). This project used ground-based portable silver iodide generators to seed portions of winter storms on a random basis. A statistical analysis of the results indicated an increase during the seeded 24-hour periods of 13 percent. Some of the more interesting trends suggested by the results were that (1) the positive seeding effects seemed to occur in the two 6-hour blocks from 2300 to 1100 Mountain Standard Time (MST) and (2) the highest indicated increases occurred with the 700-millibar (mb) (approximately 10,000 feet above mean sea level [ft msl]) winds blowing from 135 to 180 degrees.

North American Weather Consultants (NAWC) has conducted a large number of operational winter projects since 1950, including a number of projects in the State of Utah beginning in 1974. Evaluations of these projects have consistently indicated increases in target area precipitation (Griffith et al., 1991; Griffith et al., 1997).

The above information and that contained in the Duke study (2001) suggest that a winter cloud seeding project would be feasible during the months of October through April over the Jemez and Sangre de Cristo higher-elevation watersheds that are within the various sub-basins of the study area. All sub-basins should be suitable except the Caja del Rio, which does not contain a significant orographic barrier. A general definition of the proposed target areas would be drainage basins higher than 7,500 ft msl in elevation. Such a project could use either ground-based delivery systems, aircraft, or a combination of the two to dispense silver iodide particles into clouds that form on the upwind sides of these barriers. Clouds in these locations have been shown to frequently contain super-cooled liquid water droplets, which are the targets of glaciogenic seeding.

The NWS provides a number of products that can be used to direct the real-time seeding decisions on such a project. These products include twice daily upper-air rawinsonde observations, surface weather reports, surface- and upper-air analyses, weather satellite photographs, next generation radar (NEXRAD) weather radar displays, and weather forecasts.

Most technical obstacles to conducting a project of this type have been addressed and overcome in the performance of similar projects in the western United States dating back to the 1950s. However, two concerns remain for a cloud seeding program in the study area:

- *The relatively warm temperatures of the winter storms that affect this area.* Silver iodide does not become an effective ice nucleant until it reaches temperatures in the cloud of approximately −4 to −5°C. The results of an NAWC preliminary analysis of the temperature at the height of the 700-mb (approximately 10,000 ft msl) level and atmospheric stability from the surface to 700 mb suggest that ground-based silver iodide generators would be ineffective in approximately 25 percent of the winter storms. Aircraft would be necessary to seed these storms.

- *The relatively narrow nature of the two mountain barriers.* The goal of a winter seeding project is to have the effects occur in the mountainous areas. Yet the silver iodide material needs time to reach the −5°C level and interact with cloud droplets, causing them to freeze, and then the resulting ice crystals need time to grow into snowflakes and fall to the ground. If the winds are strong or the formation of snowflakes takes too long, the effects of seeding will occur some distance downwind, possibly beyond the extent of the mountain barriers. There are a couple of solutions to this problem: (1) fast acting complexes of silver iodide can be used to speed up the formation of ice crystals or (2) aircraft seeding can be used in the stronger wind cases (in which case, the aircraft is flown further upwind to compensate for the stronger winds).

2.2 Summer Convective Cloud Seeding

The study areas receive a considerable amount of their annual precipitation in the summer months due to summer monsoons. A monsoon is the result of clockwise flow around a semi-permanent Bermuda high pressure area that brings moisture into New Mexico from the Gulf of Mexico. This influx of moisture provides the fuel to drive the formation of thunderstorms over the study area, which produce significant amounts of precipitation. The summer activity peaks in the month of August.

Thunderstorms initially begin as cumulus clouds. A large number of research and operational cloud seeding projects designed to increase precipitation from cumulus clouds have been conducted. Results from these projects have indicated that substantial increases from individual cumulus clouds are possible but that the possibility of impacts on area rainfall over a season is less conclusive (Rosenfeld and Woodley, 1993). Less rigorous evaluations of a number of operational projects have, however, indicated increases in season area rainfall from seeded clouds (Jones, 1997).

Selective seeding of growing towering cumulus clouds with silver iodide flares in the study area is considered feasible. This technique consists of an aircraft penetrating the tops of towering cumulus clouds at the −5 to −10°C level. Silver iodide flares are dropped from the aircraft into the updraft regions of these clouds. These updraft regions have been shown to contain large amounts of super-cooled water droplets, which are the targets in glaciogenic seeding.

Streams are fed by snowmelt and the recharge of the snowmelt that issues as springs. Therefore the acequias, City of Santa Fe and riparian ecosystems, and others who benefit from flow in the streams would benefit from the increased snowmelt and resulting groundwater recharge that would result from seeding over the mountains. Seeding would be conducted over other lower-elevation areas as well, with the goal of producing direct rainfall on croplands (either dryland farm or rangelands and irrigated agriculture). Increased rainfall over irrigated agricultural areas would have the impact of lowering demands on surface or underground water supplies.

Some projects use cloud base seeding of cumulus clouds. Recent investigations in South Africa, Mexico, and Texas have used salt (NaCl) flares as a precipitant to seed near the bases of cumulus clouds in the summer months. To date, these programs have indicated a positive effect only for individual clouds, and although promising, this technology will require more research and demonstration to prove it as a viable method of cloud seeding. In addition, this approach has not been recommended due to the underlying mountainous terrain in much of the area, which would preclude the application of this approach.

Weather radars are typically used to direct the cloud seeding operations. The other NWS products mentioned in the Section 2.1 would also be used. As in the case with winter seeding, since this type of project has been conducted previously in a large number of operational projects in the U.S. and a number of other countries, there are few technical obstacles to be overcome.

3. Financial Feasibility

The costs of conducting winter or summer cloud seeding projects can vary according to the intended size of the target area, the length of the seeded period, and the amount of personnel and equipment needed to perform the work. Such costs can be expected to range from $75,000 to $300,000 per season of operations. Analyses of a number of operational cloud seeding projects have indicated that precipitation from cloud seeding projects generally can be produced in the range of $1 to $10 per acre-foot. Depending upon the value of the water in a given area, the benefit/cost ratios of such projects often range from 5/1 to 20/1.

4. Legal Feasibility

Cloud seeding is governed by the Weather Control Act (NMSA 1978, §75-3-1 *et seq.).* As declared in the Act, “the State of New Mexico claims the right to all moisture in the atmosphere which would fall so as to become a part of the natural streams or percolated water of New Mexico, for use in accordance with its laws” (NMSA 1978, §75-3-3). Therefore, pursuant to the

Act, any water gained through cloud seeding would be considered unappropriated water and therefore subject to appropriation through the statutory appropriation process.

Weather control, cloud modification, or attempts to control precipitation are activities that must be licensed. Such licenses are issued by the Weather Control and Cloud Modification Commission, which is a three-member commission appointed by the board of regents of the New Mexico Institute of Mining and Technology (NMSA 1978, §75-3-13). Such a license will only be issued upon the demonstration of (1) sufficient financial responsibility necessary to meet the obligations likely to result from weather control or cloud modification and (2) the skill and experience necessary to accomplish weather control without injury to persons or property (NMSA 1978, §75-3-7). Thus, the only legal restraints placed on the region related to cloud seeding are the licensing requirements set forth in the Weather Control Act.

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

Increases in the winter snow pack in targeted watersheds typically ranges from 5 to 15 percent. These increases are spread over rather large higher-elevation areas, where a large majority of the increases translate into additional surface streamflow. Several studies have indicated that the percentage change in runoff resulting from an increase in precipitation can be higher than the percentage change in precipitation (Stauffer and Williams, 2000). To demonstrate the potential magnitude of an increase in snow water content, 10 percent of the average water content at the Natural Resources Conservation Service (NRCS) Snotel site in the Sangre de Cristo Mountains would amount to 1.45 inches. Given that a total of 83,000 acres in the region are above 9,000 feet, an elevation where most of the snowfall occurs, the total amount of additional snow pack produced through winter cloud seeding could be about 10,000 acre-feet (1.45 inches [0.12 foot] x 83,000 acres). Based on the results of recent studies at a site in Arizona at an elevation of 9,200 feet (Godfried et al., 1997), in which about 61 percent of snowpack was observed as streamflow, the additional 10,000 acre-feet of snow pack might produce about 6,000 acre-feet of streamflow. Similarly, if a 5 percent increase in snowpack results from a cloud seeding program, about 3,000 acre-feet of streamflow would be gained.

Increases in rainfall from a summer project over irrigated lands would lower the demand on stored, diverted, or underground water supplies. Increases in summer rainfall over the mountainous areas may produce additional groundwater recharge in lower-elevation areas, but no additional surface runoff is expected from a summer cloud seeding program. Area increases in summer precipitation should also be in the 5 to 15 percent range. A 10 percent increase in May through September rainfall at the Santa Fe 2 observing station would amount to 0.85 inch of rainfall, while a 10 percent increase at the Santa Fe NRCS high-elevation Snotel site would amount to 1.94 inches of additional rainfall.

6. Environmental Implications

A considerable amount of research has been conducted on the potential environmental impacts of cloud seeding projects. Much of this research in the western United States has been funded by the Bureau of Reclamation under their Project Skywater project. Some of the more common concerns that were addressed included toxicity of seeding materials (i.e., silver iodide), extension of the snowmelt in higher elevations, and increases in soil erosion. Published results from these projects indicate no significant impact from winter or summer projects (e.g., Smith and Berg, 1979), and no significant environmental impacts are expected from any winter or summer cloud seeding projects conducted in the study area. However, because EPA has issued a Human Health Advisory level of 180 μg/L for silver in water (New Mexico Environment Department Water Quality Control Commission standard is 50 μg/L) and 3,900 mg/kg in soil, a careful study must be conducted to ensure that these standards would not be exceeded, particularly considering the potential for bioaccumulation.

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 *acequia* 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.

Increasing precipitation, runoff, and infiltration through cloud seeding would increase surface water and groundwater yield for beneficial uses, including acequias and other traditional uses, thus directly benefiting associated socioeconomic and cultural values. Direct economic impacts from the conduct of cloud seeding projects include additional streamflow available for irrigation or municipal uses, recharge of underground aquifers, which can also be used for irrigation and municipal water supplies, direct rainfall on croplands and rangelands, which can increase production, and reduction of irrigation demands due to direct rainfall on croplands. Secondary impacts include favorable impacts to farming and ranching communities' economies if crop or livestock production rises and lower fire danger due to increased rainfall over forested areas during the summer. Beyond measurable economic impacts, increasing surface water and groundwater yield for rural uses, including acequias and domestic wells, directly benefits the many socioeconomic and cultural values associated with traditional communities.

Two specific concerns are sometimes mentioned regarding cloud seeding projects:

- *The possibility of increasing snow removal costs from mountain roads in winter project areas.* Studies conducted in Colorado and California have indicated little impact in this regard.

- *A reduction in precipitation in downwind areas due to upwind seeding.* Based upon the analysis of a number of research and operational projects, precipitation appears to be increased rather than decreased in these downwind areas. The reasons for this outcome are several, but the primary reason is that in any given year large amounts of water suspended in vapor form pass over the U.S., of which only approximately 10 percent reaches the ground as precipitation. Advisory groups can be formed to provide a forum for the public to become informed about the project(s) and also can be used to provide input to the conduct of the cloud seeding project (i.e., excessive rainfall on croplands may necessitate a temporary suspension of cloud seeding activities).

In addition, the perception of cloud seeding as “meddling” with natural climatic processes would possibly generate some negative public opinion and opposition. Negative perceptions of cloud seeding could be minimized if it were conclusively shown through targeted public education that it would be environmentally/climatically benign and would not have an adverse effect on downwind precipitation. Depending on the expense and financing of a cloud seeding program, increasing available water with this alternative would probably reduce the cost for all water users.

8. Actions Needed to Implement/Ease of Implementation

Cloud seeding projects are relatively easy to start or to stop. Some New Mexico licensing requirements must be met to begin a project. There are also some Federal initial, interim and final reporting requirements. Contracts are typically awarded to firms that conduct cloud seeding projects, thus entailing the preparation of project specifications and solicitation and evaluation of proposals. In general, 1 to 2 months are required to set up a project following contract award and 1 to 2 weeks to dismantle a project. This fast response aspect of cloud seeding is often viewed as an asset in contrast to other water augmentation alternatives that may take much longer to implement. The American Society of Civil Engineers has published a manual on cloud seeding that provides useful information on the steps needed to implement a project as well as other useful information concerning this subject (ASCE, 1995).

For a cloud seeding project to move forward, the formation of partnerships is recommended. Interested parties may want to recruit local entities to conduct a pilot program and propose cost-sharing with the Interstate Stream Commission (ISC). A public information program will be necessary to garner public support and facilitate the solicitation of potential sponsoring agencies.

Review of recent experiments by ISC in the Pecos Valley and research of silver iodide monitoring in California and Utah are recommended next steps before proceeding with a project. For a large-scale cloud seeding program, modeling of the predicted runoff would be necessary to establish the program's viability and garner support and funding.

9. Summary of Advantages and Disadvantages

Potential advantages of implementing cloud seeding projects over the study area are:

- Potential 5 to 15 percent increases in precipitation
- Potential 5/1 to 20/1 benefit/cost ratios
- Potential increases in surface runoff and underground water recharge
- Secondary beneficiaries (those parties that will indirectly benefit from increases in precipitation)
- No significant environmental impacts
- Relative ease in implementing projects quickly with no long term obligations
- Possibility of incorporating the design of a large number of operational projects that have been conducted in a number of countries with apparent success

Potential disadvantages of implementing cloud seeding programs over the study area are:

- Difficulty in evaluating the actual impacts of seeding on precipitation
- Scientific disagreement about the effectiveness of cloud seeding
- Need to make long-term commitments to conduct projects rather than viewing cloud seeding as only a drought relief tool
- Significant cost, which may require funding from several entities (i.e., local irrigation groups, municipalities, farm groups, state agencies) working together
- Ability to divert water generated from cloud seeding

References

American Meteorological Society. 1998. Policy statement on planned and inadvertent weather modification. *Bulletin of the American Meteorological Society* 79:2771 – 2778.

American Society of Civil Engineers (ASCE). 1995. *Guidelines for cloud seeding to augment precipitation.* ASCE Manual No. 81. 140p.

Bomar, G.W., W.L. Woodley, and D.L. Bates. 1999. The Texas weather modification program, objectives, approach and progress. *Weather Modification Association, Journal of Weather Modification* 31:9 - 22.

Duke Engineering & Services. 2001. *Water supply study, Jemez y Sangre water planning region, New Mexico.* Prepared for Jemez y Sangre Water Planning Council, Sangre de Cristo Water, and City of Santa Fe, Santa Fe, New Mexico. January 2001.

Gottfried, G.J., M.B. Baker, Jr., P.F. Ffolliott, and G.K. Colmer. 1997. Snowpack-runoff relationships for a small forested watershed in eastern Arizona. *Hydrology and Water Resources in Arizona and the Southwest* 27:1-8.

Griffith, D.A., J.R. Thompson, and D.A. Risch. 1991. A winter cloud seeding program in Utah. *Weather Modification Association, Journal of Weather Modification* 23:27 -34.

Griffith, D.A., J.R. Thompson, D.A. Risch, and M.E. Solak. 1997. An update on a winter cloud seeding program in Utah. *Weather Modification Association, Journal of Weather Modification* 29:95 -99.

Jones, R. 1997. *A summary of the 1997 rain enhancement program and a review of the area rainfall and primary crop yield.* Report 97-1, Colorado River Municipal Water District. 54 pp.

Keyes, C.G. Jr., F.D. Stover, and R.D. Wilkins. 1972. An evaluation of the results of four years of randomized seeding in northern New Mexico. pp. 137-141 *In Preprints of Third Conference on Weather Modification, American Meteorological Society,* Rapid City, South Dakota, June 1972.

Rosenfeld, D., and W.L. Woodley. 1993. Effects of cloud seeding in west Texas, additional results and new insights. *American Meteorological Society, Journal of Applied Meteorology* 32:1848-1866.

Smith, J.L., and N.H. Berg. 1979. *Biography of the environmental effects of weather modification.* The Sierra Ecology Project, 4, Office of Atmospheric Resources Management, Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado.

Stauffer, N.E., and K. Williams. 2000. *Utah cloud seeding program, increased runoff/cost analyses.* Utah Department of Natural Resources, Division of Water Resources Report.

White Paper 9

Alternative: Appropriate Flood Flows During Spill Years

Alternative: Appropriate Flood Flows During Spill Years

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Dominique Cartron (primary author), John W. Utton (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

The goal of this alternative is to appropriate flows above and below the Otowi gage that would be available only in the unusual circumstance that an actual or hypothetical spill would occur at Elephant Butte Dam. In simple terms, an actual spill occurs when the reservoir spills or releases water for flood control. A hypothetical spill occurs if an actual spill would have occurred but for changes in the upstream release regime. In either case, Rio Grande Compact limitations on this alternative would be avoided because a real or hypothetical spill at Elephant Butte Dam would erase all debts and credits of the three Compact signatory states (Colorado, New Mexico and Texas). Successful appropriation of flood flows by the Jemez y Sangre region would result in a net increase in water available to the region during the very wet years. This excess water could be (1) diverted and used to meet demand or (2) captured and stored in local or upstream reservoirs or in aquifers for future use. The key issue is determining if excess water is available above and below the gage. Because the region has not been entirely adjudicated, the total number of water rights is unknown.

2. Technical Feasibility

Elephant Butte Reservoir has spilled in 6 years between 1940 and 1997 (SSPA, 2000), or in about 10 percent of those years. Given this low frequency, construction of additional costly diversion structures solely for the purpose of appropriating this water would not likely be feasible. If, however, additional streamflow during the spill years could be diverted to the existing reservoirs in the region, or if aquifer storage and recovery facilities are in place, the spill year streamflow could be used to recharge groundwater supplies. Discussions regarding reservoir storage and aquifer storage and recovery are provided in separate white papers (DBS&A, 2002c, 2002a). Since Elephant Butte spills only in wet years, when water supplies are likely to be fairly abundant within the region, this alternative will be most advantageous if water can be stored. The problem is that storage is often not available in wet years.

Ideally, in order to determine how much flow would potentially be available during spill years, historical flood flows would be compared to water rights to determine the amount of water, if any, that exceeded water rights during the historical spill years. However, until the area has been adjudicated, an analysis of how much flow would be available is not possible. Instead, the annual flow for four gaging stations in the region during Elephant Butte spill years was examined (Table 1). All of the gages are affected by reservoir releases and consequently do not represent natural flow conditions. Nevertheless, comparing the flows for the spill years to the long-term average flows indicates the magnitude of flows that may be expected in the spill years.

3. Financial Feasibility

As discussed in Section 4, the costs associated with this alternative if existing infrastructure is used are related primarily to submission of the water rights application, which would include minimal filing costs. Legal and technical consulting costs would be standard unless the New Mexico Office of the State Engineer (OSE) required specialized technical studies (to establish no impairment). The total cost of the appropriation process, including the legal process and supporting hydrologic studies, should be in the range of $200,000 to $500,000.

As discussed in Section 2, this alternative will be most feasible if the excess water is stored for future use. However, if additional storage or artificial recharge facilities are needed to capture and store the water, the costs would be significant. As discussed in a separate white paper, design and construction costs for aquifer storage and recovery facilities can range from about $2 to $10 million (DBS&A, 2002a). Costs for construction of new reservoir facilities vary greatly depending on size, on the order of $10 million to $50 million (DBS&A, 2002c).

Table 1. Flow Analysis for Spill Years at Elephant Butte Reservoir

Water Year	Total Flow (ac-ft)	Amount Exceeding Annual Median[a] (ac-ft)
Gage 08316000, Santa Fe River near Santa Fe (1913 to2001 period of record) *Annual median for period of record is 4,700 afy*[b]		
1942	12,307	7,607
1985	12,190	7,490
1986	5,903	1,203
1987	9,675	4,975
1988	4,496	−204
1995	7,864	3,164
Total period of record annual average	5,877	NA
Average flow for spill years	8,739	4,039
Gage 8313000, Rio Grande at Otowi Bridge, NM (10/01/18 to 09/30/00 period of record) Annual median for period of record is 1,064,157 afy		
1942	2,404,713	1,340,556
1985	1,934,727	870,570
1986	1,753,971	689,814
1987	2,000,890	936,733
1988	835,651	−228,506
1995	1,617,500	553,343
Total period of record annual average	1,083,388	NA
Average flow for spill years	1,757,909	693,752
Gage 8317400, Rio Grande below Cochiti Dam, NM (10/01/70 to 09/30/00 period of record) *Annual median for period of record is 1,027,393 afy*		
1985	1,691,150	663,756
1986	1,705,033	667,640
1987	1,694,570	667,177
1988	880,798	−146,595
1995	1,556,078	528,685
Total period of record annual average	1,033,211	NA
Average flow for spill years	1,505,526	478,133

[a] Total amount above the long-term median does not equal the potential amount available for diversion during a spill year. Until the basin is adjudicated, the amount of water in excess of the water rights cannot be determined.

[b] City of Santa Fe has water rights on the Santa Fe River of 5,040 afy, which is 340 afy more than the median, 837 afy less than the average

ac-ft	= Acre-feet	NA	= Not applicable
afy	= Acre-feet per year		

4. Legal Feasibility

Generally, the surface waters of the Rio Grande are considered "fully or over-appropriated." However, just because the flows in an average year may be less than the amount needed to supply all existing rights does not mean that additional appropriations could not be satisfied in spill years. As an extreme example, a right to appropriate 100-year flood flows could be exercised on average once every 100 years without impairing existing water rights. A more practicable example would occur when flows above the quantity needed to satisfy existing uses could be appropriated without impairment to other diverters. In many years insufficient flows would be available and the right could not be exercised, but in years of higher flows, appropriations could be made.

An applicant may commence a request to appropriate surface waters by first filing a notice to appropriate and then filing an application to appropriate (NMSA 1978, §72-5-1 (1907)). The notice is not required, but establishes the applicant's priority date and allows time to prepare the application. After filing a notice, the applicant has up to three years to file the application and still have the appropriation relate back to the filing date of the notice (State Engineer Rules and Regulations, Surface Waters, II.B [August 1953]). The State Engineer will then determine whether a permit may be issued:

> Upon the receipt of the proofs of publication, . . . the state engineer shall determine, from the evidence presented by the parties interested, from such surveys of the water supply as may be available and from the records, whether there is unappropriated water available for the benefit of the applicant. If so, and if the proposed appropriation is not contrary to the conservation of water within the state and is not detrimental to the public welfare of the state, the state engineer shall endorse his approval on the application, which shall become a permit to appropriate water . . .. (NMSA 1978, §72-5-6)

Because of the very junior status of any new appropriation, the permit would require the complete curtailment of river depletions during low flow conditions because no water would be available to fulfill the new appropriation. As a result, unless a conjunctive management alternative were in place, diversions would have to be made directly from surface flows in order to keep the junior use in priority, as discussed in the white paper on conjunctive use (DBS&A, 2002b).

Another legal restraint that applies to appropriations within the Rio Grande Basin is derived from the Rio Grande Compact of 1938 (NMSA 1978, §72-15-23). The Compact utilizes an input-output model to determine the water delivery obligations of Colorado and New Mexico. The Rio Grande Joint Investigation of the Upper Rio Grande Basin in Colorado, New Mexico, and Texas that took place on December 23, 1937 (hereinafter referred to as the Rio Grande Joint Investigation) (Natural Resources Committee, 1938) compiled data over a number of years to determine water inflow and outflow at various points in the Rio Grande system and to establish relationships between inflows and outflows based upon the level of use as of 1929. The investigation established the relationships between (1) inflows in the San Luis Valley in Colorado and outflows at the Colorado/New Mexico state line and (2) inflows in the Middle Rio Grande Valley and outflows into Elephant Butte Reservoir. These correlations were used to establish water delivery schedules for Colorado to New Mexico and New Mexico to Elephant Butte Dam, and these schedules were expressly incorporated in the Compact (Hill, 1974; Rio Grande Compact arts. III, IV; Natural Resources Committee, 1938).

Pursuant to the 1938 Compact delivery schedules, measurements at gages in the Rio Grande and its tributaries in Colorado determine Colorado's delivery obligation to New Mexico. Delivery is measured at the Lobatos gaging station near the Colorado/New Mexico state line (Rio Grande Compact of 1938 arts. II, III). Similarly, flow measurements at the Otowi gage in New Mexico determine New Mexico's delivery obligation to Elephant Butte Reservoir for subsequent deliveries to Mexico, southern New Mexico, and Texas (Rio Grande Compact of 1938 art. IV). The amount of water delivered by New Mexico into Elephant Butte Reservoir is calculated by the recorded flow at the downstream gage plus or minus the net gain or loss in Elephant Butte Reservoir for that year (NMSA 1978, § 72-15-23 Historical Annotations).

The Otowi gage is in the approximate center of the Jemez y Sangre planning region. The issues discussed below are whether flood flows may be appropriated either above or below the gage. Above the gage, the Compact's inflow-outflow index is based on uses as of 1929

(DBS&A, 2002d). Appropriation of flood flows above that amount implicates Compact deliveries by reducing the amount crossing the gage and therefore the amount required to be delivered to Elephant Butte Reservoir. Below the gage, depletions are limited to a maximum of 405,000 acre-feet of waters flowing at Otowi, plus inflows between Otowi and Elephant Butte Reservoir.

An opportunity to appropriate flood flows exists when either New Mexico has accrued credits or when the reservoir is spilling. New Mexico accrues credits when its deliveries exceed scheduled deliveries. When an actual or hypothetical spill occurs, delivery obligations are reduced or eliminated. Under such circumstances, a new appropriation could be permitted without violating New Mexico's delivery obligations.

On May 22, 2001, the City of Albuquerque filed an application to appropriate nearly 200,000 acre-feet of flood flows in Abiquiu Reservoir. On June 26, 2001, Santa Fe County filed a notice to appropriate all unappropriated water above the Otowi gage, on behalf of northern New Mexico users, including the Jemez Y Sangre water planning region. The application to appropriate must be filed by June 26, 2004. Appropriation of flood flows would have to be as part of or in addition to these applications.

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

This alternative will add to the water supply in the region only during the years that Elephant Butte is spilling. During the period from 1940 through 1997, Elephant Butte spilled during the following years: 1942, 1985, 1986, 1987, 1988, and 1995. The more than 40 no-spill years during this period could easily be repeated, limiting the effectiveness of this option. However, some benefit can be gained during the years that do spill. Table 1 lists the annual streamflow during the Elephant Butte spill years measured at three gages in the planning region: (1) Santa Fe River near Santa Fe, (2) Rio Grande at Otowi Bridge, and (3) Rio Grande at Cochiti Dam. Though streamflow is affected by reservoir releases, this comparison indicates potential tributary flow increases during the spill years.

6. Environmental Implications

Capturing runoff flows can have environmental benefits such as reducing erosion, allowing the aquifer to recharge, and improving water quality (by limiting the introduction of sediment and poor-quality water due to fast-moving and poor-quality runoff). By increasing the amount of water in storage or allowing water managers to divert surface water and let the aquifer rest, the water supply in the region will become more sustainable

Having excess water in storage in upstream reservoirs would also allow water managers to maintain minimum flows in the river. For example, while normal flows are 0 to 1 cfs, the flow in rivers and tributaries following a rainstorm can be as high as 1 to 5 cfs. Water captured during these high-flow periods may be used to maintain more normal flows during the drier months. This possibility can greatly benefit aquatic species that rely on minimum flows for survival.

For these environmental benefits to be achieved, however, the water must be managed for that purpose. Appropriating the excess flow provides an additional source of water, but water managers and the region will decide how that water will be used.

Planners should carefully consider the environmental implications of how and to where excess water will be conveyed and distributed. Excess water appropriated and removed from the natural stream course would result in lower than normal flows farther downstream that might impact riparian habitat and endangered species.

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 acequia 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.

While it might provide additional available water for lower basin needs, appropriating flood flows could have a perceived negative socioeconomic and cultural impact on rural water users. However, the prior appropriation doctrine is designed to protect senior users such as acequias. In response to an application to appropriate water, the OSE would first have to determine that water is available in the region. If water were available, the applicant would have the burden of proving non-impairment. If circumstances exist where senior users would not be impaired and the application could be approved, the OSE would condition the permit such that senior users were protected. If impairment is inevitable, then the application would be denied.

If the system is not managed to protect priorities, this alternative would clearly have a negative socioeconomic and cultural impact on traditional water rights, agriculture, and communities in the upper basin. Many upper-basin acequia irrigators already perceive threats to their water rights from downstream municipalities and industries, and appropriating any additional water above Otowi gage, whether Elephant Butte Reservoir is spilling or not, will be viewed as a dangerous precedent and vigorously opposed. Recognizing the significance of this issue, the 2001 New Mexico Legislature sought to prohibit water right transfers from above to below Otowi gage in House Joint Memorials 14 and 6.

Appropriating flows below Otowi gage when Elephant Butte Reservoir is spilling would probably not stir the same opposition, but raises the same legal issues. The question of ownership of flood flows, including the potential impacts to unadjudicated Indian water rights, is a key threshold issue that must be dealt with. In this socioeconomic context where rural water users feel they must be eternally watchful, any move to appropriate water above the Otowi gage is certain to involve a lengthy legal conflict.

Positive social and economic impacts include enhanced recreation (e.g., rafting and fishing) if water is stored aboveground, ability to maintain instream flows or other uses during subsequent drier years, reduction in damage from floods, and a decrease in dependence on groundwater, thus enhancing the yield during drier years.

8. Actions Needed to Implement/Ease of Implementation

Santa Fe County has already submitted an application to appropriate excess flows. The application will need to be supported by technical analyses to address issues of potential impairment. Should the application be successful, local governmental entities could develop contracts or joint powers agreements to establish allocations for the appropriated water and a plan for diverting and storing it when it becomes available.

9. Summary of Advantages and Disadvantages

This alternative would augment the supply available to the region and is relatively inexpensive, providing that existing infrastructure is used. Although the process to legally appropriate the water may be prolonged and difficult, the region may benefit by pursuing this alternative. Specific benefits include:

- Reducing damage caused by flood flows
- Saving the aquifer by using renewable supplies when available
- Creating the potential for instream use at a later, drier year, if the water can be stored.

Disadvantages of pursuing this alternative include:

- Uncertainty regarding the availability of excess flows
- Limitations on storing excess flow
- High cost and difficult implementation if new storage is required

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002a. *Alternative: Aquifer storage and recovery.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002b. *Alternative: Conjunctive use of surface and groundwater.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002c. *Alternative: Optimize reservoir management / increase allowable storage.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002d. *Alternative: Reappropriate water above Otowi Gage up to 1929 conditions*. White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Hill, R.A. 1974. Development of the Rio Grande Compact of 1938. *N. Res. J.* 14:163.

Natural Resources Committee. 1938. *Regional planning part VI - The Rio Grande joint investigation in the Upper Rio Grande Basin in Colorado, New Mexico, and* Texas, 1936-1937. United States Government Printing Office, Washington, DC.

S.S. Papadopulos & Associates, Inc. (SSPA). 2000. *Middle Rio Grande water supply study*. Prepared for the U.S. Army Corps of Engineers, Albuquerque District, and the New Mexico Interstate Stream Commission. August 4, 2000.

White Paper 10

Alternative: Reappropriate Water Above Otowi Gage Up to 1929 Conditions

Alternative: Reappropriate Water Above Otowi Gage Up to 1929 Conditions

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Dominique Cartron (primary author) and John W. Utton (legal).

1. Summary of the Alternative

This white paper addresses the possibility of reappropriating water in the Rio Grande above the Otowi gage to ensure that New Mexico uses all allowable depletions as of 1929. The Rio Grande Compact uses an input-output model to determine the water delivery obligations of Colorado and New Mexico. These obligations are based on uses as of 1929 and as documented in the 1938 Rio Grande Joint Investigation (National Resources Committee, 1938). Since uses have shifted (decrease in amount of irrigated agriculture, increase in number of groundwater wells), it is possible that New Mexico's depletions above Otowi gage are less than they were in 1929, and water is available to appropriate under normal hydrologic conditions.

This alternative would involve submitting an application to the Office of the State Engineer (OSE). If the State Engineer determines that water is available for appropriation, then additional water rights may be available in the region. Such an appropriation would provide additional water rights for use, storage, transfer, or even to serve as offsets for additional groundwater pumping. However, it is possible that streams where the amount of use is less than the 1929 condition are those tributaries to the Rio Grande where the amount of wet water is often insufficient to meet existing water rights. The insufficient supply, possibly reduced by the watershed conditions, could in fact be the reason for the decrease in water use. Careful technical analysis can help determine whether this alternative is worth pursuing.

2. Technical Feasibility

In order to have an appropriation of this type approved by the OSE, a comparison of waters being depleted in 1929 with waters currently being depleted is required. In 1929, a greater percentage of the region was in agricultural use than is presently. Conversely, more groundwater is currently being used by domestic and municipal wells than in 1929. If the net change between 1929 and the present reflects lower water use, more water would potentially be available for appropriation.

Waters being used in 1929 were documented in a Rio Grande Joint Investigation done in 1937 (Natural Resources Committee, 1938). The 1937 study did not desegregate depletions in the Jemez y Sangre area. The study presented depletions for the San Luis Valley (Colorado), the Middle Rio Grande Valley (Colorado border to Elephant Butte), and the area below Elephant Butte. The Middle Valley included some sub-areas (i.e., Isleta to Socorro), but did not include a separate area corresponding to the Jemez y Sangre region or the area above Otowi. Estimates for depletions in the entire Middle Valley are about 500,000 acre-feet per year. According to the 1937 study, streamflow depletions are defined as:

> The amount of water which annually flows into a valley, or upon a particular land area (I), minus the amount which flows out of the valley or off from the particular land area (R) is designated "stream-flow depletion" (I-R). It is usually less than the consumptive use and is distinguished from consumptive use in the Rio Grande studies.

The Jemez y Sangre Water Planning Council developed water budgets for each subregion within the planning area. The subregions that are located above Otowi gage include Velarde, Santa Cruz, Santa Clara, Pojoaque-Nambe, Tesuque, and portions of the Los Alamos sub-basin. The water budgets included both a total inflow component and a total outflow component for surface water and groundwater. To be consistent with the 1937 study, total inflows minus total outflows (as reported by Jemez y Sangre [2001]) were calculated for both surface water and groundwater (groundwater was included because it is considered to be stream-connected). The total mean annual inflow minus the total mean annual outflow for the sub-basins above Otowi gage (excluding Los Alamos) was approximately 36,000 acre-feet.

The outcome of the application is uncertain. In order for an appropriation of this type to be approved by the OSE, a comprehensive study comparing current depletions to depletions in the areas surveyed in the 1937 study would be required, and only after conducting the technical studies would the region understand whether depletions have decreased, thus potentially making water available for appropriation. If no water is available, then the proponents of this alternative would have expended considerable funds without securing additional water rights.

3. Financial Feasibility

The costs associated with this alternative are primarily related to submission of the water rights application, which would include minimal filing costs, as well as the legal and technical fees to complete the application process. Certain local governmental entities may apply for community development block grants to support water rights acquisitions.

As noted in Section 2, technical studies would need to be conducted to determine whether depletions have decreased, thus potentially making water available for appropriation. Even if depletions have decreased, the OSE would need to make a determination regarding impairment before approving the appropriation and could require the applicant to conduct further technical studies to establish no impairment. Combined legal and technical studies to obtain OSE approval could possibly be completed for $100,000 to $200,000. However, as it is likely that extensive modeling will be required and/or contested legal issues will be present, this alternative could cost $1 million or more, and as also noted in Section 2, the outcome of the application would be uncertain.

4. Legal Feasibility

As discussed in Section 1, total depletions in New Mexico may have decreased since 1929, and therefore, northern Rio Grande water users above the Otowi Gage may not be receiving the full surface water supply allowed under the Compact. If such water is available, it could be re-appropriated for use in northern New Mexico. On June 26, 2001, Santa Fe County filed a notice to appropriate all unappropriated water above the Otowi gage, on behalf of northern New Mexico users, including the Jemez y Sangre water planning region. The application to appropriate must be filed by June 26, 2004. The County is planning an organizational meeting for early Spring 2002 to identify participating water users and to establish a process to prepare and submit the application. The applications will be subject to an earlier application filed on May

22, 2001 by the City of Albuquerque requesting an appropriation of nearly 200,000 acre-feet of flood flows in Abiquiu Reservoir.

Because appropriation up to the 1929 condition has Rio Grande Compact implications, the OSE would most likely submit the application to the Compact Commission for review.

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

If implemented, this alternative could potentially increase the number of upper basin marketable water rights in the region. These water rights could be used to meet future demand by providing direct diversion rights or as offsets for groundwater pumping. The actual number of additional water rights will be determined by the OSE based on technical studies documenting changes in depletions.

6. Environmental Implications

The environmental impact of this alternative will depend on how the additional water rights would be used. If additional diversions are envisioned, then streamflows would be altered, possibly affecting aquatic and riparian habitats. Excess water appropriated and removed from the natural stream course could result in lower than normal flows farther downstream that might impact riparian habitat and endangered species. These effects would be local depending on diversion and return flow points. If the surface water rights were used to offset groundwater pumping, then no direct diversions would occur, thus avoiding direct streamflow impacts. If the water were kept in storage, it could be used to augment streamflows in low-flow conditions.

Planners should carefully consider the environmental implications of the conveyance and distribution of reappropriated water.

7. Socioeconomic Impacts

Appropriating up to the 1929 condition is generally positive because the entire region benefits from using the water in the Jemez y Sangre region rather than allowing it to flow to Texas. Since the historical depletions occurred above the gage and the water right would thus presumably have a point of diversion above the gage, this alternative benefits primarily users above the Otowi gage. Water right owners in this part of the region have traditionally been concerned about all aspects of water management in the area, and this alternative may raise issues with those users. The following discussion of historical and cultural issues explains the context for these concerns.

The Jemez y Sangre region, particularly the northern part, is distinguished by its rural and agricultural character, predominantly Indian and Hispano population, localized land-based economies, and pockets of persistent poverty. 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. Particularly pertinent to water management is the ancient acequia 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.

Appropriating any water above Otowi Gage, particularly if that water is transferred to below Otowi Gage, will be viewed by acequia irrigators as a dangerous precedent and will be vigorously opposed. Recognizing the significance of this issue, the 2001 New Mexico

Legislature sought to prohibit water right transfers from above to below Otowi Gage in House Joint Memorials 14 and 6.

Despite the perceived negative socioeconomic and cultural impact of this alternative on rural water users, the prior appropriation doctrine is designed to protect senior users such as acequias. In response to an application to appropriate water, the OSE would first have to make a determination that water is available in the region. If water were available, the applicant would have the burden of proving non-impairment. If circumstances exist where senior users would not be impaired and the application could be approved, the OSE would condition the permit such that senior users were protected. If impairment is inevitable, then the application would be denied.

Legalities aside, certain users have significant concerns regarding the fairness of adjudications and the socioeconomic and cultural impacts of appropriating water rights that rural communities have traditionally used and come to rely on for years. These users have also expressed concern that they may not benefit from the water rights that may be appropriated through the County application due to lack of funds. The OSE will allocate water to the entities listed in the application. Presumably only applicants participating in the legal and technical fees will be included in the application. Water users (particularly acequias) located above Otowi gage may not have the funds to participate and therefore may be excluded from the application even though they are currently listed in the notice to appropriate.

In addition to these concerns, legal questions of ownership of stormflows and the potential impacts to unadjudicated Indian water rights are key threshold issues that must be dealt with first and foremost, similar to the appropriating above-average runoff alternative (DBS&A, 2002). In short, the process of identifying “excess” water for appropriation would be an onerous administrative task, would possibly conflict with ongoing adjudication suits, and would undermine rural water rights by adding further to the undue legal and financial burden already placed on lower-income rural water users. Given all these issues, any move to appropriate water from the upper Rio Grande is certain to involve a lengthy legal conflict.

8. Actions Needed to Implement/Ease of Implementation

In order to appropriate excess water above Otowi gage, the following actions would be needed:

- Submit an application (County of Santa Fe has submitted an application to pursue this alternative).
- Meet with the Interstate Stream Commission (ISC) to discuss its position on this appropriation and determine whether ISC would participate in or fund technical studies.
- Set up a process to allocate water among water suppliers in the region and determine who would contribute to the costs to pursue the alternative and benefit from the possible appropriation. Discuss the participation of water users who may not be able to contribute funds, but would benefit from availability of additional water rights.
- Conduct technical studies to determine whether depletions have been reduced.
- Address negative perceptions that may surround this alternative (include public education and participation, and propose solutions that might alleviate the threats perceived by the acequias).
- Determine the status of the City of Albuquerque application and whether it would affect this appropriation.

9. Summary of Advantages and Disadvantages

This alternative could potentially make more water available for use and transfer, thus helping to meet future demand. Having additional water rights available provides flexibility to water managers. Since this appropriation would be shared among users in the region, it may provide a means to mitigate potential conflicts. Conversely, disadvantages include uncertainty and potential conflicts that may create obstacles to its implementation. Expensive technical studies would be required to quantify the amount of water available.

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Appropriate above-average runoff flows.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Jemez y Sangre Water Planning Council. 2001. *Presentation of water supply assessment and populations projections.* February 2001.

National Resources Committee. 1938. *Regional planning part VI - The Rio Grande joint investigation in the Upper Rio Grande Basin in Colorado, New Mexico, and* Texas, 1936-1937. United States Government Printing Office, Washington, DC.

White Paper 11

Alternative: Replace Septic Tanks

Alternative: Replace Septic Tanks

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Mike McGovern (primary author) and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

Septic tank/leach field systems are the main wastewater treatment disposal method in use today for virtually all residences and commercial establishments in the planning region outside the service areas of the major central collection, treatment, and disposal systems of Española, Los Alamos, and Santa Fe. Replacing and/or upgrading septic tank treatment and disposal systems in the Jemez y Sangre water planning region would have two primary benefits:

- The quality of the region's groundwater supplies would be better protected.
- A consolidated waste stream from new, centralized treatment facilities would allow the region to apply for more return flow credits and potentially increase their water rights.

Septic tanks are basically clarifiers and biological treatment systems that settle solids and rely on anaerobic or facultative microorganisms to provide biodegradation of organic wastes. Conventional septic tanks and leach fields also include follow-on physical and biological treatment in receiving soils. The technology is well established and, when applied, designed, sited, and installed properly, provides a known and cost-effective level of wastewater treatment as well as adequate protection for receiving groundwater.

However, the use of conventional septic tank/leach field systems can become problematic for various individual and combined reasons such as poor planning, poor design and/or application, poor construction, and lack of adequate maintenance. In some cases, septic tank system failures or the use of septic tanks in an urban or suburban setting where septic tank density is high can cause groundwater pollution and resultant drinking water and human health problems from possible exposure to bacteria and nitrates.

In New Mexico, there are hundreds of small water systems that serve small numbers (30 to 1,500) customers. Approximately 70 such small systems serving approximately 25,000 people exist in the Jemez y Sangre water planning region. Many times, these small water systems have no central wastewater collection system, treatment facility, or disposal system, and their customers therefore rely upon septic tanks/leach fields for wastewater treatment and disposal. If approved by the Office of the State Engineer (OSE), these community water systems can count septic tank wastewater effluent as a return flow. A consolidated waste stream flowing from conventional centralized collection and treatment systems serving these users could effectively increase the amount of return flow credits realistically obtainable.

An additional estimated 46,000 people in the planning region who rely on septic tanks are not connected to these small central water systems, instead obtaining their water from individual domestic wells. Domestic well water rights are not eligible for return flow credits from septic tank wastewater effluent.

This white paper examines two options for eliminating/replacing septic tanks in the planning area:

- *Construct regional wastewater treatment systems for wastewater reuse:* Under this option the planning area would be divided into several collection areas in which central collection, treatment, and disposal facilities would be designed and constructed. After treatment, the wastewater might be reused by reinjecting the effluent to the groundwater or transmitting the effluent to a golf course, ranch, or some other facility that now uses surface water and/or groundwater.

- *Wastewater solutions other than regional wastewater treatment for septic tanks:* Other innovative on-site approaches are available as alternatives to conventional septic tank/leach field wastewater disposal. These more advanced or intensive methods to treat wastewater are intended to produce a higher-quality effluent that protects soils, groundwater, and human health. An example of such a system is a combination gray/black wastewater system, which separates individual on-site residential waste streams so that some wastewater (e.g., from showers and kitchen use) can be stored

> and used for landscaping or garden watering, with sanitary wastes being segregated and directed to some on-site (or off-site) wastewater treatment system. This approach to residential wastewater treatment and disposal greatly reduces the daily volume of residential wastewater that, after treatment, is discharged to surface or groundwater. Some of these advanced systems incorporate disposal processes that include evaporation of some of the effluent liquids. Use of such systems may impact return flow credit levels that currently could be assigned to existing groups of septic tank systems.

As indicated above, both of these septic tank replacement options may include reuse of treated wastewater, which would be another, or second, beneficial use of the resource. If a central system pumped treated effluent for some other beneficial use or if gray-water systems were widely used, a reduced amount of water would be withdrawn for consumptive uses such as landscape, garden, stock, and/or ranch land watering. There would also then be a reduction in the primary use return flow credit equal to the consumptive use of the follow-on reuse or gray-water application. This reduction would need to be calculated when determining water savings.

Because of transmission costs, however, reuse of effluent makes sense in this alternative only if some large water user or group of users is within a reasonable distance to the treatment plant(s). This and other issues associated with wastewater reuse are discussed in more detail in a separate white paper (DBS&A, 2002).

Replacement of septic tanks will not necessarily provide more water to the region. The effluent from septic tanks currently recharges the aquifers, thus impacting the supply available to domestic wells, and the potential return flow credits available if the effluent were treated in a centralized system are not necessarily more than those currently available for septic tank seepage. Thus this alternative will not increase the amount of water allowed for full consumption under a water right.

Nevertheless, in considering new developments, the water that can be lost on new septic tanks, particularly those located distant from the source of supply, should be considered by planners. In addition, replacing septic tanks with a centralized or on-site system that allows for reuse of the effluent could reduce the demand, improve system efficiency, and protect the water resources. Regardless of any potential increase in water supply, the water quality benefits alone may make this an option worth pursuing.

2. Technical Feasibility

For a large portion of the planning area in and around Española and the Pojoaque Pueblo, an excellent in-depth study has been completed that examines the issues of this white paper (ASCG Incorporated, 2001). Similar studies will be needed throughout the planning area to properly evaluate options and present costs and benefits so that decision-makers have enough information to plan for the future.

One very important point that is examined in the ASCG study is the need for cooperation and inclusion of all the pueblos in such planning, project implementation, and facility management. As an example of the need for this cooperation with the pueblos, the *North Central New Mexico Water Quality Plan* also notes that septic tank systems are expected to still be used by many residents, regardless of the option adopted for its management area, and the disposal of septage from these systems will thus need to be addressed. It notes:

> Septic tanks will continue to be used as an interim wastewater treatment and disposal measure for many of the Region's residents until sewer service is eventually extended. Many of these on-site systems are owned by non-Indians who live within the boundaries of the Region's six Pueblos. An enforceable management plan for properly maintaining these systems and disposing of their septage is needed. In specific, this management plan needs to resolve concerns by the Region's local units of governments and the six Tribal governments over who has jurisdiction to enforce septic tank management.

2.1 Regional Wastewater Treatment Systems

The technology exists to collect, centrally treat, and dispose of all wastewater now generated by rural residents of the planning area. In the normal course of an area's growth, it is not unusual for housing units to become denser and for wastewater treatment to eventually be centralized. The decision to centralize wastewater treatment is normally taken for public safety and health and environmental protection, as well as for economic reasons. In some parts of the planning area, the density of rural housing lends itself to this consideration now.

This alternative would involve potentially complicated federal and state permitting for the discharge of some or all of the treated wastewater effluent to surface water and/or groundwater or for some reuse purpose. Return flow credits might also be impacted depending on the type of reuse option used.

The planning, design, and construction of regional wastewater systems would require contracted external professional assistance and, after completion, qualified regional management, operations, and maintenance staff. Reuse of wastewater might also require:

- More person hours and material/equipment costs for overall operations and maintenance than a treatment plant that simply discharges its effluent to some receiving waters

- More sophisticated treatment than simple secondary treatment unit to produce an effluent of higher quality for reuse applications. While golf courses might be able to use effluent from secondary treatment processes, some other applications might require smaller concentrations of solids or a reduction in some other physical or chemical constituent of the treated wastewater effluent.

An excellent source of information on small conventional wastewater systems relevant to this alternative is the U.S. Environmental Protection Agency's Office of Wastewater Management-Small Communities (http://www.epa.gov/OSM/smcomm.htm).

2.2 Alternate On-Site Wastewater Treatment Solutions

Innovative or advanced on-site wastewater treatment/disposal systems are the subject of considerable attention, study, and practice. These systems, which may either enhance or replace conventional septic tank/leach field systems, include the use of filtration, disinfection, and other biological processes in addition to clarification. Descriptions of these systems and their use are beyond the scope of this white paper; however, information on such on-site technology is available at West Virginia University's National Small Flows Clearinghouse (http://www.estd.wvu.edu/nsfc). Another excellent resource on this subject is the National Onsite Wastewater Recycling Association, Inc. (NOWRA) (http://www.nowra.org/who.shtml).

In an effort to address serious groundwater pollution problems, municipalities may consider adopting regulations that call for advanced on-site wastewater treatment technologies for most new residences that would have otherwise installed simple septic tanks. Ordinances may also include wording that requires existing system compliance over time. Adoption of such regulations would represent a solid beginning to achieving better control and management of on-site wastewater in New Mexico.

The planning, design, and construction of improved on-site wastewater treatment systems requires the use of more professional engineering assistance than the installation of conventional septic tank/leach field systems. Such systems are also more costly and require higher levels of operations and maintenance skills and annual activities.

The use of gray-water residential-type systems involves modifications of residential plumbing to separate waste streams and requires equalization/storage tanks and distribution systems. These systems also require new operation and maintenance responsibilities for rural homeowners that will add to existing homeowner maintenance costs.

3. Financial Feasibility

The Jemez y Sangre water planning region is estimated to include approximately 24,500 septic tank/leach-field systems. The costs to replace these systems with either regional wastewater treatment systems or other on-site technologies are discussed in Sections 3.1 and 3.2.

3.1 Regional Wastewater Treatment Systems

The cost to plan, design, build, and then operate and maintain a system of smaller collection, treatment, and disposal facilities would be high. As an example, assume that 80 percent of all residences now on septic systems are tied into a group of small wastewater treatment plants and that the distribution of the rural housing in the planning area dictates that each of these plants have an average initial treatment capacity of 200,000 gallons per day. Given these assumptions, 12 new, small wastewater treatment plants would be required in the planning region. Assuming that these regional systems included only conventional secondary treatment, conventional gravity-type collection systems, and disposal to groundwater or to some other existing water user, this alternative has an estimated capital cost exceeding $95 million. The true cost of such a project would also include right-of-way acquisition, recurring annual operations and maintenance, and future parts and equipment replacement costs.

At least some of the costs of developing central wastewater collection and treatment systems would be passed onto rural residents. In contrast to their current relatively low and periodic ongoing costs associated with conventional septic tanks, these residents would receive a monthly wastewater bill to cover their share of the management, operations, and maintenance of the small central systems.

While the benefits of this option would be mainly in the areas of human health and safety and environmental protection (e.g., improved drinking water quality and groundwater protection), some cost savings may be realized. If some of the treated wastewater were reused, the value of the surface and/or groundwater not used as a result of the reuse application(s) would be saved. If 200,000 gallons of treated wastewater were reused each day and the cost of this water was $5,000 per acre-foot, the resulting savings would be a little less than $13 million. Considerable additional savings might also be realized if the user(s) would have otherwise bought needed water at a higher cost, such as that charged each month to public water system customers (a typical charge is $2 per 1,000 gallons).

At first glance, the capital costs to develop such a system of small central systems, even when they include reuse, would appear to be much greater than the value of the water saved. However, the value of human health and safety improvements due to water quality benefits, although not specifically considered here, would be substantial. Some external federal and state funding for such construction might be available depending on the level of need established.

3.2 Alternate On-Site Wastewater Treatment Solutions

Again, the capital costs alone to employ these systems appear to be huge in comparison to the value of saved water. The cost to bring new systems on line as a result of new home construction would be between $6,000 and $10,000 compared to a conventional septic tank/leach field system cost of approximately $2,400. Gray-water system conversion on existing residences might be priced at a similar estimated capital cost per residence. Thus the costs to upgrade 80 percent of the approximately 24,500 septic tank/leach-field systems in the planning area to an advanced on-site system, even at the low end of the scale (i.e., $6,000 each), would be more than $110 million.

In contrast to regional wastewater systems, the costs of replacing septic systems with advanced on-site treatment systems would likely be borne entirely by individual property owners, although external funding is available for some small community on-site projects. Instituting a wastewater ordinance requiring alternative on-site wastewater systems to septic systems (Section 2.2) would result in much greater on-site wastewater system costs for new ($6,000 to $10,000) and retrofitted ($3,000 to $7,000) residences than the cost to maintain a septic tank system (assuming that a comparison of the cost of maintaining a failing septic tank system with the cost for a functioning advanced system is valid).

Again, however, the value of groundwater improvements and human health and safety benefits associated with system upgrades might be the deciding factor in adopting mandates for advanced on-site treatment. In his paper *Septic Tanks, Good or Evil,* Dr. Richard Rose, P.E., of the NMED Construction Programs Bureau, notes:

> . . . decentralized management has captured national attention and is promoted by EPA because of the potential for substantial reduction in wastewater construction costs. It can provide both short and long term protection of the environment and does not preclude “Big Pipe” options in the future. Funding for the decentralized approach is available from mainstream funding agencies, such as NMED and USDA Rural Utility Service.

This paper (Rose, 2001) also discusses in detail the debate regarding on-site versus centralized treatment and describes an ongoing EPA-funded, NMED-implemented demonstration project in Willard, New Mexico.

4. Legal Feasibility

The legal issues which would arise when examining whether replacing such septic tanks and constructing regional wastewater systems or some other type of water treatment system will increase the supply of water available in the region center around the issues arising from the construction of regional wastewater systems. If the system were to treat water and return water to, for example, the Rio Grande, a number of federal laws would govern the construction and operation of such system. For example, the National Environmental Policy Act (NEPA) would come into play. NEPA is a federal law that addresses process, not substance. It dictates the steps that must be taken to analyze environmental impacts of actions; it does not place limits on what actions may be taken. In a nutshell, NEPA requires that an analysis of environmental impacts be prepared for all “major federal actions significantly affecting the quality of the human environment” (42 U.S.C. §4332). ”Major federal actions“ that must be subject to a NEPA analysis include ”projects and programs entirely or partly financed, assisted, conducted, regulated, or approved by federal agencies” (40 C.F.R. 1508.18(a)). For our purposes, we can presume that any action that either receives significant federal funding or has federal agency involvement will have to be subject to a NEPA environmental analysis. Most likely, a regional wastewater treatment system would receive such funding.

Further, once a regional wastewater system is operational, it can only discharge treated water into the ”waters of the United States“ under a permit issued pursuant to the Clean Water Act (33 U.S.C. §1251 *et seq.*) Such permits are called National Pollutant Discharge Elimination System (NPDES) permits and are implemented to control water pollution by regulating point sources that discharge pollutants into surface waters.

A further issue arises in looking at the return flow ramifications associated with replacing septic systems with a regional wastewater system or other type of treatment regime. Depending on the depth to groundwater, individual septic systems return a certain amount of water to the aquifer. Likewise, wastewater treatment plants which discharge to a surface system also return water to the system. Therefore, a technical question arises as to which type of treatment regime returns more water to the system.

An important issue to municipalities, counties, and other entities that supply water and treat wastewater is the reuse of return flows. In some instances, such an entity may wish to reuse effluent to meet growing municipal demands. Such reuse will result in less water returning to the river system for use by other users and, consequently, raises questions of whether State Engineer approval is necessary and whether downstream users may oppose the reuse. Another type of reuse occurs when the water user seeks to increase its diversions based upon the amount of return flows it makes to the river system. Diversions may be increased by approval by the State Engineer of a return flow plan that has the effect of crediting the water user with the return flows and allowing diversions to increase in the same amount.

From a legal standpoint, a right to divert water provides its user with two types of water: the diversion portion, which equals the total amount withdrawn from the stream system, and the consumptive use portion, which is the portion that is consumed. Any amount left over that returns to the stream system by seepage, discharge or even injection is a return flow. Where the State Engineer has already issued a permit to divert a specified quantity of water, the State Engineer's authority is limited. Other than the power to prohibit a user from using more water than permitted, the State Engineer's authority is restricted to evaluating proposed new uses or new points of diversion to determine whether the change would impair other users or be contrary to public welfare or conservation. Accordingly, the State Engineer lacks jurisdiction to regulate the implementation of a reduced discharge system, as long as the system would not result in a use of municipal water in a place, for a purpose, or in an amount not already allowed by the city's permit.

In the case of *Reynolds v. City of Roswell* (99 N.M. 84, 654 P.2d 537 (1982)), the New Mexico Supreme Court addressed the issue of the State Engineer's imposition of a return flow requirement on a city permit that previously contained no condition. The court held that the requirement was unlawful, concluding that all of the water appropriated under the permit could be used and consumed by the city, as the water was ”artificial“ water belonging to the city (99 N.M. 87-88, 654 P.2d 540-1).

A more complex question concerns a municipality's ability to reuse waters when some or all of its permits contain discharge requirements. A return flow condition will typically require a city to return all measurable return flow to the river, including sewage effluent, or may state a percentage of pumping, such as 30 percent, that must be returned to the river system. Under these circumstances, the municipality may not use more than its consumptive use right. But it could reuse some or all of its effluent if it reduced its pumping correspondingly, so that the total consumptive use did not increase. In other words, by limiting pumping under a permit to the consumptive right and replacing any consequent shortfall in municipal supply with effluent, the municipality could make use of its return flows within its legal authority. Again, as long as the substitution of effluent did not result in a change in the purpose or place of use of municipal water, no State Engineer approval would be necessary, in most instances.

Alternatively, a city that is discharging and returning to the stream system more effluent than is required could seek return flow credits for the discharge. A return flow credit would allow the city to offset the effects of increased diversions for use elsewhere in its water system. Such offsets could allow additional pumping from municipal wells. State Engineer approval would be required for increased diversions based on return flow credits.

With respect to challenges by downstream users, the issue is one of title to water once it is released back into a public watercourse. New Mexico law contains an exemption for artificial waters from the general rule that waters returned to the river system are appropriable public waters. The fact that a city has discharged waters in the past does not extinguish the city's right to its use and consumption and, further, does not create a right to the waters in another, and a downstream user could not assert a claim against the city to the use of the discharged effluent, absent agreement by the city (§72-5-27 NMSA 1978 (1997 Repl. Pamp.)).

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

The effectiveness of septic tank replacement in increasing available supply or reducing projected demand is limited. In some cases it may have some effect on the available supply by allowing the region to apply for more return flow credits and potentially increase their water rights. In addition, it may effectively reduce demand by offering more possibilities for reuse of treated wastewater or gray water (although such reuse raises some public health and safety issues). These possibilities are discussed in Sections 5.1 and 5.2.

5.1 Regional Wastewater Treatment Systems

If the total population of the planning area is assumed to be 163,000 and 90 percent of all residents of Santa Fe, Los Alamos and Española are connected to their municipality's central wastewater collection, treatment, and disposal system, the approximate number of planning area residents who use septic tanks is estimated at just over 73,000, with a corresponding 24,500 septic tanks. If the wastewater generated by a rural resident on a septic tank system is estimated to be 40 gallons per day, the total amount of wastewater that flows to septic tanks in the planning area each day will be close to 2.9 million gallons. This flow equates to approximately 3,125 acre-feet of available return flow liquid wastewater per year.

However, the amount of additional return flow credits available to the region as a result of replacing septic tanks with regional systems is not necessarily significantly more than current potential return flow credits. Even with no reuse, community water systems (excluding individual domestic wells) could potentially receive OSE approval for return flow credit. In addition, the return flow credit might be reduced by the amount of wastewater effluent from a central system that is consumed by another beneficial use. Some portion of the return flow credit would be available at the end of the second beneficial use. How much water is consumed and how much can then be claimed as a return flow credit in the second use will determine the effectiveness of this alternative in increasing the legally available supply.

Reuse of treated effluent would presumably save water now withdrawn from surface water and/or groundwater. Assuming that all of the treated effluent could be reused, the reduction in existing demand is estimated to be less than 2,500 acre-feet.

5.2 Alternate On-Site Wastewater Treatment Solutions

Advanced wastewater treatment systems offer no increase in available supply. The employment of gray water systems will result in a reduction of projected demand through the use of gray water in applications that would otherwise require surface water and/or groundwater. If gray-water systems were retrofitted to all residences and small businesses that currently use septic systems, an estimated 70 percent of the normal domestic flow, or just less than 1,750 acre feet, could be reused. However, the return flow credit available for reused wastewater or gray-water is probably smaller than if the gray water was discharged directly to a conventional septic tank, because some of the water will be lost to evapotranspiration during outdoor applications.

6. Environmental Implications

Replacement of septic tanks would have NEPA implications in archaeological and biological terms but none that would stop the projects. Cultural remains and endangered species habitat would have to be identified and avoided. Some floodway, floodplain, and perhaps wetlands issues under Section 404 of the Clean Water Act would be associated with the construction of regional wastewater treatment systems.

Considering the fact that many rural septic systems are faulty and often located too close to surface water and wells, replacing septic tanks would reduce contamination of surface water and groundwater and therefore enhance human health and safety. Constructing regional wastewater treatment systems would yield greater streamflow downstream, but would reduce locally available water by diminishing local groundwater recharge and seepage to surface water. If alternative wastewater treatment systems are local and small-scale, the discharge could increase local surface streamflow.

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 acequia 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.

Considering the fact that many rural septic systems are faulty and often located too close to surface water and wells, replacing septic tanks would have the direct socioeconomic and cultural benefits of reducing contamination of surface water used for consumption and irrigation and reducing contamination of groundwater used for domestic wells.

If wastewater treatment systems were local and small-scale, replacing septic systems would have the additional direct benefit of increasing local streamflow for irrigation and other local beneficial use. Planners should consider “living machines” (natural biological treatment using greenhouse plants), constructed wetlands, or other small-scale, natural, environmentally friendly alternatives. Administration of local wastewater treatment systems could be easily integrated into rural community structure through existing institutions such as mutual domestic water associations or acequia associations.

Assuming that any effluent water quality issues can be overcome, constructing regional wastewater treatment systems would yield greater streamflow for downstream users, but would have a negative socioeconomic and cultural impact on rural upstream users, reducing available water by diminishing local groundwater recharge and seepage to surface water. In addition, rural users would likely see an increase in their monthly wastewater treatment costs, which could be perceived as a threat to an established rural lifestyle. The cost of retrofitting or replacing an existing septic system with an advanced or gray water wastewater system would be onerous on the rural poor or lower middle class. Such additional expense for the rural poor or lower middle class may not be seen as politically acceptable and could result in some polarization of urban and rural residents in the planning area. Conversely, increasing available water would probably reduce the cost for all water users.

8. Actions Needed to Implement/Ease of Implementation

The actions needed to construct regional wastewater treatment systems for wastewater reuse are:

- Establish a regional authority.
- Determine location(s) for regional treatment plant(s).
- Investigate available reuse options.
- Gather public input.
- Plan, design, and construct wastewater collection, treatment and reuse facilities.
- Identify and secure financial assistance from large external funding source to help cover the capital costs over the life span of such a project (i.e., 10 to 15 years).

The planning and implementation of this option would be time consuming.

To implement wastewater solutions other than regional wastewater treatment for septic tanks, the political entities in the planning area would have to enact some sort of enabling legislation. Some external funding source might be needed to help the rural poor and lower middle class fund the improvements. Any public opposition would need to be overcome.

9. Summary of Advantages and Disadvantages

The advantages and disadvantages of the options for replacing septic tanks are summarized in Table 1. In general, both options examined here seem to have high cost and low value added in terms of water saved. The planning-area-wide discussion in this white paper does not, however, consider smaller locations and areas within the planning region that might better individually lend themselves to these alternatives. Examples exist in other areas of smaller-scale implementation of the options discussed herein that were successful in conserving water. Opportunities to implement these alternatives in smaller areas in a cost-effective, water conserving manner need to be studied and evaluated. Successfully and cost-effectively implementing these alternatives in such places where they make sense will result in water savings through projected future demand reductions.

Table 1. Advantages and Disadvantages of Septic Tank Replacement Options

Septic Tank Replacement Option	Advantages	Disadvantages
Regional wastewater treatment systems	• Reduced projected demand • Technology available • Minimum environmental issues • Improved human health and safety • Improved groundwater quality	• Cost high • Value of water saved low • Politically difficult • Negative cultural impact, monthly charges • Potential medium-difficulty environmental issues
Alternate on-site wastewater treatment solutions	• Reduced projected demand with gray water system • Technology available • Minimum environmental issues • Improved human health and safety • Improved groundwater quality	• Cost high • Value of water saved low • Politically difficult • Negative cultural impact, high costs

References

ASCG Incorporated. 2001. *North Central New Mexico water quality plan*. Albuquerque, New Mexico. September 21, 2001.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Wastewater reuse.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Rose, Richard P. 2001. *Septic tanks good or evil? The future of managed decentralized wastewater treatment in New Mexico.* Prepared for Rocky Mountain Section, American Water Works Association and Rocky Mountain Water Environment Association Annual Conference—September 12, 2001.

White Paper 12

Alternative: Aquifer Storage and Recovery

Alternative: Aquifer Storage and Recovery

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Jeffrey Forbes and Herman Bouwer (primary authors), Susan C. Kery (legal), and Ernest Atencio (socioeconomic).

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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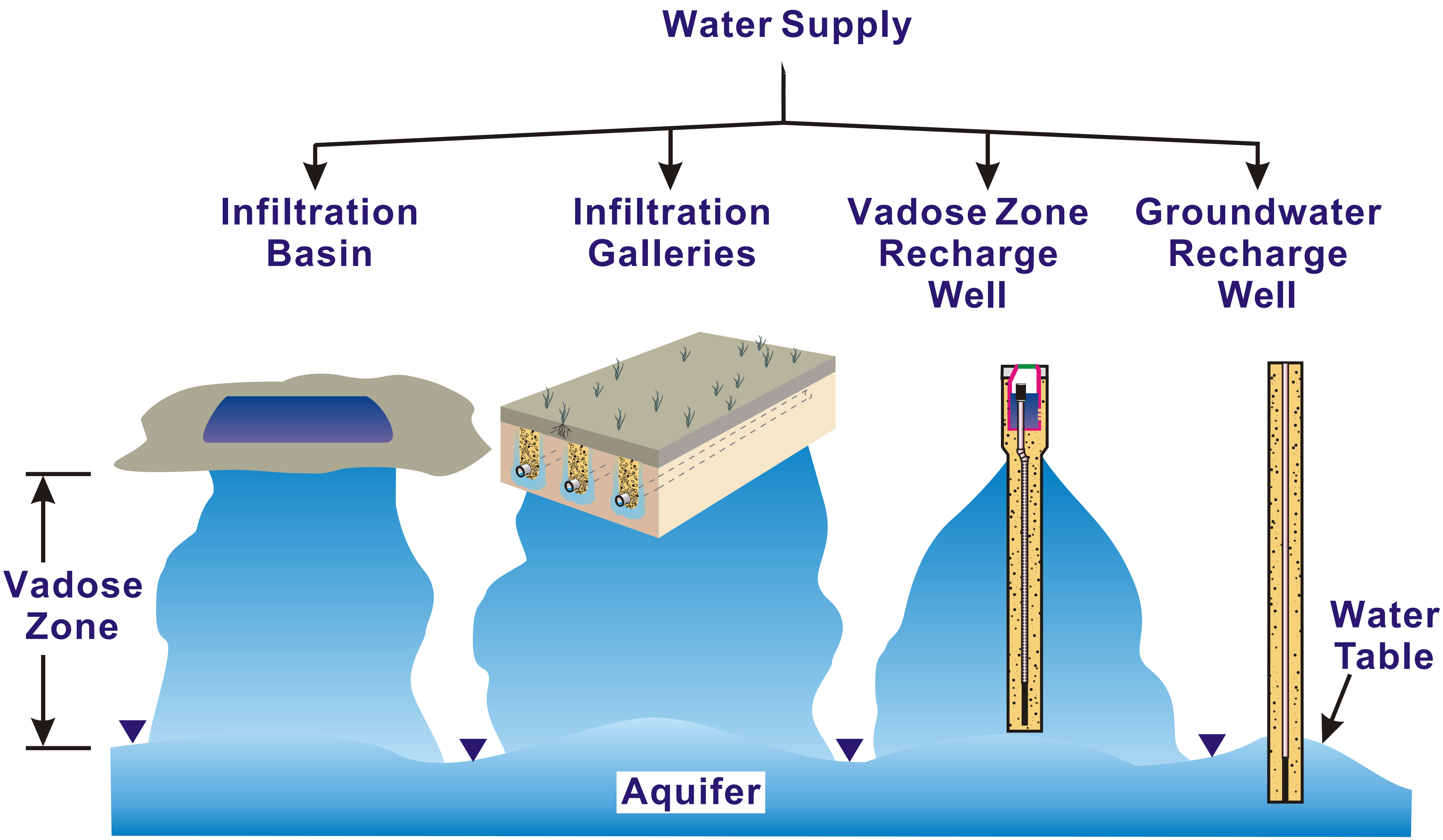

Not to Scale

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2-5-02
JN 9419

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

References

Arizona Department of Water Resources (ADWR). 1999. *Artificial recharge and integrated water management.* Proceedings of 9th Biennial Symposium on the Artificial Recharge of Groundwater, June 10-12, 1999, Tempe, Arizona.

Bouwer, H. 1989. Effect of water depth in groundwater recharge basins on infiltration. *Journal of Irrigation and Drainage Engineering* 115(4):556-567.

Bouwer, H. 1991. Groundwater recharge with sewage effluent. *Water Science Technology* 23:2099-2108.

Bouwer, H. 1992. Reuse rules. *Civil Engineering,* July 1992, pp. 72-75.

Bouwer, H. 1996. Issues in artificial recharge. *Water Science Technology* 33(10-11):381-390.

Bouwer, H. and R.C. Rice. 2001. Capturing flood waters for artificial recharge of groundwater. p. 99-106 *In Proceedings of 10th Biennial Symposium on the Artificial Recharge of Groundwater,* June 7-9, Tucson, Arizona.

Bouwer, H., R.D.G. Pyne, and J.A. Goodrich. 1990. Recharging ground water. *Civil Engineering,* June 1990, pp. 63, 66.

Bouwer, H., J.T. Back, and J.M. Oliver. 1999. Predicting infiltration and ground-water mounds for artificial recharge. J*ournal of Hydrologic Engineering,* October 1999, pp. 350-357.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002a. *Alternative: Purchase surface water rights in the marketplace.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002b. *Alternative: Wastewater reuse.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Lluria, Mario. 1999. Hydrogeochemistry and groundwater quality impacts on the receiving aquifer of a large water-spreading recharge facility. p. 225-236 *In Artificial recharge and integrated water management,* Proceedings of 9th Biennial Symposium on the Artificial Recharge of Groundwater, June 10-12, Tempe, Arizona.

Nellor, M.H., R.B. Baird, and J.R. Smith. 1984. *Summary of health effects study: Final report.* County Sanitation Districts of Los Angeles County, Whittier, California.

Pyne, R.D.G. 1998. *Groundwater recharge and wells.* Lewis Publishers, Boca Raton.

Sedlak, David L. 1999. Pharmaceutically-active compounds in the aquatic environment and their relationship to water reuse. p. 5-14 *In Artificial recharge and integrated water management,* Proceedings of 9th Biennial Symposium on the Artificial Recharge of Groundwater, June 10-12, Tempe, Arizona.

Sloss, E.M., S.A. Geschwind, D.F. McCaffrey, and B.R. Ritz. 1996. *Groundwater recharge with reclaimed water: An epidemiologic assessment in Los Angeles County, 1987-1991.* RAND, Santa Monica, California.

Thomas, Carole L., A.E. Stewart, and J. Constantz. 2000. *Determination of infiltration and percolation rates along a reach of the Santa Fe River near La Bajada, New Mexico.* Water-Resources Investigations Report 00-4141, U.S. Geological Survey.

Unangst, Leslie, A. Fisher, and D. Swieczkowski. 1999. Trends and issues in effluent recharge for the Phoenix and Tucson active management areas. p. 67-77 *In Artificial recharge and integrated water management,* Proceedings of 9th Biennial Symposium on the Artificial Recharge of Groundwater, June 10-12, Tempe, Arizona.

White Paper 13

Alternative: Manage Well Field/ Install New Municipal/ Industry Supply Wells and/or Domestic Supply Wells

Alternative: Manage Well Field / Install New Municipal/ Industry Supply Wells and/or Domestic Supply Wells

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Christopher Wolf and Neil Blandford (primary authors) and Susan C. Kery (legal).

1. Summary of the Alternative

Meeting water supply demands in the future will require sound management of existing well fields and possibly the installation of additional well fields. This white paper combines the discussion of both expansion and management issues faced in the Jemez y Sangre region:

- Well field management, including optimizing the number, sizes, depths, pumping rates, and locations of municipal/industrial water supply wells.

- Installation of new municipal/industry supply wells and/or domestic supply wells, including:
  - Acquiring water rights and installing more municipal/industrial water supply wells
  - Installing new individual domestic water supply wells
  - Creating new mutual/community water systems
  - Improving existing mutual/community water systems.

Issues associated with these options include investigating hydrologic conditions and obtaining land and financing for well construction.

For this discussion, a well field refers to any group of wells, municipal or domestic, producing from the same aquifer. Generally, a well field is designed to meet immediate and projected needs over several decades, roughly corresponding to the expected life of a well. Expansion of a well field to increase yield requires the proper hydrologic conditions and available water rights.

All of the large municipalities in the Jemez y Sangre planning region rely on local groundwater resources for at least a portion of their water supply (DE&S, 2001). The City of Santa Fe has the Buckman and City of Santa Fe well fields. Los Alamos uses several well fields including Los Alamos, Guaje, Pajarito Mesa, and Otowi. Española and small communities such as El Dorado also have well fields. In addition to the municipal well fields, numerous domestic wells throughout the planning region supply single or sometimes multiple homes. Community and mutual domestic water associations also play an important role in supplying rural homes throughout the region.

The hydrologic conditions in the Jemez y Sangre region are favorable to expansion of existing well fields to increase supply. The region lies mostly in the Española Basin, which corresponds to the Española structural geologic basin described by Kelley (1978). This basin consists of the Rio Grande and Rio Chama valleys and is bounded by the Jemez Mountains to the west and Sangre de Cristo Mountains to the east. The main water-bearing unit or aquifer consists of sand and gravel units deposited along the river valleys throughout geologic history and are collectively termed the Santa Fe Group. Hydrogeologic characteristics vary within the Santa Fe Group and throughout the region, but overall, the Santa Fe Group yields fairly high quantities of good-quality water to wells.

Availability of water rights in the Jemez y Sangre planning region will be the primary controlling factor in the expansion of well fields. The subtleties of water rights in the region are beyond the scope of this discussion, but parties attempting to acquire water rights should be aware of the following entities that influence control of water rights and overall availability of water in the region:

- The Office of the State Engineer (OSE) administers New Mexico water law.
- Traditional entities such as acequias have a very active role in local water use.
- Several Pueblos are located within the planning region, and their water rights are reserved under federal law and will play a major role in the future water use of the area.

- The federal government maintains water rights for public lands such as U.S. Forest Service or Bureau of Land Management holdings.

The presence of substantial volumes of water in the aquifer units that underlie the planning region does not necessarily ease the water rights issue. Although the consequences may not become evident for many years, extraction of the water from the aquifer units will eventually cause reductions in streamflows of the Rio Grande and its tributaries. Because of this effect on the Rio Grande, which is a fully appropriated stream system, water rights that offset the expected amount of streamflow depletion must be obtained before any new pumping at existing or expanded well fields will be permitted by the OSE. This constraint currently applies to all municipal, industrial and agricultural users; it does not currently apply to domestic wells, although that condition will likely change in the near future (Section 4).

Of the options discussed in this white paper, the installation of domestic wells is the only one that could actually increase the supply available to the region without purchasing water rights (although this gain may be short-term if the new domestic wells impair senior water rights). The other options focus on better management of well fields to increase sustainability and reduce vulnerability during a drought. Installing more municipal wells can increase the supply, but water rights are required for this option. The potential gain from such an action is considered under the alternative Purchase Water Rights (DBS&A, 2002a).

2. Technical Feasibility

The prime benefit of expanding well fields or increasing the number of domestic supply wells is the acquisition of additional water. Within the Jemez y Sangre planning region, land and substantial amounts of good quality groundwater are generally available to expand existing well fields or to create new ones. However, the groundwater supply is not infinite and groundwater mining has already begun in several of the sub-basins due to pumping for municipal supply (DE&S, 2001). In addition, some areas, such as the South Galisteo Sub-basin, have fairly limited groundwater availability. An up-to-date numerical model would greatly assist with the determination of the technical feasibility and long-term implications of installing new wells.

Given the acquisition of the necessary water rights, the installation of new wells is readily accomplished and involves the following steps:

- Evaluating the hydrogeologic conditions
- Determining appropriate well spacings to avoid excessive pumping interference
- Designing the new wells
- Constructing the wells
- Performing well yield and water quality testing
- Connecting the well(s) to conveyance systems for distribution

These steps are discussed in further detail in Sections 2.1 through 2.5.

2.1 Hydrogeologic Conditions

The Santa Fe Group within the Española Basin has a very substantial, but not unlimited, quantity of groundwater in storage (DBS&A, 1994). Due to relatively small recharge rates that occur within the planning region (less than 1 inch per year), the groundwater resource is essentially non-renewable, and depletions to the aquifer caused by mining groundwater from storage (pumping water at a greater rate than it is recharged) should be carefully planned to achieve maximum benefit.

DE&S (2001) presents estimated groundwater budgets for each basin in the planning region based on estimated inflows and outflows to the groundwater systems. Their calculations indicate that for most of the basins inflows approximately equal the outflows and the groundwater system appears to be in a state of equilibrium (i.e., mining is not occurring). In only two of the basins, the Los Alamos and Caja del Rio basins, did their estimated overall outflows exceed inflows, indicating that groundwater within those basins is being mined, apparently due to the Los Alamos and Buckman well fields, respectively (DE&S, 2001). The calculations conducted by DE&S are only approximate, however, and anecdotal evidence such as apparent reduction in spring flows may indicate that more widespread groundwater mining has occurred over the past 20 years.

Water level declines in the vicinity of the wells fields also indicate that the resource is being mined in these locations. These localized declines can result in aquifer compaction and loss of storage capacity in the aquifer, and the reduction in storage capacity results in a permanent decline in yield from the well field. With better management of the well field, water level declines could be reduced, thus preventing such degradation. However, legal constraints in the water rights system do not generally allow for such flexibility.

2.2 Well Field Design

Well field design involves the determination of effective well spacing to create cost-effective pumping and conveyance systems. The same design considerations apply to municipal and domestic wells, although efficient design is generally more critical for municipal wells due to their larger pumping rates. Determination of appropriate well spacing is primarily dependent upon the transmissivity and storage coefficient of the aquifer and the locations, pumping rates, and depths of the wells.

Hantush (1964) discusses well field design in terms of interference between pumping wells. When a well pumps water from an aquifer such as the Santa Fe Group, the aquifer material near the well is dewatered (or depressured) and a cone of depression forms around the well. Well interference occurs when the cones of depression caused by multiple wells overlap one another. This condition results in additional drawdown in the wells as compared to the case where only one well (with its own cone of depression) is present.

The disadvantage of well interference is the additional pumping capacity needed to overcome the increased lowering of water levels caused by the interference. Wells should be spaced far enough apart so that the effects of interference are minimal; however, if the wells are too far apart, conveyance and pumping system costs may be prohibitive. In practice, a certain amount of interference is usually accepted to maintain reasonable short-term costs for infrastructure.

To address this issue, the OSE has promulgated aquifer management criteria for various groundwater basins in the state within which the groundwater is being mined (e.g., the Mimbres and Lordsburg Basins). These basins are administered based on a grid system in which pumping is restricted based on allowable rates of drawdown in the aquifer, a condition that imposes minimum spacings between production wells dependent upon pumping rates and aquifer characteristics. The OSE has not promulgated an aquifer management rule in the planning area. However, Santa Fe County through its Land Development Code effectively regulates the spacing of domestic wells through minimum lot sizes and requirements on water availability beneath the lots. The primary groundwater users in the planning region, the public water systems, do not have any aquifer management rules or guidelines.

An additional benefit of efficient well field design is that it will minimize, through causing smaller drawdowns over larger regions, aquifer compaction and associated reduction in well capacity. If significant drawdowns persist sufficiently long, land subsidence and earth fissures are likely to occur.

2.3 Well Design and Construction

Well construction will be needed both for replacing older wells removed from service and for development of new well fields. Design of supply wells should follow the procedures and standards presented by the U.S. Environmental Protection Agency (EPA) (1975) and the American Water Works Association (AWWA) (1997). Roscoe Moss Company (1990) and Driscoll (1986) also present standard practices of well design and construction.

Hydrogeologists and engineers keep several goals in mind while designing supply wells (Driscoll, 1986). Will the well produce a maximum amount of water with a minimum amount of drawdown within the given aquifer? What is the water quality at the well field? Will the well design and selected well materials produce sand-free water? Will the well have a long life of 25 years or even more? Are the costs within reason in the short and long term? These questions apply both to individual wells and to well fields as a whole.

2.4 Well Testing

When a well is installed, yield and water quality tests are performed. Well yield is determined through a series of pumping tests over a given amount of time. The data collected are used to calculate pumping rates and project drawdown in the well and in the surrounding aquifer. These calculations are also used to determine well interference within the well field.

Water quality testing must be completed before the water is distributed to consumers. Expansion of domestic well fields may raise water quality issues in areas where septic tanks are relied on for domestic wastewater treatment. According to DE&S (2001), water quality in the planning region is generally very good to excellent. Total dissolved solids (TDS), nitrate, and fluoride in groundwater may be of concern in local areas but they are not a major large-scale concern. Uranium concentrations are naturally elevated in the Pojoaque Valley (DE&S, 2001), and a new arsenic standard by the EPA is exceeded in many locations in the planning region (DBS&A, 2002b).

2.5 Water Distribution

Water distribution consists of conveyance systems to deliver water from the point of diversion (wells) to treatment facilities, if needed, and then to the consumer. Generally conveyance infrastructure includes (1) the pumping system in the well or pump station to pressurize the water and deliver it to the storage tanks and (2) the conveyance system that transports the stored water to users. Treatment, if needed, usually includes disinfection by chlorination or may include filtering to remove unwanted constituents such as dissolved solids, arsenic, sulfate or uranium.

2.6 Well Field Management

As municipalities expand their well fields, their existing water departments would expand their management duties to include the new well field. No such management capability generally exists for domestic wells. Yet as domestic wells increase in number, especially when considering the potential population increases in the planning region, problems may develop such as excessive well interference and localized drawdown or the drying up of older, shallower wells. Some form of collective management would greatly assist in avoiding, or at least minimizing, these issues.

One alternative to individual homeowners drilling their own wells is the formation of community or mutual domestic water associations for small water systems that serve 3,300 households or less. The New Mexico Environment Department defines a community water system as a "public water supply system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents" (20 NMAC 7.1). Due to the rural nature of the many parts of the Jemez y Sangre planning region, small community water systems will be critical to managing water resources. One added benefit of this approach is that water use can be more easily quantified (e.g., metered), which will lead to more accurate data for long-range planning decisions.

3. Financial Feasibility

Increasing infrastructure is fairly straightforward, and financing is available for municipalities and community water associations through, for example, the Community Development Block Grants and the New Mexico Finance Authority. Another option is to pass the costs on to the consumer. Domestic well owners must seek their own financing to pay for a new well.

The magnitude of water well costs varies with the quantity of water that the owner expects to pump from their well. Municipalities in the planning area need relatively deep wells capable of producing 500 to 600 gallons per minute (gpm). A large municipal well requires the services of an experienced hydrologist or engineer capable of designing, overseeing construction of, and testing the new well. The hydrologist assists the municipality in selecting an experienced driller, provides contract administration, and oversees the construction activities. The costs presented in Table 1a include drilling and consulting services for municipal supply wells. A community well should yield between 50 and 150 gpm and will not need to be as deep as a municipal well. A community would benefit from the services of an experienced hydrologist or engineer for well design and construction oversight. A local driller may also provide insight for well design based on their experience in the area. Costs for community wells are shown in Table 1b, including estimates for submersible pumps and a modest well house.

Domestic wells are generally designed and installed by a local well driller. Most domestic wells are intended to produce less than 50 gpm. Table 1c presents estimated costs for installation of domestic supply wells in the Jemez y Sangre region.

Table 1a. Cost Estimate for Construction of Municipal Water Supply Wells in the Alluvial Valley Jemez y Sangre Water Planning Region

Item	Unit	Unit Cost ($)	Quantity	Total ($)
Well Installation				
Mobilization	Lump sum	90,000	1	90,000
Drill pilot hole, 8-inch	Linear feet	45	1,260	56,700
Geophysical logs (electric logs)	Lump sum	9,500	1	9,500
Ream pilot hole for surface casing, 30-inch	Feet	125	80	10,000
Conductor casing, 30-inch installed	Feet	140	80	11,200
Ream pilot hole, 26-inch	Feet	50	1,180	59,000
Blank casing, 16-inch, in place	Feet	65	420	27,300
Casing, perforated, 16-inch, in place	Feet	100	840	84,000
Gravel feed line, in place	Feet	8	390	3,120
Gauge line, in place	Feet	6	620	3,720
Gravel, in place	Cubic yard	300	80	24,000
Cement annular seal, in place	Cubic yard	220	76	16,720
Development by zoned air-lift pumping and swabbing	Hour	225	72	16,200
Furnish, install and remove test pump	Lump sum	17,500	1	17,500
Development and test pumping	Hour	175	100	17,500
Video survey	Lump sum	1,500	1	1,500
Disinfection	Each	500	1	500
Water quality testing	Lump sum	2,000	1	2,000
Design and oversight [a]	Lump sum	57,500	1	57,500
Well installation subtotal				*507,960*
Well House and Pumping Equipment				
Pumping equipment and controls, installed	Lump sum	145,000-200,000	1	145,000-200,000
Disinfection equipment, installed	Lump sum	40,000	1	40,000
Piping and valves, installed	Lump sum	35,000	1	35,000
Well house with climate control	Square foot	100	625	62,500
Well house foundation	Square foot	15	625	9,375
Utilities (electrical and alternative power supply)	Lump sum	25,000-100,000	1	25,000-100,000
Site fencing	Lump sum	7,500	1	7,500
Grading and drainage	Lump sum	12,500	1	12,500
Energy dissipater	Lump sum	25,000	1	25,000
Engineering design, specifications, and oversight	Lump sum	40,000	1	40,000
Well house and pumping equipment subtotal				*401,875-531,875*
Grand total				**909,835-1,039,835**

[a] Design and oversight includes well design, permitting, geological logging, and construction oversight.

Table 1b. Cost Estimate for Construction of Community Wells
Jemez y Sangre Water Planning Region

Item Description	Unit	Estimated Quantity	Unit Price ($)	Amount ($)
Mobilization and demobilization	Lump sum	1	15,000	15,000
Drill 7 7/8-inch hole	Linear feet	385	30	11,550
Geophysical logging	Lump sum	1	3,500	3,500
Casing, blank, 6 5/8-inch, Roscoe Moss, in place	Linear feet	320	6	1,984
Casing, perforated, 6 5/8-inch, 0.188-inch wall, in place	Linear feet	60	37	2,205
Cement annular seal, in place	Linear feet	80	9	720
Development, air lift	Hours	8	180	1,440
Well disinfection	Lump sum	1	750	750
Goulds 70J10, 10-HP pump and motor	Lump sum	1	3,240	3,240
Install pump	Lump sum	1	1,500	1,500
Column pipe for pump, 3-inch, low carbon steel, galvanized	Linear feet	300	6	1,938
Pitless adaptor, spool type	Lump sum	1	600	600
Pump panel/starter box, single phase	Lump sum	1	670	670
Pressure tank, 119-gallon	Lump sum	2	800	1,600
Development and test pumping	Hours	30	85	2,550
Water quality testing	Lump sum	1	1,500	1,500
Well house	Lump sum	1	4,000	4,000
Well house pad	Lump sum	1	2,000	2,000
Total				56,747

Table 1c. Cost Estimate for Construction of Domestic Wells
Jemez y Sangre Water Planning Region

Item Description	Unit	Estimated Quantity	Unit Price ($)	Amount ($)
Well Installation: 8-inch boring, 6-inch PVC well, total depth of 350 feet [a]	Lump sum	1	5,250	5,250
Submersible pump: 3-HP pump and motor, installed	Lump sum	1	1,600	1,600
Pitless adaptor, spool type	Lump sum	1	600	600
Pump panel/starter box, single phase	Lump sum	1	670	670
Pressure tank, 119-gallon	Lump sum	1	800	800
Water quality testing	Lump sum	1	200	200
Total				9,120

[a] Well installation includes mobilization, drilling, casing, screen, annular seal, gravel pack, and development.

4. Legal Feasibility

Changes in the number, sizes, depths, pumping rates and locations of wells serving municipal and industrial purposes require approval of the OSE. State law allows "The owner of a water right may change the location of his well or change the use of the water, but only upon application to the state engineer and upon showing that the change will not impair existing rights and will not be contrary to the conservation of water within the state and will not be detrimental to the public welfare of the state." (NMSA 1978, §72-12-7(A)). As long as the change does not result in increased total pumping, then the primary legal obstacle will be assuring that the change does not cause localized well interference or increase surface depletions by a change in the location of a well field pumping center or by timing of uses.

New groundwater points of diversion can be permitted as municipal wells or as domestic wells. In this context and with regard to municipal systems, one option being considered by the region is acquiring water rights and installing new municipal supply wells. The acquisition of water rights in a basin where all surface water effects of groundwater pumping must be offset can only occur through the marketplace between a willing seller and a willing buyer. Generally, the State Engineer only allows the transfer of perfected consumptive water rights. Such transfer can only occur after publication and notice and after a determination that the new point of diversion and place and purpose of use will not impair existing water rights, will not be contrary to the conservation of water, and will not be detrimental to the public welfare. The continued perfection of a municipal water permit may be limited to a 40-year well. For example, the City of Santa Fe has been limited in its ability to perfect its permitted water rights.

The issue of the continued viability of domestic wells is currently in a state of flux, based on the State Engineer's plan to propose legislation in the 2003 legislative session to greatly curtail the right to appropriate water for domestic purposes. The proposed legislation would give the State Engineer new authority in areas where domestic wells affect the State's ability to meet delivery obligations to Texas. Under the proposed legislation, the State Engineer would be allowed to turn down new permits, limit the amount of water pumped, and require metering.

Although this discussion focuses on the current state of the law for domestic wells, all participants in the region's planning process must be aware of the potential for major changes in this area. One important note, though, is that if domestic wells are prohibited or severely limited in the future, such a prohibition may be most compelling in the adjudication context. Several of the tributaries in the planning region are subjects of stream system adjudication suits. Once these cases are complete, it is likely that the Court will appoint a water master to oversee the administration of priorities. In instances where recent junior domestic wells are depleting surface flows, the water master and/or the Court may regulate or could prohibit the use of such wells if their use interferes with the exercise of senior water rights. There are very old Pueblo and acequia water rights which would have first priority in these tributary basins. Where existing rights afford little or no room for additional withdrawals from an aquifer, persons in need of domestic water may have to purchase water rights to transfer to their property or tie into a community system.

Under the New Mexico Water Code, an applicant may receive a domestic well permit to appropriate up to 3 acre-feet per annum of water for "household or other domestic use, and in prospecting, mining or construction of public works, highways and roads or drilling operations designed to discover or develop the natural resources of the state." Such a permit may be obtained from the State Engineer without acquiring commensurate groundwater rights or retiring offsetting surface water rights (NMSA 1978, §72-12-1). Historically, the domestic well statute has not given the State Engineer discretion to deny a permit application: "[u]pon the filing of each application . . . the state engineer shall issue a permit." (NMSA 1978, §72-12-1). The State Engineer currently allows interconnection of domestic wells, as long as the total amount taken from the combined wells does not exceed 3 acre-feet per annum.

A significant recent legislative development is the passage by the 2001 legislature of Senate Bill 602, which amended the domestic well statute by providing specific statutory authority for local regulation of domestic wells. Senate Bill 602 provisions require the State Engineer to issue permits ". . . if applications for domestic water use within municipalities conform to all applicable municipal ordinances and an application is made for a municipal permit pursuant to Chapter 3, Article 53 NMSA 1978." Therefore, any new use of domestic water in the region must comply with all applicable municipal ordinances. Further, because several adjudications are underway in the basin, the prospect of court orders regulating domestic well rights should be expected, especially once final decrees are entered and basins are administered by priority. Indeed, in *State of New Mexico v. Aamodt* (adjudication of Pojoaque/Tesuque/Nambe stream system), the Court has already limited new domestic well uses on an interim basis, even before entry of a final decree. Once a final decree is entered, further restrictions could be placed on domestic wells.

Municipalities and counties may regulate water use, including imposition of conservation measures, by assuming responsibility through a utility for supplying water to their residents. Municipalities may exercise their powers of eminent domain to establish or expand water utilities. A municipality may condemn various water supplies, water rights, rights-of-way “or other necessary ownership for the acquisition of water facilities” (§ 3-27-2(A)(1) NMSA 1978 (1995 Repl.)). Counties, like municipalities, may also own utilities. Both the City of Santa Fe and Santa Fe County have used the existence of public water utilities to prohibit drilling of new domestic wells within 200 feet of a utility water line (e.g., City of Santa Fe Ordinance No. 1993-3, adopted January 13, 1999). Recently, well owners filed suit against the City challenging its right to regulate domestic wells.

Under Senate Bill 602 and effective June 15, 2001, municipalities have the power to restrict by ordinance the drilling of new domestic water wells, except for property zoned agricultural land, if the property line of the applicant is within 300 feet of the municipal water distribution lines and the property is located within the exterior boundaries of the municipality. Counties could probably also derive such authority from §4-37-1 NMSA 1978 [1992 Repl.], which states “counties are granted the same powers that are granted municipalities . . . [including those powers] necessary and proper to provide for the safety, preserve the health, promote the prosperity and improve the morals, order, comfort and convenience of any county or its inhabitants.” A municipality may not deny a new domestic well permit if the total cost to the applicant of extending the municipal water lines, meter and hookup exceeds the cost of drilling a new well. A municipality declining to authorize a new domestic well must provide domestic water service within 90 days at regular rates. Existing wells are not affected by the law.

The legislation creates a new section of Chapter 3 (Municipalities), Article 53 NMSA 1978, and amends §72-12-1 (groundwater statute) to require the State Engineer to grant a permit for a domestic well within municipal boundaries provided it conforms to all applicable municipal ordinances. The amendment language (underlined) reads "Upon the filing of each application describing the use applied for, the state engineer shall issue a permit to the applicant to so use the waters applied for if applications for domestic water use within municipalities conform to all applicable municipal ordinances and an application is made for a municipal permit pursuant to Chapter 3, Article 53 NMSA 1978." Thus, effective June 15, 2001, all domestic well applications filed with the State Engineer must conform to municipal ordinances governing domestic wells, as well as to the new statute allowing municipalities to prohibit domestic wells near water lines.

Another issue is whether a domestic water right can be aggregated and transferred into a common or central water system. There are many examples in New Mexico of the State Engineer approving transfers of domestic rights into community water systems, such as mutual domestic associations. New Mexico law provides for the formation of mutual domestic water associations (NMSA 1978, §§ 53-4-3 and 43-4-1(A)). Mutual domestic water associations are formed through the incorporation of any five or more individuals or two or more associations (NMSA 1978, §§53-4-2). However, because the OSE has at various times stated reservations about this practice and has not established formal procedures governing it, the question arises of the legal basis for this method of creating a community water system.

Neither the domestic well statute nor the New Mexico Constitution contains any language limiting the transferability of domestic water. A water right is a real property right (e.g., *New Mexico Prods. Co. v. New Mexico Power Co.,* 42 N.M. 311, 77 P.2d 634 (1937) ["A water right is property and held to be real property by most authorities."]). Further, there is no language in the water transfer statute that would somehow distinguish a domestic water right as a type of water right that cannot be transferred.

Transfers of groundwater rights are governed by NMSA 1978, §72-12-7. Pursuant to this statute, the owner of a water right may change the location of a well or change the use of water, but only upon application to the State Engineer and upon showing that the change will not impair existing water rights, will not be contrary to the conservation of water within the state, and will not be detrimental to the public welfare of the state. In reviewing an application to transfer domestic well rights into a community system, the State Engineer will require a showing that the proposed transfer will not result in increased withdrawals from the stream system. In other words, the current statutory exemption provided by §72-12-1 may not be used to create a water rights loophole community-wide. The problem can be solved by limiting transfers to the perfected amount of the domestic well and, after the transfer, disallowing further perfection of domestic rights in the same well.

Currently, there is a limited market for the purchase of domestic water rights, since anyone can obtain one through a permit application. But if the State Engineer or a court were to prohibit new domestic wells in fully appropriated basins or limit the amount of water that can be used pursuant to a domestic well permit, a more active market for domestic water might develop.

Another option being explored in the region is improving existing mutual/community water systems. There are no significant legal obstacles which would limit the ability to improve existing systems.

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

Additional groundwater supplies can be obtained from most of the sub-basins in the planning region for a significant, albeit finite, period of time. Table 2 provides population, groundwater inflows and outflows, net groundwater use (groundwater pumping minus return flow), and groundwater in storage for the sub-basins in the planning region. Available volumes of groundwater in storage are clearly enormous compared to existing uses, but as discussed in Sections 2 and 4, this water cannot be pumped without obtaining water rights and offsetting the resulting depletions to the Rio Grande and its tributaries.

Table 2. Groundwater Budget by Sub-Basin
Jemez y Sangre Water Planning Region

Sub-Basin	Year 2000 Population [a]	Inflow [a] (ac-ft/yr)	Outflow [a] (ac-ft/yr)	Change in Storage [a] (ac-ft/yr)	Net Groundwater Use [a,b] (ac-ft/yr)	Groundwater in Storage in Top 1,000 Feet of Sediment (ac-ft)	Major Well Field in Sub-basin
Velarde	4,870	8,835	8,663	172	278	9,570,000	---
Santa Cruz	19,481	10,650	12,516	–1,866	2,366	5,460,000	---
Santa Clara	4,870	5,120	5,111	9	271	5,430,000	---
Los Alamos	19,481	4,400	6,612	–2,212	3,832	11,020,000	Los Alamos Well Fields
Pojoaque-Nambe	6,494	13,730	14,118	–388	878	3,970,000	---
Tesuque	4,870	8,615	8,944	–329	574	2,930,000	---
Caja del Rio	0	4,700	8,643	–3,943	4993	10,160,000	Buckman Well Field
Santa Fe River	87,666	14,835	12,039	2,796	2094	9,260,000	City Well Field
North Galisteo Creek	11,364	2,580	4,211	–1,631	1,401	0	---
South Galisteo Creek	3,247	6,655	7,225	–570	330	0	---

[a] Source of information: Jemez y Sangre Water Planning Council, 2001.
[b] Groundwater diversions minus return flows.

ac-ft/yr = Acre feet per year
ac-ft = Acre feet

--- = No major well field present in the sub-basin

6. Environmental Implications

As with any construction project, ground will be disturbed. For municipal and domestic wells, the drill rig must have access or easement with enough room for support trucks and equipment. Any projects that include federal funding must conform to the National Environmental Policy Act of 1969 (NEPA) to consider the environmental impacts of the action; such compliance may involve environmental impact statements and endangered species evaluation.

All wells must be sited to avoid contaminated groundwater or surface conditions. The well must be properly constructed to minimize the potential for surface contaminants travelling through the borehole to the water table. The site will need to be located such that the well is protected from flooding, surface contamination, and vandalism.

By lowering the local water table, flows of streams and springs may be reduced or stopped entirely. This condition may cause perennial streams to become ephemeral and local springs to dry up. The implications are not only aesthetic but may impact natural habitat and threatened or endangered species.

7. Socioeconomic Impacts

The drilling of new municipal wells, which would require a transfer of water rights, may cause socioeconomic impacts in the location the water is transferred from. The impacts of water rights transfers are discussed further in another paper (DBS&A, 2002).

Managing well fields to optimize the number, sizes, depths, pumping rates, and locations of municipal/industrial water supply wells would have the socioeconomic benefit of increasing available wet water over the long term. And because such increases would be limited by existing water rights, well field optimization would have no direct significant impact on upstream rural water users and existing water right owners. Using up groundwater supplies would have the indirect impact, however, of increasing the desire for and pressure on upstream rural and agricultural surface water rights to support municipal and industrial needs, once local groundwater supplies are depleted.

Depending on the expense and financing of well field development, the alternative might also have the short-term benefit of reduced water costs for all users. In addition, well field management will help prevent land subsidence and the concomitant damage to buildings and irreversible damage to the aquifer due to the compaction of the aquifer material.

Conversely, installing new domestic supply wells, although increasing available water, would result in greater water use that would diminish groundwater supplies more quickly. Increasing supply through the drilling of domestic wells usurps the water rights process and does not protect senior water rights users in the region. As a result, the long-term socioeconomic and cultural impacts would be contrary to the collective public welfare and contrary to conservation. Socioeconomic and cultural benefits might result from improving existing mutual/community water systems, if those improvements translated into greater efficiency and conservation.

8. Actions Needed to Implement/Ease of Implementation

Management of the aquifer in the region requires a region-wide approach, with input from all stakeholders. With a common understanding of the aquifer conditions—that is, a region-wide model that is supported by all entities—the planning council can better understand the impacts of current stresses on the aquifer and determine better ways to manage the resource. Accordingly, the recommended next steps are:

- Develop a region-wide, ongoing comprehensive groundwater assessment, culminating in a hydrogeologic model for use as a management tool.

- Seek improved and better defined administrative guidelines from the OSE.

- Establish improved planning and zoning guidance at the local (i.e., county) level to incorporate protection of groundwater quality and quantity.

- Evaluate groundwater conditions from a regional perspective that is coordinated around sub-basins.

- Develop an approach to managing new domestic wells in the region.

The steps involved in installing a single new well or expanding a well field are:

- Assess water rights (obtain new ones or alter existing ones)
- Design and site new wells
- Install and construct new wells, including required conveyance systems
- Perform water quality and pump testing

Groundwater modeling may be required to determine optimum locations for new wells.

9. Summary of Advantages and Disadvantages

The advantages of expanding well fields are:

- Relatively quick increase in water supply from new wells
- Proven technology/approach
- Potential shortening of the distance from diversion to user
- Potentially lower operational costs due to more efficient wells
- Potentially increased production through replacement of old wells with better designed wells
- Reduced vulnerability during drought periods
- Inevitable requirement in the future
- Widespread treatment of water quality problems (i.e., removal of naturally occurring arsenic and uranium) through regional well fields

The disadvantages of well field expansion include:

- Increased mining of the aquifer
- Potential water quality problems in expansion areas
- Expense
- The necessity to obtain additional water rights or transfer points of diversion for existing rights
- Potential negative impacts on perennial stream reaches, lowering flow and possibly making them ephemeral
- Additional operation and maintenance costs for greater number of wells
- Interference among wells and lowering of the water table
- Potential land subsidence as aquifer is significantly dewatered
- Potential impairment of senior water rights by large number of domestic wells
- Potential irreversible damage to the aquifer due to lowering of water levels in the aquifer
- Difficulty of removing trace constituents (arsenic and uranium) in individual domestic wells

References

Alley, W.M., T.E. Reilly, and O.L. Franke. 1999. *Sustainability of ground-water resources.* United States Geological Survey Circular 1186, 79 p.

American Water Works Association (AWWA). 1997. *Standards for water wells, American National Standard.* AWWA No. A100-97.

Daniel B. Stephens & Associates, Inc. (DBS&A). 1994. *Santa Fe County water resource inventory. Volume 1: Text and plates.* Prepared for Santa Fe County Land Use and Planning Department, Santa Fe, New Mexico. July 13, 1994.

DBS&A. 2002. *Alternative: Purchase surface water rights in the marketplace.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Duke Engineering & Services (DE&S). 2001. *Water supply study, Jemez y Sangre water planning region, New Mexico.* Prepared for Jemez y Sangre Water Planning Council.

Driscoll, F.G. 1986. *Groundwater and wells.* Second edition. US Filter/Johnson Screens, St. Paul, Minnesota.

Hantush, H.S. 1964. Hydraulics of wells. Pages 281-433 *In* Chow, V.T., (ed.) *Advances in hydroscience.* Academic Press, New York.

Jemez y Sangre Water Planning Council. 2001. *Presentation of water supply assessment and populations projections.* February 2001.

Kelley, V.C. 1978. *Geology of the Española Basin, New Mexico.* New Mexico Bureau of Mines and Mineral Resources Geologic Map 48, scale 1:125,000.

Roscoe Moss Company. 1990. *Handbook of groundwater development.* John Wiley & Sons, New York, New York.

U.S. Environmental Protection Agency (U.S. EPA). 1975. *Manual of water well construction practices.* EPA-570/9-75-001.

White Paper 14

Alternative: Bank Water

Alternative: Bank Water

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Dominique Cartron (primary author), Susan C. Kery (legal), and Bonnie Colby (socioeconomic).

1. Summary of the Alternative

Water banking generally refers to a means of reallocating or transferring the use of water through some kind of centralized management entity. Rather than trying to find buyers or lessees for a particular water right, water rights holders "deposit" their water right in a "bank," which then leases the water right to a third party. The water rights holder is protected from forfeiture of the water right and benefits from revenues obtained for use of the water by a third party.

For example, a farmer could deposit his or her water right in a local water bank (run by an irrigation or conservancy district or by the New Mexico Office of the State Engineer [OSE]). Simultaneously, water users in need of additional water rights could apply to the water bank to lease water for a specific period of time and use. Using databases and other management tools, the water bank would be able to match the amount and location of the farmer's deposits with appropriate users and then set up leases with those users to reallocate the farmer's water rights deposited with the bank. The farmer would then cease irrigating the land appurtenant to those water rights.

In the West, water banking is increasingly used for allocation of scarce water resources. Texas, Arizona, and Idaho, among others, all have state water banking statutes and operational water banks. Many times, water banking serves as a transfer mechanism from agricultural water use (where water is available) to urban water uses (where water is in demand). Alternatively, water banks are used as a management tool to address drought. For example, the state of California has set up the California Drought Water Bank.

New Mexico does not have a comprehensive water banking statute. Water banking legislation has been introduced in several legislative sessions but has yet to pass. Although there is varying opinion about current water mechanisms, irrigation and conservancy districts may have *de facto* water banks in that water can be shifted to various lands within the districts. However, the water use remains agricultural and therefore this mechanism cannot satisfy urban demand for agricultural water. The Middle Rio Grande Conservancy District has drafted water banking rules that would allow a transfer from agricultural to urban uses outside the district. However, these rules have not been endorsed by the OSE, and no water transfer from within the district to entities outside the district has occurred.

Water banking could serve as an efficient and timely mechanism to address short-term water management issues. In New Mexico, however, it is uncertain how quickly a water banking transaction could occur given the requirement that changes in points of diversion and purpose and place of use require OSE approval. These transactions require notice and provide water users the opportunity to protest, which can greatly delay the process. Nevertheless, the notice requirement and opportunity to protest afford scrutiny of the impact of the water transaction on other users in the region.

Water banking in the Jemez y Sangre region could address the need for short-term reallocation of water during water shortages. Areas hardest hit by drought could turn to subregions or neighboring regions for short-term water supplies. Longer-term issues such as population growth and the accompanying increase in demand may best be addressed through long-term water rights sales or leases. Therefore, this alternative is considered as a potential component of a drought management plan rather than a method to provide new supply to meet growing demand.

2. Technical Feasibility

The primary issues determining the feasibility of water banking are the financial feasibility, legal feasibility, and socioeconomic impacts resulting from the transfer of water among users. Technical considerations associated with this alternative center around the ability to physically transfer water from one or more points of diversion or places of use to other locations. Potential transfers of water are easier if the recipient has an operational diversion structure from the same hydrologic system as the original water use. Thus water banking within irrigation and conservancy districts, with their limited geographical extent and shared distribution system, will generally not encounter any significant technical issues.

When water is transferred over a greater distance, such as from an irrigation district or acequia to a more distant urban area, not only is there a potential problem with physically obtaining the water, but the issue of impairment arises as well. New Mexico water law requires that transfers of water do not impair existing users. When transfers of water are made, protestants and the OSE may conduct technical analyses, including modeling, to evaluate the impact on other water rights holders. Thus the primary technical issue with establishing a water bank that serves users across different hydrologic systems is the determination of how potential impairment will be evaluated and/or monitored and still allow the transfers to occur in a timely manner.

3. Financial Feasibility

Establishing a water bank, either within the OSE or by creating an entity with the legal authority to manage the water bank, will require startup funding as well as funds for annual operational costs, including salaries and equipment. An administrative water bank would require few, if any, large infrastructure costs. Costs will increase significantly if additional diversion structures or storage facilities are needed.

Startup costs include public and stakeholder participation to define the bank's mandate and powers and to obtain technical expertise adequate to assess the effects of proposed transfers in the region in which the bank operates. For water purchases, informational costs often are borne by the buyer and/or seller. However, for temporary transactions, the net economic returns are not usually large enough to support sophisticated modeling and data gathering. Low costs and swift results are necessary to ensure success of a water bank. To this end, the bank will need to develop some mechanism (such as a state-of-the-art web site) that allows potential transactors to obtain information, to offer and bid for water, and to have their questions answered.

Given the high price for water in the Jemez y Sangre area, it may be possible to generate sufficient revenues through fees and costs imposed on the water transactions managed by the water bank. Two types of fees could be structured: (1) annual membership fees to participate in the bank (membership would confer voting privileges regarding bank policies), and (2) specific fees levied when transactions occur. Should the region choose to pursue creation of a water bank within the OSE, a legislative initiative to increase the OSE budget may be one way to cover the cost of the program.

4. Legal Feasibility

Although New Mexico passed a water banking statute in 2002, that statute is limited to the reach of the Pecos River below Sumner Dam, and New Mexico still has no comprehensive water banking statute. However, several statutory provisions in New Mexico can currently be utilized to some extent to allow water storage without fear of forfeiture. While these statutes allow for water transfer and storage, they do not provide an efficient transfer mechanism as would a water bank.

A statutory provision which helps encourage but does not specifically provide for water banking is the statutory exemption that allows certain water rights to go unused without being subject to forfeiture. This statute (NMSA 1978, §72-5-28(G)) provides that periods of non-use when water rights are acquired and placed in an OSE-approved water conservation program—by an individual, acequia or community ditch association, conservancy district, irrigation district, soil and conservation district, or the Interstate Stream Commission—shall not be computed as part of the four-year statutory forfeiture period. This provision gives the stated entities the incentive to conserve by ensuring that any saved water will not be subject to forfeiture. Thus, this is the mechanism used by the Interstate Stream Commission to lease water rights in order to increase surface water flows on the Pecos River.

Conservancy districts are also protected from forfeiture of conserved or banked water through NMSA 1978, §73-14-47(F). This provision states that "[w]here the district acquires . . . water or water rights, or where it conserves, develops or reclaims water, it shall have the rights which go with the appropriation and beneficial use thereof . . .. Conservation or reclamation of water by the district is hereby declared to be an appropriation thereof by the district, and the disposition thereof under the terms of this act is hereby declared to be a beneficial use thereof by said districts and by the lands included therein."

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

Water banking would not change the overall amount of water available in the region (unless neighboring regions deposited water in the bank). However, it would address short-term allocation problems and streamline the water transfer process. A successful water bank would facilitate water management in the region.

6. Environmental Implications

Water transfers from one location and use to another could have environmental and aesthetic impacts. For example, agricultural areas tend to attract wildlife and support surrounding vegetation and habitat as opposed to the urban environment. In addition, reduction in surface flows of water and in groundwater levels due to water withdrawals that without water banking would not have occurred can directly affect the health of riparian ecosystems.

7. Socioeconomic Impacts

The water bank transactions discussed in this analysis are temporary transfers of water from irrigation use to municipal or industrial uses. Socioeconomic impacts of permanent transfers are examined under the *Purchase Surface Water Rights in the Marketplace* alternative (DBS&A, 2002).

The primary advantage a regional water bank can provide is to arrange water transfers with lower costs, better use of technical information, and fewer procedural and political obstacles than parties can accomplish in transferring water on their own. To accomplish this, a water bank requires political buy-in from local governments and water user organizations and needs to establish a reputation for effective water management and for fairness in dealing with diverse stakeholders.

The nature and magnitude of socioeconomic impacts depend on the size and duration of the change in water use. A short-term lease that involves a small proportion of the water typically used for irrigation in the subregion from which the water is being leased will have little negative impact of any type. Given that transactions are arranged through voluntary negotiations, the price paid to lease the water will necessarily exceed its economic and cultural value to the irrigator. However, there may be impacts on the viability of local agriculture and on local communities in the sub-basin from which the water is being transferred. If the amount of water leased represents a small portion of irrigation use in the area, those impacts will be negligible. For the recipient of the banked water, the economic benefits of short-term transfers can be substantial, especially if such transfers prevent significant economic dislocation due to lack of water during a drought or other crisis.

To reduce transaction costs and to mange conflicts that arise when water is proposed to be transferred, the bank will need clear guidelines (consistent with OSE) regarding the types of transfers it will facilitate and the circumstances under which third-party compensation will be warranted. To help reduce local government opposition to water transfers out of their jurisdiction, compensation mechanisms could be established for losses in local property tax or sales tax payments when the transactions causes a reduction in property value or in local economic output. The bank also could require compensation to cover transaction fees and any increased costs created by the transfer for acequias or community ditch associations.

Acequia interests have long been opposed to a statewide mechanism for water banking. Moving water rights, even temporarily, outside of their local watershed or area of origin would likely result in negative impacts to community ditch systems and important associated socioeconomic and cultural values. There is also a concern that statewide water banking would open the door for more aggressive acquisition of community water rights on the open market. Acequias are vital both as a sustainable irrigation system for subsistence and market agriculture and also as part of the social glue that holds together rural communities. Planners should consider the fact that acequias and other local traditions are critical not only for the continuity of rural culture and communities, but also for the local tourism industry, which is built in large part upon the unique cultural and historical personality of the region.

Regional acequia associations have proposed smaller, localized water banking systems that would allow transfers of temporarily unused water rights only within a local watershed or area of origin. Local water banks, equitably controlled by local water right owners, would minimize potential socioeconomic and cultural impacts, as well as the environmental impacts outlined in Section 6. However, allowing only local transfers could limit the bank's ability to move water to high-demand uses, and in years when insufficient water is available to grow a crop, temporary leases of water rights for municipal uses can have significant financial benefits for acequias. Such leases would also allow municipalities to avoid severe drought restrictions and their economic consequences.

Acequia representatives have indicated that before they will support any further discussion of water banking, they would like the following protections to be in place:

- Area of origin protection against adverse effects on local communities
- Recognition of Acequia authority to veto a water transfer out of the Acequia
- Establishment of Acequia authority to create local water banks
- Development of a public welfare statement to address water transfers

8. Actions Needed to Implement/Ease of Implementation

To initiate water banking-type transactions, the Jemez y Sangre Water Planning Council could pursue several actions:

- Investigate whether "functional" water banking in other areas of the state (Pecos Valley) would actually apply to the Jemez y Sangre area or whether those water banks are unique as a result of court-ordered adjudication or settlements.

- Identify whether existing entities in the region (acequias) could operate a water bank (whether they have legal authority). If they cannot, identify what type of entity should be created and how to proceed.

- Use the Ground Water Storage and Recovery Act (Section 4) to its maximum potential.

- Determine if water is available for storage pursuant to the Ground Water Storage and Recovery Act.

- Advocate the expansion of NMSA 1978, §72-5-28(G) to allow water planning regions to acquire and place water rights in an OSE-approved water conservation program, thus providing the regions with the incentive to conserve by ensuring that any saved water will not be subject to forfeiture.

- Determine whether a sound regional water plan would require a type of water banking not available or permitted through the existing statutory scheme.

- Study the implications of the passage of a comprehensive water banking bill for New Mexico, including whether the passage of such legislation could occur prior to the implementation of a regional water plan, and investigate other ways of assuring that “wet water,” rather than waterless water rights, is the currency of exchange in the water bank.

9. Summary of Advantages and Disadvantages

Advantages of water banking to the Jemez y Sangre region are:

- Regional water banks could provide much-needed flexibility for managing water use and allocation during drought.

- Water banking could facilitate water transfers to meet future demand, although if adequate protections are not in place, such facilitation could potentially have a negative impact on the areas that the water is transferred from.

Water banking could have negative socioeconomic impacts to certain areas of the region unless it is conducted with rigorous technical and administrative oversight and political support from all affected areas.

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Purchase surface water rights in the marketplace.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

MacDonnell, L.J., C.W. Howe, K.A. Miller, T.A. Rice, and S.F. Bates. 1994. *Water banks in the West.* University of Colorado Natural Resources Law Center, University of Colorado School of Law, Boulder Colorado.

U.S. Office of Technology Assessment. 1993. *Preparing for an uncertain climate.* OTA-O-567, Government Printing Office, Washington, D.C. http://enso.unl.edu/ndmc/mitigate/policy/-ota/demand.htm#reallocate.

White Paper 15

Alternative: Purchase Surface Water Rights in the Marketplace

Alternative: Purchase Surface Water Rights in the Marketplace

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Dominique Cartron (primary author), Susan C. Kery (legal), and Bonnie Colby and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

Purchasing or entering into long-term leases for native Rio Grande water rights is an option that could help some water suppliers in the Jemez y Sangre region meet growing demand by transferring water from one sector to another. Water rights purchases generally involve at least a permanent transfer from one owner to another and in many cases involve a change in location and/or purpose of use. Other transfers can be more temporary and may take the form of a lease.

The feasibility of purchasing water rights to meet future demand is influenced by the locations of the move to and move from diversions and places of use, the number of willing sellers, and administrative limitations created by the New Mexico Office of the State Engineer (OSE). In particular, the market for surface water rights purchases is limited by the OSE restriction on moving the point of diversion for water rights from above the Rio Grande Compact's measuring gage at Otowi (located in the central part of the Jemez y Sangre region) to points of diversion below the Otowi gage and vice versa (part of the region is above the Otowi gage). One ramification of this restriction is that water rights below the Otowi gage may have a significantly higher price because the demand for those rights will be very high due to future growth in this part of the region. In the portion of the region above the Otowi gage, prices may not be quite as elevated if the restrictions continue.

One way to minimize this limitation may be to purchase water rights with above-Otowi gage diversion points (i.e., not change the point of diversion), but move the place of use to a point below the gage. The New Mexico legislature passed a memorial in 2001 stating that the place of use could not move below the latitude of the diversion point. Although the memorial has no legal weight, the OSE could consider the memorial to be a statement of public welfare, which could serve as a basis for denying a transfer application. Additional discussion of transfers across Otowi gage is provided in a separate paper (DBS&A, 2002).

2. Technical Feasibility

Because the availability of water rights for sale or lease is extremely limited at the present time, this alternative may not be viable in the short term (it can take up to one year to locate water rights for willing buyers). At some point, demand may drive the price of water rights sufficiently high that owners will sell their water. A standing offer program coordinated among municipalities might be an effective mechanism for attracting sellers. Such a program could be coordinated with a regional water bank.

If surface water or groundwater rights are purchased, an application must be filed with the OSE to transfer the point of diversion and/or place of use and/or purpose of use. Other water users will have the opportunity to protest that application. Technical analyses regarding the hydrologic effects of transferring the point of diversion or place of use may be required.

In most cases the transfer will be to an existing well or surface diversion. There should be no significant technical obstacles to the installation of routine surface water diversions or new wells, as the design and construction techniques for these facilities are well developed. Conversely, as discussed in Sections 6 and 7, environmental or socioeconomic obstacles may arise if a new surface or groundwater diversion needs to be installed.

This alternative has the potential to increase the supply available to meet growing demand by either transferring water rights from an existing agricultural use within the region or from areas to the north or south of the Jemez y Sangre water planning region, yet within the State of New Mexico.

3. Financial Feasibility

Purchasing water rights is generally a far less costly strategy for increasing water supplies than new supply development, which commonly requires construction of reservoirs and conveyance structures in addition to the expensive environmental documentation necessary to comply with the National Environmental Policy Act and the Endangered Species Act. However, the existing infrastructure, particularly in the Santa Fe subregion, is insufficient to deliver water rights presently held. Therefore, new infrastructure will likely be required to accommodate any large purchase of water rights.

While water rights prices vary according to many factors, such as priority date and location relative to the Otowi gage, some water rights in the Pojoaque Valley have sold for as much as $20,000 per acre-foot of consumptive use. This price would not include additional transaction and procedural costs—such as retaining legal and technical expertise, complying with OSE requirements, responding to protests—and, should the transfer require additional diversion structures, engineering costs. Combined legal and technical studies to obtain OSE approval could possibly be completed for $100,000 to $200,000; however, if extensive modeling is required and/or contested legal issues are present, implementing this alternative could cost up to $1 million or more.-

Sources of public financing for water rights purchases are available to the region. The New Mexico Legislature created the Water Trust fund with the goal of financing water projects to help meet New Mexico’s water requirements. Although long-term financing for the fund is uncertain, it could potentially be a long-term source of financing for these types of transactions. Additionally, state or federal line-item appropriations offer another vehicle for financing at least part of the water rights purchase.

The new local option Capital Outlay gross receipts tax (GRT) for which both the City and the County of Santa Fe are eligible (and the County has passed), provides a mechanism to fund the purchase of water rights. This GRT has the potential to provide up to $80 million in bonding authority. Counties and municipalities that are not eligible for this tax have other GRT authority they can use. General Obligation bonds also provide substantial bonding capacity in the region if the political will or public support exists. Other mechanisms that can be used by water purveyors to fund the purchase of water rights include impact fees and user fees.

4. Legal Feasibility

The process for transferring surface water rights is an administrative process governed by NMSA 1978, §§72-5-22 through 24 and will only be approved by the State Engineer upon application, after notice and publication, and if such transfer will not impair existing water rights, be contrary to the conservation of water, or be detrimental to the public interest. One noteworthy restraint on transfer is the State Engineer's policy of not allowing transfers across the Rio Grande Compact's measuring gage at Otowi Bridge, as discussed in Section 1. In addition, not all water rights in the region have been adjudicated, which means that priority dates and amounts of certain water rights are not clear.

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

This alternative would increase water rights for individual purchasers. By having additional water rights, water providers will be better able to meet demand. If available, water rights could be purchased from areas outside of the Jemez y Sangre water planning region to serve sub-basins below the Otowi Gage. For sub-basins above the Otowi gage, water rights, if they are available, could be transferred within the Jemez y Sangre region or outside of it, up to the Colorado state line.

The amount of water that could be obtained from this alternative is dependent on the amount of water consumed by the crop (not diverted) and the amount of acres presently irrigated. The amount of water consumed by each acre of irrigated land varies depending upon the consumptive irrigation requirement (CIR) and the incidental depletions (ID). For most of the irrigated acreage in the Jemez y Sangre water planning region, approximately 3 acre-feet are diverted for every acre irrigated. However, only about 1 to 2 acre-feet per acre are consumptively used (CIR+ID), with an average for the region of 1.3 acre-feet per acre. Because the irrigated acreage may not have received a full supply historically, the water right that may be transferred is likely to be reduced by 40 to 50 percent. A total of 19,627 acres are irrigated in the Jemez y Sangre region (Duke, 2001) with a consumptive use of approximately 25,000 acre-feet. If the historical availability is only 50 percent, then the amount of water to be gained by this alternative would be about 12,700 acre-feet per year.

6. Environmental Implications

The purchase and transfer of water rights may change river flows locally, depending on the locations of diversions and return flows (these impacts are greatest for water rights transferred from downstream to upstream on the Rio Grande), and changes in flows could affect the riparian ecosystem. Although users in the system have the opportunity to protest if the flows are so altered that their water rights are affected, the protest mechanism has not traditionally been geared toward preventing damage to aquatic species and riparian habitat. In fact, the OSE has allowed certain river reaches in New Mexico to be entirely depleted to fulfill water rights. Thus changes in points of diversion so that water is diverted in places it previously had not been diverted could negatively impact the riparian habitat and aquatic species in that reach.

In addition, transfers from agricultural to urban uses can reduce the amount of greenspace and wildlife habitat that occur around flood-irrigated fields.

7. Socioeconomic Impacts

Surface water right purchases can be structured in differing ways to minimize potential economic impacts linked to changes in water use. For instance, water needed for future urban growth can be purchased by a municipal provider and then leased back for continued use in irrigation until needed for new uses. This practice, however, can lead to an erosion of the rural community before the impacts are actually felt, which if perceived, might prompt local actions to retain water within the area of origin. Water purchases can also be structured as dry year options in which the water is used in irrigation except during dry years when urban supplies are short.

The Jemez y Sangre region has subregions that are defined by traditional agricultural communities. These areas could be negatively impacted if large amounts of water are transferred away from agricultural uses.

Permanent transfers from agricultural use can decrease revenues from crop sales and may affect jobs (and cultural values) linked to irrigated lands. Although urban uses of water generate higher levels of local economic output and employment than agricultural uses, rural households may be located too far for convenient commuting to off-farm jobs. Nevertheless, irrigated agriculture in the region is primarily small-scale and generally provides only part-time and seasonal employment. Most households with irrigated land earn the majority of their household income from off-farm jobs, and these households may experience better off-farm income opportunities as a result of water transfers to urban uses.

In the Jemez y Sangre region, community and cultural effects of surface water transfers may be of more concern than direct effects on rural jobs and household income. Those water providers seeking to acquire surface water rights could consider establishing guidelines for circumstances under which they would pay third-party compensation. Such voluntary compensation practices may reduce conflicts and thus reduce the costs of implementing water transfers. For instance, a water provider could compensate for losses in local property tax or sales tax payments if a water transfer causes a reduction in property values or in local economic output. Municipal water providers also could adopt a policy of covering fees and any increased costs created by the transfer for acequias and community ditch associations.

Given high regional prices for surface water rights, and depending on the financial mechanisms used to pay for purchases, increases in municipal water rates may be necessary. Municipal water supply authorities could incorporate higher water rates into a pricing structure that would include conservation incentives.

Socioeconomic obstacles will likely arise from the transfer of water rights, particularly if the transfer is to a point of diversion outside of the area of origin or to a point across the Otowi gage. Acequia interests have long been opposed to the transfer of water rights, even temporarily, outside their local watershed if the transfer would likely result in negative impacts to community ditch systems and important associated socioeconomic and cultural values. Acequias are vital both as a sustainable irrigation system for subsistence and market agriculture and also as part of the social glue that holds together rural communities. Planners should consider the fact that acequias and other local traditions are critical not only for the continuity of rural culture and communities, but also for the local tourism industry, which is built in large part upon the unique cultural and historical personality of the region.

Regional acequia associations consider transfers of temporarily unused water rights within a local watershed or area of origin as acceptable. Local exchange of water rights, equitably controlled by local water right owners, would minimize potential socioeconomic and cultural impacts, as well as the environmental impacts. However, allowing only local transfers does not address the need to move water to high-demand uses in other locations.

Acequia representatives have indicated that before they will support any further discussion of purchasing surface water rights, they would like the following protections to be in place:

- Area of origin protection against adverse effects on local communities
- Recognition of Acequia authority to veto a water transfer out of the Acequia
- Establishment of Acequia authority to create local water banks
- Development of a public welfare statement to address water transfers

8. Actions Needed to Implement/Ease of Implementation

Should the Jemez y Sangre planning region choose to purchase surface water rights on the marketplace, several actions are needed:

- Conduct a regional water rights pricing study to assist planners with predicting future costs associated water rights acquisitions for future growth.

- Determine whether the OSE would allow a change in place of use from above to below Otowi gage.

- Identify water rights available for purchase in the marketplace.

- Allocate adequate funds for the purchase of water rights.

- Identify points of diversion for any newly acquired rights.

9. Summary of Advantages and Disadvantages

The advantages of purchasing surface water rights include:

- Water rights are secured for future urban use and urban quality of life.
- Bringing in water from areas outside the region does not impair local cultural resources within the region.

Some disadvantages may be:

- Lack of water available for purchase on the market

- Impacts to traditional communities in the upper portion of the planning region due to transfers from agricultural use

- Further degradation of riparian systems if water right is transferred upstream.

- Water supply is vulnerable during periods of drought as compared to a groundwater supply.

References

Colby, Bonnie G. 1990. Transactions cost and efficiency in western water allocation. *American Journal of Agricultural Economics* 72(1990):1184-1192.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Transfer water across Otowi Gage.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

White Paper 16

Alternative: Utilize San Juan-Chama Project Water

Alternative: Utilize San Juan-Chama Project Water

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Dominique Cartron and Rob Leutheuser, Leutheuser Consulting (primary authors), Alletta Belin (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

The objective of this alternative is to beneficially use, within the Jemez y Sangre water planning region, all of the 10,835 acre-feet of the San Juan-Chama (SJ-C) project water collectively contracted by governmental entities in the region. These entities are the City and County of Santa Fe, San Juan Pueblo, Los Alamos County, Pojoaque Valley Irrigation District, and the City of Española.

Authorized by Congress in 1962, the SJ-C Project brings Colorado River Basin water from the San Juan Mountains in southwestern Colorado across the continental divide and into the Rio Grande Basin of northern New Mexico. A series of diversion structures and tunnels operated by the U.S. Bureau of Reclamation diverts water from three tributaries of the San Juan River and delivers it for storage in Heron Reservoir located on Willow Creek just above its confluence with the Rio Chama. The SJ-C Project is a participating project of the Colorado River Storage Project and provides a little less than 7 percent of New Mexico's share under the Upper Colorado River Compact. Authorized uses for the 96,200 acre-feet of the annual firm yield of the SJ-C Project is to provide water for irrigation, municipal, domestic, and industrial uses in the Rio Grande Basin above Elephant Butte Reservoir. SJ-C Project water also provides incidental recreation and fish and wildlife benefits.

The other SJ-C contractors, all outside of the Jemez y Sangre region, are City of Albuquerque, Middle Rio Grande Conservancy District, Jicarilla Apache Nation, Town of Belen, Town of Bernalillo, Village of Los Lunas, Town of Red River, Town of Taos, and Village of Taos Ski Valley. An additional 2,990 acre-feet is allocated, but currently uncontracted, to the Taos area. An additional 5,000 acre-feet is authorized to compensate for evaporation losses from the permanent recreation pool in Cochiti Reservoir.

Currently, the Pojoaque Valley Irrigation District (PVID), the City of Española, and the City of Santa Fe are the contractors within the Jemez y Sangre water planning region that have the means to use their SJ-C Project water. The New Mexico Office of the State Engineer (OSE) directs the release of contracted water to offset calculated effects of pumping on the Rio Grande by the Cities of Española and Santa Fe. Consumption by the PVID on the Pojoaque River and tributaries is offset by exchange in accordance with calculations performed by the U.S. Bureau of Reclamation as approved by the Rio Grande Compact Commission. The City of Santa Fe has at times, when Article VII of the Rio Grande Compact is in force, stored some of its SJ-C water by exchange with Santa Fe River water in the Santa Fe River Reservoirs. That water was then directly consumed upon release. Article VII of the Compact prohibits the City from increasing the storage of Rio Grande water in those reservoirs whenever Usable Water in Rio Grande Project storage falls below 400,000 acre-feet. Contractors in the region have, on occasion, leased SJ-C water to the Bureau of Reclamation or water users in the Middle Rio Grande.

This alternative, therefore, would consist of various projects to actively divert and deliver water to users in the region, thereby increasing the water available for use within the region. The SJ-C contracts are for a total of 10,835 acre-feet to be used consumptively; consequently, projects that can result in 100 percent consumptive use of the SJ-C waters are considered.

Diversion of the SJ-C waters for use within the region would alter Rio Grande flows, especially between points of diversion and points where return flows discharge to surface water. If return flows are credited only for groundwater recharge and are therefore not discharged to the river, then flows in the Rio Grande will diminish.

2. Technical Feasibility

Table 1 summarizes SJ-C contractors within the Jemez y Sangre region, the annual amount of water under contract, and the type of contract with the Bureau of Reclamation. Contractors with a water service contract are presently in the National Environmental Policy Act (NEPA) process of converting their contracts to a repayment contract.

Table 1. San Juan-Chama Project Water Contractors in the Jemez y Sangre Water Planning Region

Contractor	Contract Amount (acre-feet per year)	Type of Contract	Year of Renewal
City/County Santa Fe	5,605	Water service	2016
San Juan Pueblo	2,000	Repayment	none
Los Alamos County	1,200	Water service	2017
Pojoaque Valley Irrigation District	1,030	Repayment	none
City of Española	1,000	Water service	2017

SJ-C contractors have three options to use their contracted water: (1) directly (or in the case of infiltration galleries, indirectly) divert the water, (2) use SJ-C water to offset the effects of groundwater pumping where a hydrologic connection between the well field and the Rio Grande exists, or (3) exchange SJ-C water for use of native water at another location. All three options are technically possible, as discussed in Sections 2.1 through 2.3.

2.1 Direct Diversion of San Juan-Chama Water

Direct diversion of SJ-C water is technically feasible, although at this time no contractors are directly diverting Project water from the Rio Grande. The San Juan Pueblo does have irrigation diversion dams in place that could be used in the future but has not yet diverted any SJ-C water.

New diversion could be accomplished by construction of a diversion dam on the river, whereby surface water would be directly diverted, or by constructing infiltration galleries or horizontal collector wells under the bed of the river, which would in effect “pull” the river water through the river substrate. A pilot gallery horizontal collector well has been installed on San Ildefonso Pueblo land and is currently being evaluated.

The City of Santa Fe currently is actively developing plans for a project to divert SJ-C water from the Rio Grande. The City of Española has recently initiated investigations to either withdraw its contracted water directly from Abiquiu Reservoir (a form of direct diversion) and transport it to the city in a closed pipeline or divert it from the channel of the Rio Grande.

Regardless of the diversion method, extensive technical studies would be required prior to implementation of the diversion. Alternatives for diversion require modeling to evaluate options and engineering studies to evaluate options, designs, and costs. Likewise, the transport, treatment, and integration of the SJ-C water into existing infrastructures, while all technically feasible, would have to be studied.

Because municipalities generate a high percentage of effluent (50 to 60 percent) and because the SJ-C water can be 100 percent consumptively utilized, the SJ-C contractors have an opportunity to divert more than their annual allocation as long as the return flow is measured and other water right users are not impaired. Return flow credits could be obtained through any method of diverting SJ-C water.

In order to consumptively use 100 percent of the SJ-C water, the contractor must be able to prove to the New Mexico Office of the State Engineer (OSE) that 100 percent of the "delivery water" (the amount "over-diverted" to permit the 100 percent consumption) is returned to the river. If there are any exercised water rights between the point(s) of SJ-C diversions and the point(s) of return flow, significant technical issues will likely arise regarding potential impairment of others' water rights.

Where the SJ-C contractor can demonstrate that return flow will result in no loss to the system or impairment of downstream users, the SJ-C contractor will most likely be able to use all of their contracted amounts. Lined ditches or pipes may be required to manage or eliminate conveyance losses of the return flow water. If the return flow is discharged to groundwater, there will be technical issues associated with the method of groundwater recharge and, presumably, subsequent recovery.

2.2 Offset Groundwater Pumping

The technical feasibility of using SJ-C water to offset groundwater pumping is entirely dependent upon the geology surrounding the well field, which establishes the connectivity between the deep wells and the surface water system. The more porous and barrier-free the geologic material, the greater the impact groundwater pumping has on the river, in this case the

Rio Grande or the Rio Chama. The better the connectivity, the more efficient use of SJ-C water will be.

Ultimately, the OSE, through the use of hydrologic models, determines the quantitative effects of groundwater pumping on a river. For example, in the Jemez y Sangre planning region, the City of Santa Fe began using SJ-C water in 1972 to offset the effects of its groundwater pumping program on the Rio Grande. (The City leased SJ-C water from the City of Albuquerque from 1972 until 1976, when Santa Fe began diverting its own SJ-C contract water.) The pumping impacts have increased each year (2,552 acre-feet in 1999). When the practice began, it was thought that the system would be managed at an equilibrium point, that is, the entire annual allocation of SJ-C water would be used to offset the effects of pumping on the Rio Grande. This approach was thought to be an inexpensive method of using the water. However, the yield of the aquifer has been less than expected, and the City is not able to pump enough water to use its full SJ-C allocation. This shortfall, coupled with the increasingly scarce tributary water rights, has prompted the City to pursue other options for diverting SJ-C water.

Where SJ-C water is used to offset the stream impacts from an existing well field, a transfer to a direct diversion may not increase that contractor’s total supply, even though the SJ-C water would be fully utilized.

2.3 Exchange of San Juan-Chama Water for Native Surface Water

Where adequate tributary water supplies are located closer to and/or upgradient from an SJ-C contractor’s area of need, it would be technically possible to use the native water and replace it downstream, in the Rio Grande, with SJ-C water released for that purpose. The technical considerations to capture and transport the tributary water would be the same as those for diverting water from the Rio Grande, but desirable locations could reduce the costs. The lack of adequate water supplies and the likelihood of impairment of other water rights render this option unlikely.

The PVID is currently using all of its SJ-C water (1,030 acre-feet) through surface diversions, by storing Rio Nambe water in the Nambe Falls Reservoir (also constructed under the SJ-C

Project) and exchanging it for SJ-C water released from Heron Reservoir. The stored water is subsequently diverted downstream of the dam through a series of small diversions on the Rio Nambe.

Santa Fe has also exchanged Santa Fe River water for SJ-C water in 8 of the past 24 years. These exchanges efficiently utilize the SJ-C water and limited storage space available to Santa Fe. In years when Elephant Butte and Caballo Reservoirs have less than 400,000 acre-feet of Usable Water in storage, New Mexico is prevented from increasing the amount of water held in post-Compact reservoirs. Under Article VI of the Compact, New Mexico must retain in storage an amount equivalent to its accrued debit. Under Article VIII, Texas, during the month of January, may call upon the release of this debit storage sufficient to bring the amount of Usable Water in project storage to 600,000 acre-feet by March 1. These exchanges have been made not to protect post-Compact storage, but so the City could continue to use its storage space in the canyon reservoirs.

The exchange steps are:

1. Store Santa Fe River water in the canyon reservoirs and call it SJ-C water by exchange.

2. Release an equivalent amount of Santa Fe SJ-C water, including conveyance losses, from Heron or Abiquiu Reservoirs.

3. Use the SJ-C water in the canyon reservoirs to meet demand, as necessary.

3. Financial Feasibility

Costs of any new diversion, transport, and treatment systems would be significant. Estimated costs for the City of Albuquerque's San Juan-Chama Drinking Water Project, comprising diversion, treatment and treated-water transmission, is around $200 to $250 million, depending on the diversion alternative. The preliminary estimate for the City of Santa Fe's surface water diversion is $61 million. Santa Fe's estimates for the expansion of its well complex (a less feasible option due to the scarcity of additional available water rights) is $25 million and for the horizontal collector wells, $34 million.

Public financing for such structures would be required. Such financing may be obtained through various means including federal appropriations, government bonds, federal funding sources (e.g., Safe Drinking Water Act Revolving Loan Fund), and state funding sources. Funding for large infrastructure projects usually takes many years and multiple sustained efforts to obtain since many different sources are involved.

4. Legal Feasibility

Any system to divert and consumptively use SJ-C water will require an OSE permit to appropriate that water. Applicants may initiate a request to appropriate surface waters by first filing a notice to appropriate and then filing an application to appropriate (NMSA 1978, §72-5-1 (1907)). The notice is not required but establishes the applicant's priority date (which may not be relevant in the case of SJ-C water) and allows time to prepare the application. After filing a notice, the applicant has up to 3 years to file the application and still have the appropriation relate back to the filing date of the notice (State Engineer Rules and Regulations, Surface Waters, II.B (August 1953)). The State Engineer will then determine whether a permit may be issued:

> Upon the receipt of the proofs of publication . . . the state engineer shall determine, from the evidence presented by the parties interested, from such surveys of the water supply as may be available and from the records, whether there is unappropriated water available for the benefit of the applicant. If so, and if the proposed appropriation is not contrary to the conservation of water within the state and is not detrimental to the public welfare of the state, the state engineer shall endorse his approval on the application, which shall become a permit to appropriate water. (NMSA 1978, Section 72-5-6)

It is likely that other SJ-C contractors will seek a permit from the State Engineer to divert significantly more water than the amount for which they have contracted, in order to consume the full amount of SJ-C water in their contract. For example, the City of Albuquerque is seeking a State Engineer permit to divert approximately double the amount of its SJ-C contract, based on its calculations that half the water diverted will be returned to the river as wastewater return flows. In this circumstance, a contractor will, in addition to seeking a permit for a new appropriation of its SJ-C water, also be seeking a permit to divert "native" Rio Grande water and return it at a different location, where the contractor's treated wastewater effluent returns to the river system. A system that calls for diverting additional native water above and beyond the permitted SJ-C water, in order to consume all of the SJ-C water and not return any of it to the river, would require obtaining additional water rights, water rights that must be senior enough in date to provide the desired level of security. That is because all native water in the river is fully appropriated and the State Engineer would have to be assured that the proposed use of water will not impair downstream water users.

The question arises whether SJ-C contractors can assume that they will receive 100 percent of their contracted deliveries every year. Although this is a complex question that might ultimately be decided in the courts, the short answer is no. We say this even though, to date, contractors have always been able to receive the full amount of contracted water. The reason that contractors should be cautious is primarily that the SJ-C contracts allow for prorated reduced deliveries in the event of a shortage. Although the definition of shortage is currently being discussed in legal arenas, it is assumed with reason that when the SJ-C Project was authorized, and contracts subsequently entered into, "shortage" referred to hydrologic conditions in the San Juan River Basin. However, there is some contemporary thinking in different quarters that the shortages could also be associated with other needs, such as federally listed endangered species, or Native American water rights considerations. Nevertheless, SJ-C contractors may reasonably assume that they will usually receive most or all of the water for which they have contracted.

Using SJ-C water will also require compliance with the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). NEPA compliance will be required if there is any federal action involvement (e.g. funding, permits--both virtually certain). Compliance with the ESA, through the U.S. Fish & Wildlife Service, can be fully anticipated because of projects' potential direct or indirect effects on the Rio Grande silvery minnow and the southwestern willow flycatcher and their associated proposed or designated critical habitats. Depending on the outcome of the ongoing negotiations, the Middle Rio Grande ESA Collaborative Program might or might not achieve compliance with the ESA for other SJ-C water contractors.

Finally, some SJ-C contractors in the planning region have fixed-term water service contracts with an expiration date, in contrast to repayment contracts, which are in essence perpetual (Table 1). Discussions with the Bureau of Reclamation have been initiated by some of contractors in the Jemez y Sangre planning region to convert their water service contracts into repayment contracts. Such contract modifications would likewise require compliance with NEPA and the ESA. As with any action to divert and use contracted SJ-C water, a key issue will be providing assurance to the U.S. Fish & Wildlife Service that making the contracts perpetual will not jeopardize or adversely affect endangered species

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

As discussed in Section 2, there are five contractors for SJ-C water rights within the region, with a total of 10,835 acre-feet of water rights. Taking into account the current usage of SJ-C water by the PVID and the City of Santa Fe, and assuming that all of the contractors can beneficially use all of their SJ-C water rights within the region and that the City of Santa Fe continues its groundwater pumping program at its current production level, the net gain to the region's consumptive water supply would be around 7,000 to 7,500 acre-feet per year. If Santa Fe curtailed its current pumping program when its diversion project came on line, as is being anticipated, the region's net gain of consumptive water would be about 4,500 acre-feet per year.

6. Environmental Implications

The environmental implications of increasing the use of SJ-C contracted water through direct diversions would be two-fold: impacts from construction activities and modifications to the Rio Chama and Rio Grande hydrographs. Construction impacts, although they should not be minimized, usually can be fully addressed during the planning, design, and implementation phases. Many construction impacts to the environment can be avoided, and others can be minimized and mitigated. Certainly the riparian ecosystems are of special concern, and the extent of disturbances resulting from delivery pipeline construction would need to be fully addressed.

The effects on the rivers' hydrographs are more complicated. On one hand, establishing more predictable water delivery regimes down the Rio Chama and conjunctively managing the SJ-C deliveries with other water delivery activities upstream from the point(s) of diversion provide opportunities to enhance river conditions for aquatic species. However, downstream of the point(s) of diversion, the withdrawals could likely be considered a negative impact on the downstream riverine and riparian system, all the way to Elephant Butte Reservoir. Loss of streamflow and recharge to the shallow aquifer could affect riparian bosques and river function in the following manner.

- Loss of native vegetation
- Spread of exotics
- Increased risk of fire,
- Lower habitat quality for wildlife
- Alteration of ecosystem functioning

Integrated water management decisions could help mitigate these impacts.

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 acequia 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.

Though contrary to the traditional watershed-based wisdom of keeping water rights tied to the land and local area of origin, SJ-C water is nonetheless available and ought to be put to some use. The question with this bonus water is what constitutes “beneficial use” for the collective public welfare. Consumptively utilizing 100 percent of the SJ-C contract water would directly benefit all SJ-C water right holders, with the 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. Additional available streamflow would probably reduce costs for all water users. Planners should also carefully consider the public welfare and conservation benefits of utilizing SJ-C water for downstream environmental purposes, including ecosystem restoration and endangered species support.

Indirect negative impacts would include the public perception by local rural irrigators of such a great volume of water flowing past acequia headgates but unavailable to them, and public opposition to SJ-C water being strictly consumptively used rather than aiding downstream environmental concerns.

8. Actions Needed to Implement/Ease of Implementation

In order to fully use all the SJ-C Project water collectively contracted by governmental entities in the region, the following actions are needed:

- Convert SJ-C fixed-term water service contracts to perpetual contracts (if possible).

- Conduct preliminary feasibility studies of alternatives for diverting and using SJ-C-contracted water (this should be integrated into a NEPA environmental document).

- Integrate results of alternatives study into contractors' water supply plans

- Submit to OSE a notice of intent to file application and the application for permit itself, and obtain permit.

- Ensure NEPA compliance.

- Ensure ESA compliance.

9. Summary of Advantages and Disadvantages

Bringing SJ-C water into the region could significantly increase the total amount of water available to the region. However, numerous technical, legal, and environmental issues would need resolution prior to implementing this alternative.

White Paper 17

Alternative: Transfer Water Across Otowi Gage

Alternative: Transfer Water Across Otowi Gage

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Dominique Cartron (primary author), John W. Utton (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

This alternative addresses the appropriation or purchasing of water rights above the Otowi Gage for subsequent use below the gage. It is closely related to two of the other alternatives under consideration by the Jemez y Sangre Water Planning Council: Purchase Surface Water Rights in the Marketplace and Reappropriate Water Above Otowi Gage up to the 1929 Condition (DBS&A, 2002a, 2002b). Under the Rio Grande Compact, New Mexico is required to deliver a portion of the flow of the Rio Grande measured at the Otowi gage, which is located in the central portion of the Jemez y Sangre Water Planning Region. The New Mexico Office of the State Engineer (OSE) generally does not allow surface water transfers across the gage because transfers could increase the amount measured at the gage, thereby increasing the amount of water that New Mexico must deliver to Texas. San Juan-Chama water can be moved across the gage because it is excluded from Compact calculations.

This alternative addresses the issue of appropriating or purchasing additional water above the Otowi gage for subsequent diversion or use below the gage. Because movement of water between the upper and lower portion of the regions is made difficult by the Compact requirements relative to the gage, the Otowi gage represents a barrier to flexible management of water in the region. This dividing line is problematic because the storage reservoirs (where additional water obtained for the region could be stored) are located above the Otowi gage, while the areas with highest predicted growth are below the gage. Finding a way to move water across Otowi gage would provide a new supply for growing urban demand by removing it from other uses either within the region or to the north of the region.

2. Technical Feasibility

The primary technical issue in transferring water from above the Otowi gage to below the gage is obtaining the hydrologic data necessary to track the transfer of the water for OSE and Compact accounting. As part of the water rights application, the applicant would be required to demonstrate that such an appropriation would not result in impairment of other water rights. In addition, the historical availability of the water supply must be demonstrated to ensure that the "wet" water will actually reach the desired "move to" location and not provide water to meet demands on over-appropriated streams (although this is not an issue on the mainstem of the Rio Grande, it is for the tributaries). The technical studies required to support a water rights transfer application are standard studies routinely conducted by water experts in the state.

3. Financial Feasibility

Much of the cost of this alternative is associated with any application to appropriate, transfer, or lease water rights. An appropriation for groundwater would likely require a regional groundwater model to demonstrate no impairment, which if developed only for this application, could be costly. The applicant would bear the burden of paying the legal and technical consultant costs necessary to complete the application process. Combined legal and technical studies to obtain OSE approval could possibly be completed for $100,000 to $200,000; however, if extensive modeling is required and/or contested legal issues are present, implementing this alternative could cost up to $1 million or more.

Other costs associated with this alternative are likely to be related to Rio Grande Compact compliance administration. These would include the burden on the applicant to prove that moving water across the gage does not impair Compact compliance or increase the amount of water that New Mexico is required to deliver to Texas.

4. Legal Feasibility

The State Engineer's administration of water right transfers in conformance with the Rio Grande Compact (϶ 72-15-23 NMSA 1978 (1997 Repl.)) will affect the availability of water in the planning region. Under the Compact, which was agreed to by the States of New Mexico, Colorado and Texas in 1938, deliveries downstream are set under an inflow-outflow schedule. Deliveries to New Mexico from Colorado are calculated by upstream gages, pursuant to Article III of the Compact. Likewise, pursuant to Article IV, New Mexico's obligation to deliver water to the Rio Grande Project at Elephant Butte Reservoir is determined by reference to the index supply at the Otowi gage, which is located on the river at San Ildefonso Pueblo. Based on the quantity of flows measured at Otowi, the Compact establishes a delivery schedule of the amount of native flows that must be delivered to Texas at the Reservoir. (Imported San Juan-Chama water is exempt from the Compact's inflow-outflow requirements under Article X and may therefore be fully consumed anywhere in the Rio Grande Basin above Elephant Butte Reservoir.)

Because of the Otowi gage's role in determining delivery amounts, the State Engineer has a long-standing administrative practice of not permitting a change in point of diversion from one side of the gage to the other, whether permanent or by lease. Such a change would either increase or decrease flows measured at the gage, thereby altering the delivery requirement downstream unless a compensating adjustment were agreed to by the three states. In order to avoid proposing such adjustments, the State Engineer has simply treated the Rio Grande Basin below and above the gage as two distinct basins.

By contrast, the State Engineer has not expressed an official position regarding a change in the place of use of a water right from one side to the other. Therefore, piping water from a point of diversion above the gage to a place of use below the gage may be an option because an appropriator, piping water from his original point of diversion to another basin, is changing only the place of use of his water right, not the point of diversion.

Because the Otowi gage is located in the approximate middle of the Jemez y Sangre planning region, a critical question is how administration of water right transfers within, to, or from the planning region could affect water availability. Development of water resources has been, and is likely to continue to be, more significant below the gage than above as reflected by a higher price for water rights in the middle valley than on the mainstem in northern New Mexico. Therefore, it is reasonable to assume that any proposed transfer would be from above to below the gage.

Administrative prohibition of transfers across the gage has the effect of protecting against the net loss of water rights in northern New Mexico, including the planning region. Clearly, a ban on changes of points of diversion to the middle valley benefits that portion of the planning region above the gage. Although individual water right holders may not be able to market their rights to the highest bidder, the northern half of the region is likely better off because its existing water resources are not susceptible to predation by and export to the middle valley and because in acquiring additional water rights, it does not have to compete with Albuquerque and other middle valley users with their growing demands.

By contrast, the southern portion of the planning region, in particular the Santa Fe area, may have the distinct disadvantage of being in the middle valley basin or market, when points of diversion and regional distribution systems would more appropriately be located or engineered across the Otowi gage, or by a combination of diversions along the river, both above and below the gage. What may give the Santa Fe area some relief is the ability to change the place of use of a water right from above to below the Otowi gage. Under that scenario, water diverted above the Otowi gage could be piped and used south of the gage. Such flexibility would allow for distribution of water within the region where reasonably needed and would not limit the Santa Fe area to the middle valley market. On the other hand, for those not wishing to see reallocation of water within the region or within northern New Mexico generally, particularly from agricultural to municipal uses, transfers across the gage, even if limited to changes of place of use, could be troubling.

This issue has become important because the City and County of Santa Fe are actively studying the construction of a Rio Grande surface water diversion on San Ildefonso Pueblo lands north of the gage. From the diversion facility, the diverted water would be pumped and used predominantly in the Santa Fe sub-basin, which is south of the gage. Although the use of San Juan-Chama water below the gage is explicitly allowed by Article X of the Compact, the question has arisen whether the place of use of northern, native rights could be changed to the Santa Fe area, even if the diversion point remains above the gage.

Change in place of use of a surface water right is governed by 72-5-23 NMSA 1978. The statute requires that a surface water transfer applicant demonstrate that (1) the transfer will not impair existing water rights (2) the transfer is not contrary to the conservation of water within the state, and (3) the transfer is not detrimental to the public welfare of the state (϶72-5-23 NMSA 1978 (1997 Repl.)).

The nonimpairment criterion is satisfied as long as the change in place of use does not impair existing water rights within the basin. To assure such nonimpairment, the policy of the State Engineer is to approve transfer of only the consumptive portion of a surface water right, as opposed to the entire diversionary amount including return flow. This standard is consistent with the trans-basin export statute, which provides for the diversion of surface water from one watershed to another (϶72-5-26 NMSA 1978 (1997 Repl.)). The statute allows a trans-basin transferor to " . . . take and use the same quantity of water, less a reasonable deduction for evaporation and seepage to be determined by the State Engineer" ϶72-5-26 NMSA 1978 (1997 Repl.)).

Satisfaction of the second and third requirements for a valid transfer (i.e., conservation and public welfare) is less clear, in part because these conditions were only recently (in 1985) made requirements by amendment to state law (see annotations to ϶72-5-23 NMSA 1978 (1997 Repl.)).

The public welfare requirement, in particular, is largely open-ended and undefined. Of the three transfer criteria, public welfare is the least understood. A precise definition of "public welfare" as it appears in the statute has not been articulated by the state legislature, the courts, or the State Engineer. Consequently, inter-basin transfers of water from above the Otowi gage to below the gage will be questioned on public welfare grounds.

During the 2001 state legislative session, two House Joint Memorials were passed on water rights transfers across the Otowi gage:

- House Joint Memorial 6 (45th Legislature, State of New Mexico, First Session 2001)
- House Joint Memorial 14 (45th Legislature, State of New Mexico, First Session 2001)

House Joint Memorial 6 supports and endorses the continuation of the State Engineer's policy of prohibiting surface water transfers from above the Otowi gage to below it. The Memorial's anti-transfer position is framed by public welfare concerns and is based on harm to acequia communities, local economies, and Compact delivery obligations caused by cross-basin Otowi transfers. Specifically, House Joint Memorial 6 states:

> It is detrimental to the public welfare of the state of New Mexico for the Office of the State Engineer or any other relevant state agency to approve water right transfer applications designed to move the point of diversion or place of use of water rights from above the Otowi stream gage to a new point of diversion or a new place of use below the latitude of the Otowi stream gage.

Thus, the Memorial is broader than the current State Engineer policy prohibiting cross-basin changes to points of diversion in that the Memorial objects to cross-basin changes in places of use as well.

House Joint Memorial 14 is virtually identical to House Joint Memorial 6, but in addition requests the State Engineer formalize a policy of prohibiting water rights transfers from above the latitude of the Otowi gage to below that latitude.

Although these memorials do not carry the force of law, they do represent a water allocation preference that must be taken into account. If a regional plan protects one portion of the planning region to the detriment of another portion, such a result must be carefully considered. In addition, because restrictions on the use of a water right may unduly interfere with exercise of a property right or could impermissibly infringe on interstate commerce, compliance with the U.S. Constitution's Fifth Amendment protections against takings (i.e., deprivation of the use and enjoyment of private property without just compensation) and the Commerce Clause's protection of interstate commerce must be considered.

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

If water rights were transferred from areas outside the Jemez y Sangre region, then this alternative would increase the amount of water available to the region. If water within the region was transferred across the gage, the total amount available to the region would not change; however, some of the subregions would have access to water that is currently unavailable to them. Above the gage but within the region, 19,627 acres are irrigated with a consumption of 25,523 acre-feet (Duke, 2001). The amount of these water rights available for purchase is not known, and the Jemez y Sangre region may find that if transfers are allowed across the Otowi gage, it will be competing with other communities such as Albuquerque and Las Cruces for the same water rights.

6. Environmental Implications

Protestants are likely to raise two environmental issues related to water transfers:

- If the water moving across the gage is being transferred from an agricultural use to a municipal use, then the loss of recharge from unlined ditches could impair riparian species that rely on shallow groundwater. Additionally, the loss of agricultural lands would reduce the amount of incidental habitat and green space created in agricultural areas.

- The river flows may change locally due to transfers across the gage and up and down the river corridor, depending on locations of diversions and return flows. The location and direction of the transfer may positively or negatively affect river and tributary flows.

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 acequia 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.

While it might provide additional available water for urban needs, transferring water across Otowi gage could have a negative socioeconomic and cultural impact on rural water users depending on the location and direction of the transfer. However, the prior appropriation doctrine is designed to protect senior users such as acequias. In response to an application to appropriate water, the OSE would first have to determine that water is available in the region. If water were available, the applicant would have the burden of proving non-impairment. If circumstances exist where senior users would not be impaired and the application could be approved, the OSE would condition the permit such that senior users were protected. If impairment is inevitable, then the application would be denied.

If the system is not managed to protect priorities, this alternative would clearly have a negative socioeconomic and cultural impact on traditional water rights, agriculture, and communities in the upper basin. Many upper basin acequia irrigators already perceive threats to their water rights from downstream municipalities and industries, and acquiring and transferring any water rights from above to below Otowi Gage will be viewed as a dangerous precedent and will be vigorously opposed. Acequias rely on a minimum flow of water for the necessary hydrological conditions to adequately deliver water to all water right owners on a ditch. Selling or leasing water rights out of an acequia imperils the entire system. Opening the upper basin as a water market for lower basin municipal and industrial interests could begin a piecemeal dismantling, one water right at a time, of the ancient acequia tradition and all its associated socioeconomic and cultural values. Recognizing the significance of this issue, the 2001 New Mexico Legislature sought to prohibit water right transfers (both diversion and place of use) from above to below Otowi Gage in House Joint Memorials 14 and 6.

An administrative protection such as the concept presented in the Joint Memorials is intended, in part, to protect the relatively low-income rural communities from having to fund the necessary legal and technical studies required if they want to protest a water right transfer. However, the prohibition of any transfer across the gage is contrary to Pueblo and other users' ability to use their water rights. Tesuque Pueblo, for instance, is located both above and below the latitude of the Otowi gage and may desire to divert water from above the gage and deliver it to the entire Pueblo.

Acequia representatives have indicated that before they will support any further discussion of water transfers, they would like the following protections to be in place:

- Area of origin protection against adverse effects on local communities
- Recognition of Acequia authority to veto a water transfer out of the Acequia
- Establishment of Acequia authority to create local water banks
- Development of a public welfare statement to address water transfers

8. Actions Needed to Implement/Ease of Implementation

A change in point of diversion across the Otowi gage would require a permit from the State Engineer and an agreement by the three compacting states to adjust delivery accounting. As noted in Section 4, there are no legal obstacles to such a transfer. Nonetheless, given the State Engineer's administrative policy (Section 1), the practical reality is that obtaining approval for a change of point of diversion would be difficult, requiring a court to overrule the policy.

Another hurdle would be objections from the area of origin that the change would be contrary to public welfare. In general, such an objection could not stop a transfer; however, an acequia may be able to successfully argue that the sale and transfer of historical agricultural rights from the acequia may render it unviable, depending on the facts, and thus contrary to the public welfare of the region. Establishment of area of origin protection could reduce the likelihood of protests against a transfer.

If the transfer involved a change of place of use, rather than point of diversion, across the gage, it might face fewer legal obstacles. If only that part of a water right that had been consumptively used above the gage was transferred below the gage, the Compact requirement should not be impacted. However, the same public welfare objections may apply.

9. Summary of Advantages and Disadvantages

An advantage of this alternative is that it could allow more flexibility to move water to areas of highest demand. Disadvantages are that it would require approval by three compact states, which may not be achievable without the intervention of the court, and that it could negatively impact the traditional community of the upper basin by creating more pressure for individual farmers to sell their rights.

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002a. *Alternative: Purchase surface water rights in the marketplace.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002b. *Alternative: Reappropriate water above Otowi Gage up to 1929 conditions*. White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Natural Resources Committee. 1938. *Regional planning part VI - The Rio Grande joint investigation in the Upper Rio Grande Basin in Colorado, New Mexico, and* Texas, 1936-1937. United States Government Printing Office, Washington, DC.

White Paper 18

Alternative: Manage Growth and Land Use

Alternative: Manage Growth and Land Use

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Robert Odland, AICP, Robert Odland Consulting (primary author), Alletta Belin (legal), and Ernest Atencio (socioeconomic).

1. Summary of the Alternative

This white paper addresses the question of whether and how growth should be managed when water is not available or is not likely to be available in the future. It examines the balance between supply and demand, rather than technical measures to increase supply or reduce per capita demand. Some issues related to land use and growth, such as landscaping and water reuse, are covered in other papers (e.g., DBS&A, 2002).

Managed growth normally means exercising some degree of control over the timing, location, type, and design of growth. What distinguishes managed growth from the type of growth dealt with by comprehensive plans or left to market forces is the addition of a time factor, that is, the timing of growth. Managed growth does not necessarily imply limits to growth unless such limits are specifically built in.

Managed growth systems have been adopted for a number of reasons, such as to ensure that the water supply is adequate for development, reduce governmental costs, ensure adequate infrastructure, preserve resource or habitat lands, and focus growth into more community-oriented growth patterns. What little experience exists in managing growth because of lack of available water appears to have come from California, especially along the Pacific Coast in areas not having access to major water sources in that state. While a community may have many reasons for managing growth, the focus of this discussion is on the mechanisms available to control growth in areas with a limited water supply.

Managed growth systems tend to fall into three categories (although some systems are hybrids):

- Designating geographical limits for growth
- Conducting project-level analyses for each development
- Setting numerical limits on rate of growth

Moratoriums are not generally considered a technique for managed growth, although they could be thought of as a numerical limit system with a growth rate of zero. Moratoriums, however, are a common response to water shortages.

2. Technical Feasibility

All of the systems outlined in Section 1 are technically feasible, and all have been adopted in at least one other jurisdiction in the U.S. The relevant technical feasibility question asks which system, or combination of systems, is most appropriate for the jurisdictions within the Jemez y Sangre regional water planning area.

As noted in Section 1, there are three general types of managed growth systems: geographical limits, project-level analyses, and numerical limits. Several important lessons have evolved from the experience of implementing these systems:

- Managed growth must not just address one issue. To be effective, any land-use system must address multiple community objectives.

- Any system must be perceived as generally fair in how it treats affected people and groups.

- The system should provide as much certainty, preferably early in the development process, as possible.

- Implementation and administration must be carefully thought out in advance.

- As with any properly designed program, there should be an evaluation and feedback component that indicates how the program is working and what changes need be made.

- When selecting any type of growth management system that relates to water supply, it is important to develop a sustainable system, rather than one that will address the supply issue only for a fixed number of years.

2.1 Geographical Limits

One of the oldest managed growth systems in the United States is that of geographical limits. Natural geographic features have always limited growth, and boundaries of local agencies, especially water and wastewater districts, have affected growth patterns. In 1969, however, the Town of Ramapo, New York, adopted a landmark managed growth system specifically to control sprawl that had disrupted municipal finances and the ability of the town to preserve its character. The Ramapo system set a sequential development system that controlled when development could take place; it differentiated development areas and established a rating system for development proposals. Although the system was tied to the ability to provide infrastructure, the issue was not unavailability of resources but rather the ability of the public agencies to finance and provide services in an efficient manner.

The Ramapo system was controversial and became very politicized. It was repealed in 1983, 14 years after adoption, when the majority on the town board shifted. The main concern was that town growth had slowed substantially, due to inadequate funding of necessary infrastructure." Since the Ramapo experience, however, the concept of treating potential growth areas differently using growth tiers has been refined and adopted by a number of other jurisdictions such as San Diego County, California.

The other type of geographically oriented managed growth system is to draw a line around a city, usually called an urban growth boundary (UGB), beyond which no city growth can take place for a fixed number of years. Portland, Oregon, which adopted a UGB in 1994, is perhaps the best known example. (Since the UGB adoption, Portland has become increasingly known as a very desirable place to live, although this may be due more to other factors, such as infill development policies and improved transit, than to the UGB alone.) A number of other cities, especially in California, also have adopted UGBs. When considering adopting a UGB, communities need to be aware of the potential for higher costs and higher in-fill densities, as well as the potential for growth to be shifted to less expensive adjacent communities.

The issues usually raised about UGBs are the impact on land costs, especially as they affect affordable housing, and the nature of development outside the UGB. Impacts on housing are addressed in Section 7. Inappropriate development outside of UGBs has been a problem, leading to the conclusion that UGBs work best when there is close city-county cooperation or, at least, compatible policies. In an extraterritorial zone outside of a municipality, a concurrency system, where developers demonstrate that all services are available, may best manage growth (Section 2.2).

Using geographically oriented managed growth systems to deal with absolute limits on water may not be the best approach because (1) the link between amounts of water and areas of land is not very direct, (2) these systems deal best with a logical expansion of infrastructure, not an often-erratic supply of water, and (3) they affect land consumption but may have little impact on the overall amount of development. However, growth systems based on location may be useful if water supply is one of several goals. Location of development is important when goals such as increasing a sense of community, collecting wastewater, reducing vehicle miles traveled, and conserving resources are taken into account. An interesting project is currently taking place in Watsonville, California, where a quite lengthy consensus-building project has produced a geographically oriented growth strategy that deals with multiple issues, including a lack of water for urban development, agriculture, and habitat preservation.

Rio Arriba adopted a new code in 2001 that requires all developers to preserve 70 percent of the land for open space or agriculture. For example, development of a 10-acre parcel of land must preserve 7 acres as open space and restrict development to 3 acres.

2.2 Project-Level Analyses

This approach provides that for each project subject to the system, the question is asked: "Is there sufficient infrastructure (such as water) available to serve the project." It differs from the third approach, numerical limits, because it focuses on development approvals for specific projects.

The most well known application of this approach is the "concurrency" system mandated for all local governments in Florida. Under this system, before a development can be approved, the applicant must show that water, wastewater, solid waste, transportation, and park facilities adequate to serve the project are currently available or available concurrent with the need for such infrastructure. Most of the attention on this approach has focused on transportation, the area with the most unmet needs. No other state has mandated this approach, but other communities, such as Washoe County, Nevada, have adopted concurrency programs. Santa Fe County requires developers to demonstrate that water is available for 100 years, which has impacted the density of development in the County, outside the City limits.

In October 2001, California adopted a new law (SB 221) that for any project of 500 or more residential units requires a local government or water provider to make a finding, based on substantial evidence, that water is available without putting the existing community at risk. Some infill and low-income projects are exempted. While the law is too new to allow any evaluation, it is being touted as a major advance in linking land use planning with water supplies. The primary concern of water providers is that it will lead to a battle of experts over the availability of groundwater.

There are several problems with this approach.

- The decision point is very late in the planning and development process. More certainty would be provided to everyone if decisions could be made on a longer-range basis.

- The process focuses on an individual project rather than taking a comprehensive view of how potential development relates to the total water supply. The proponent of an individual project is usually not equipped, technically or financially, to undertake water supply assessments. The local government, on the other hand, loses its ability to encourage the type of development it desires.

- The decision-making process must be very rigorously defined and must not contain loopholes. The New Mexico Subdivision Act, for example, includes provisions that the subdivider must show that sufficient water will be available in the future, but these provisions do not appear to provide an effective mechanism for actually ensuring that water will be available. The provisions apply only to counties; individual domestic wells are exempted, and adequate technical data are often lacking. In addition, many counties exclude individual lot splits from the review process, which creates a large loophole and fosters poor planning for infrastructure.

- There are some bookkeeping issues in keeping track of development capacity, and the system must deal with multi-phased projects where water for later phases is not needed for a number of years.

There is, however, one big advantage to a well defined system: projects do not get approved unless water is or will be available. This simplicity and finality can be quite appealing.

2.3 Numerical Limits

In 1972, the City of Petaluma, California, adopted one of the first managed growth systems based on numerical limits. The system provided for 500 housing units per year, evenly divided between single-family and multiple-family building permits. This limit was not based solely on availability of infrastructure, but also on the city’s desire to preserve its small-town character, open space, and low population density.

Since that time, numerous cities have adopted numerical limits to growth; most have dealt only with residential growth, but several have dealt with commercial growth. Several cities in California, such as San Luis Obispo and Morro Bay, have adopted annual numerical limits based directly on limited water supplies. Other California communities, such as Marin County, have indirectly limited growth by not approving bond issues for water facilities. The City of Santa Fe is currently debating the pros and cons of adopting a water budget that would limit the number of commercial and residential hook-ups each year to about 1 percent of the annual water demand.

The operation of a numerical system is quite straightforward, but its design should address a number of issues:

- *Basis for setting the limit.* If a limit is based on water supply, the amount of available water should be known with some degree of certainty. This is difficult to predict, however, because water supply is partially dependent upon rainfall, groundwater supplies are hard to measure, and future environmental and water right constraints are not always as definite as might be desired.

- *Annual limits or budgets.* Most numerical growth limits are annual limits, which appears to be a reasonable approach. However, the system must be able to deal with (1) large projects that would use up most of, all of, or more than one year's water allocation and (2) the potential carryover of unused allocations. Note that the annual period need not begin on January 1 of each year—a different starting point, based on when an annual assessment of water availability can be made, may be more useful.

- *Changeability of limits.* The annual allocation could be subject to change each year or could be set for a fixed period of time. (As a legal matter, an allocation could probably be changed in the future, but not providing for change makes changes more politically difficult.) The advantage of easy changes is increased flexibility to respond to changed conditions, while the disadvantage is that the projections of the amount of available water probably should be based, at least in part, on historical averages, which do not change rapidly.

- *Spreading out development.* The annual allocation is normally spread out over some period of time. For instance, if a community has 1,000 acre-feet of excess water, then the available supply would be divided by the number of years within a specified period to produce an annual budget or allocation.

- *What is allocated.* A numerical limit must limit something tangible. Most communities that have adopted a numerical system have limited building permits. Alternatively, the limits could apply to water hookups. Those communities that limit non-residential development usually limit square feet.

- *Timing of allocation.* Whatever budget is established, the numbers should be known as soon as possible in order to provide all parties with more certainty so that, for instance, developers and builders do not plan for projects that cannot get built. Also, the further along a project gets in the approval process, the harder it is to stop.

- *Bookkeeping issues.* The system must keep track of what potential development(s) has been allocated water. This is not a particular problem if the permitting agency is the same as the water provider. If not, the system must be structured to address this issue.

- *Residential vs. non-residential.* If water is an absolute limit, as it appears it may be in this regional water planning area, then both residential and non-residential uses must be included. The question is what percentage of water is allocated to each. It could be based on historical data, but this may not represent the vision that each community has for itself.

- *Residential uses.* All residential uses are not the same. Some communities, such as Petaluma, distinguish between single-family and multiple-family uses. Most communities with a numerical system have special provisions for affordable housing.

Location can also be one of the criteria for allocations; for example, if a community desires infill development or wants to encourage high-density neighborhood centers, it could give first priority to these efforts.

- *Non-residential uses.* While there are several types of residential uses, there are many more types of non-residential uses, ranging from government offices, retail stores, hotels, to golf courses. If the system is to make distinctions, it must employ some type of criteria, such as maximizing number of jobs, maximizing good-paying jobs, maximizing jobs that match skills of existing population, maximizing tax revenues, supporting social, cultural and environmental goals, or others.

Another type of numerical approach relies on performance standards to determine if a development can be built. An innovative system of this type was used for the Disney World area in Florida. This approach allows a range of mixed-uses but requires that development comply with design guidelines. Development is limited by the amount of water used, amount of wastewater and solid waste generated, and number of automobile trips generated. In other words, development is regulated by impacts, not by indirect and misunderstood measures such as density. This approach encourages efficient and sustainable development because the builder has an economic incentive to minimize impacts in order to maximize the number of residential units or amount of square footage.

2.4 Other Approaches

As noted in Section 1, moratoriums are generally not considered a managed growth technique, although they may be used when water is short. But in fact, they may be the ultimate managed growth technique. Moratoriums are commonly imposed in three circumstances: (1) in response to an short-term problem, such as an unexpected failure of a water well, (2) when a critical resource is simply not available or (3) when development is temporarily halted while a plan is being prepared.

Another alternative to managed growth is to rely on a market approach. The market approach (i.e., allowing housing to be built as needed based on demand) assumes that the system will balance itself without government intervention. There are several problems with a market approach in an area that has an acknowledged water supply issue:

- Industry and business do not like uncertainty, and new businesses will be very unlikely to locate in this region if water supplies are not reliable, frustrating the economic development objectives of the communities in the region.

- The market approach will lead to overbuilding in relation to average water supply. In good water years, building will take place that will result in a subsequent shortage of water in lean water years or when the water runs out. This boom and bust cycle has substantial economic and social impacts.

- Water supply is related to money and energy; given enough money and a supply of energy, water can be obtained from somewhere. But New Mexico is not a wealthy state and may find it hard to compete with cities in Arizona, Nevada, California, and other states for water from water-rich areas. And even assuming that the energy is available, water from other sources, such as desalination of ocean water, will be very expensive to produce and transport.

3. Financial Feasibility

The out-of-pocket costs of adopting and implementing a managed growth system are not substantial. The costs of drafting the ordinance(s) and administering the system should be quite small. A potentially significant cost is that of preparing and updating the necessary water supply studies. However, the costs of these studies should probably be allocated among local governments, pueblos, and the State of New Mexico, and the costs to any one entity should thus not be substantial. These studies may be done anyway, regardless of the adoption of managed growth systems. If so, they do not represent any additional cost attributable to the managed growth systems.

4. Legal Feasibility

Managed growth systems have been litigated in New York, California, and a number of other states. Well-designed systems have almost always been upheld. The typical issues that have been raised in these cases have included a taking of private property without just compensation, violation of due process rights, and infringement upon the right to travel.

These cases have not generally dealt with the absolute shortage of a necessary resource, such as water. Courts almost always allow quite restrictive actions to be taken in emergency situations or when an agency has little or no choice because of natural conditions. Building moratoriums due to lack of water are examples of approaches that should be upheld. There is a moratorium case currently before the U.S. Supreme Court; however, the moratorium in question was not one based on an emergency or lack of a resource, but on the desire to have a temporary halt in construction while a plan and the corollary regulations were prepared and adopted.

On the other hand, at least four appellate court decisions in California have invalidated planning processes due to inadequate discussion of water. Although these decisions were interpretations of the California Environmental Quality Act, which does not apply in New Mexico and in any case are not binding in New Mexico, they do indicate a trend in recognizing the importance of linking water supplies and land use planning.

Another line of cases in some states, such as California, deal with the responsibility of water agencies to provide water. These cases support the proposition that water agencies are under no responsibility to provide water they do not have, but cannot use unavailability of water as an excuse not to provide service unless there is, in fact, a lack of water.

The first legislation requiring subdivision development in New Mexico was the 1963 Subdivision Act. This act, passed in response to complaints of consumer fraud (such as developments with quarter-acre lots requiring wells and septic tanks), gave local government control, primarily over misrepresentation. The 1973 Land Subdivision Act directs the State Engineer to provide assistance to counties drafting regulations. In response, the State Engineer requires that subdivisions containing 25 or more lots averaging 10 acres or less in size must have a central water supply. The 1994 Subdivision Act further regulates subdivision development by requiring that counties develop regulations addressing assurance of water availability to meet the maximum annual requirements of subdivisions (47-6-9 NMSA).

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

To judge the effectiveness of the types of managed growth systems and the market approach, the following five criteria are used:

- *Leveling demand:* Is the system able to level or evenly spread out demand over time so that severe shortages that disrupt the economy and environment do not occur?

- *Buying time:* Does the system buy time for bringing new water supplies on line or implementing new measures to reduce demand?

- *Limiting growth:* Does the system limit growth if absolutely no more water is available or is available at prohibitive costs?

- *Balancing growth:* Does the system balance types of development, taking into account water consumption and other community goals?

- *Contributing to other public policies:* Does the system contribute to, or is it at least consistent with, comprehensive plans and other public policies?

The effectiveness of the three categories of managed growth, as well as that of a market approach, based on these criteria is summarized in Table 1.

Table 1. Effectiveness of Managed Growth Approaches

	Approach			
Criterion	Geographic Limits	Project-Level Supply Analysis	Numerical Limits	Market Approach
Leveling demand	Low	Low-medium	High	Low
Buying time	Low	Medium	High	Low
Limiting growth	Low-medium	Medium-high	High	Medium-high
Balancing growth	Low	Low-medium	Medium-high	Low
Contributing to other public policies	Medium	Low	Medium-high	Low-medium

Table 1 is obviously somewhat subjective; its primary purpose is to facilitate discussion, not provide a definitive answer. In addition, it does not consider hybrid systems.

The following example shows how effective an approach based on numerical limits can be. If one assumes a normal population increase in the basin of approximately 57,600 people between 2000 and 2020 (Bureau of Business and Economic Research, 2000, Table 2-14), a water consumption of 150 gallons per capita per day, and a 50 percent reduction in population growth, the annual water savings would be more than 1.575 billion gallons (about 4,800 acre-feet). Over a 60–year period, a 50 percent reduction in projected growth would reduce demand by about 15,500 acre-feet per year (afy) below the anticipated increased demand of 31,000 afy (based on a per capita demand of 0.18 afy per capita in the Santa Fe Sub-basin and 0.15 afy per capita in all the other sub-basins).

6. Environmental Implications

Managed growth systems need not have any significant adverse environmental impacts, and to the extent that they have any impacts, the overall result should be positive. Ensuring that demand is generally consistent with supply should help to protect habitat areas during years of limited water availability. If an absolute limit to growth is imposed because of an absolute limit of water, the system should prevent overbuilding that would result in intense battles over water for environmental purposes.

If the system took locational issues into account and resulted in more compact development patterns, some water could be saved. While the location of development, including sprawl, is clearly related to energy consumption, it has less of an impact upon total water consumption. Reducing sprawl, however, would tend to preserve the productivity of existing individual wells and would reduce the potential of groundwater contamination from septic tanks.

Managing growth in some rural areas could produce the additional positive benefit of protecting watershed resources, thereby enhancing watershed health and productivity.

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 acequia 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.

Managing growth and land use would have the direct benefit of protecting existing traditional rural land and water uses and all the associated socioeconomic and cultural values. Through comprehensive planning and growth management, this alternative would optimize conservation and watershed health and productivity. Management mechanisms might include sensible and coherent land use zoning, enforcement of water-related restrictions under the New Mexico Subdivision Act, restriction of inappropriate water-guzzling industries and activities, management of suburban and ex-urban sprawl, and development of efficient municipal domestic water supplies to replace unnecessarily consumptive private wells. Specific types of socioeconomic implications of growth, or lack thereof, include the impacts on housing costs, tax revenues, the construction industry, tourism, agriculture, and specific groups of people.

The first issue to be dealt with regarding socioeconomic implications is the cause of any impacts. If water is limited or nonexistent, the impacts are caused by a lack of water, not the existence of a managed growth system. If the managed growth system, however, favors one type of development over another or affects when or where a project is built, then it is legitimate to ask what impacts are properly attributed to the managed growth system.

It is difficult to isolate managed growth from all the other potential causes of changes in such issues as housing affordability. By their nature real estate markets are quite local, making comparisons between cities very difficult. This is best indicated by the current and very vigorous debate over the impacts of growth policies in Portland on the cost of housing and on other socioeconomic indicators.

As noted earlier, businesses like certainty and are reluctant to expand or move to areas with unstable supplies of basic necessities such as water. Agriculture and the communities it supports also depend upon a reliable supply. To the extent that managed growth smooths out water demand and prevents overbuilding, it will encourage these activities. It also will prevent economic disruptions to employees whose jobs are affected by water shortages. A managed growth system that favors job-creating uses should have an additional positive impact.

8. Actions Needed to Implement/Ease of Implementation

The basic steps in implementing a managed growth system are:

- Analyze water availability and demand.
- Conduct an educational and consensus-building program to formulate an approach.
- Undertake any necessary intergovernmental coordination activities.
- Decide how the managed growth initiative should be integrated with other community goals.
- Prepare and adopt an ordinance.
- Implement the ordinance.
- Evaluate the managed growth changes and make improvements as necessary.

Some of the above steps have already been done. The Jemez y Sangre Water Planning Council and other agencies continue to analyze water supply and demand. They also have initiatives to educate and build consensus, such as this charrette. The City of Santa Fe is in the process of analyzing a water budget, and other jurisdictions are also taking a serious look at water and growth issues.

In dealing with water issues, a regional approach has been shown to be the most effective. It is not always possible, however, to adopt regional ordinances; instead, ordinances will most likely be adopted by individual governmental agencies. However, their effectiveness will be greatly improved by close coordination with other governmental agencies so that overall regional objectives are not compromised.

9. Summary of Advantages and Disadvantages

Advantages and disadvantages of managed growth are summarized both in terms of adopting any managed growth system as compared with doing nothing and in terms of each managed growth approach.

9.1 Adopting a Managed Growth System

The advantages of adopting a managed growth system are:

- Levels the demand for water
- Allows time to solve problems
- Prevents over-building
- Promotes balanced growth (i.e., can tailor development to constraints)
- Integrates better with other public policies

The disadvantages of a managed growth system are:

- Requires background studies
- May be politically difficult
- Has some administrative costs
- Works best in short term when limits are known
- May have some unwanted socioeconomic impacts

9.2 Managed Growth Alternatives.

The three types of managed growth systems (geographical limits, project-level analysis, numerical limits) are pretty much all equal with respect to financial feasibility, legal feasibility, environmental implications, socioeconomic implications, and ease of implementation. The numerical limits approach, however, appears to be the most effective. Coincidentally, it is the one that has received the most attention within this region for dealing with water supply issues.

Bibliography

Literature Cited

Bureau of Business and Economic Research. 2000. *Population Projections for the Jemez y Sangre Water Planning Region.* University of New Mexico, Albuquerque, New Mexico.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Wastewater reuse.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Growth Management

City of Santa Fe. 2000. *A review of growth limits*. Planning Division, Santa Fe.

Freilich, Robert H. 1999. *From sprawl to smart growth*. American Bar Association, Chicago.

Kelly, Eric Damian. 1993. *Planning, growth, and public facilities: A primer for local officials*, PAS Report No. 447. American Planning Association, Chicago.

Nelson, Arthur C. and James B. Duncan. 1995. *Growth management principles & practices*. American Planning Association, Chicago.

Porter, Douglas R. 1997. *Managing growth in America's communities*. Island Press, Washington, DC.

Porter, Douglas R. (ed.). 1996. *Profiles in growth management*. The Urban Land Institute, Washington, DC.

Stein, Jay M. (ed.). 1993. *Growth management*. Sage Publications, Newbury Park, California.

Water and Growth Issues

City of Santa Fe. 2001. *Water use in Santa Fe*. Planning Division, Santa Fe.

Jemez y Sangre Water Planning Council. 2001. *Presentation of water supply assessment and population projections*. February 2001.

Kanouse, Randele. 2001. *Water supply planning and smart growth*. Paper presented at the Association of Environmental Professionals annual conference in Oakland, California.

League of Women Voters of Santa Fe County. 2001*. Linking Water and Growth*.

McEntire, Joanne. 2001. Connecting growth, land & water. *Nuestro Pueblo*, 1000 Friends of New Mexico, Winter 2001.

Nelson, Arthur C., Rolf Pendall, Casey J. Dawkins, Gerrit J. Knapp. 2002. *The link between growth management and housing affordability: The academic evidence.* Discussion Paper, The Brookings Institution on Urban and Metropolitan Policy, Washington, DC, February 2002

Nichols, Peter D., Megan K. Murphy, and Douglas S. Kenney. 2001. *Water and growth in Colorado: A review of legal and policy issues*. Natural Resources Law Center, University of Colorado School of Law, Denver.

1000 Friends of New Mexico. 2001*. Land & water: Making the connection*.

Santa Fe Land Use Resource Center. 2001. *Toolbox for Water Scarce Areas and Water Scarce Times*.

Santa Fe Land Use Resource Center. 2001. *Water Supply Options*.

Thaw Charitable Trust. 1995. *Water & growth in the Santa Fe area: Framing the issues*.

White Paper 19

Alternative: Gaining Water Use Efficiency (Reducing Water Use Demand) in the Jemez y Sangre Region

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Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Tom Ash, Irvine Ranch Water District, Alletta Belin (legal), and Bonnie Colby (socioeconomic).

1. Summary of the Alternative

The Jemez y Sangre planning region is subject to extended and severe drought and regularly experiences water shortages and peaking problems. One possible solution to these problems is water demand reduction, a generally low-cost, environmentally sound method for meeting water demands for a community as opposed to supply-side water management (infrastructure increases). However, achieving meaningful and long-term demand reductions requires an integration of a wide variety of actions to realize the benefits of efficient use of water across the different customer groups. This white paper addresses some of these actions, including (1) conserving water through lifestyle changes, (2) utilizing gray water, and (3) minimizing use through incentives, efficiency improvements, and accountability. Demand reductions from reducing losses in conveyance systems and agricultural irrigation systems are discussed in a separate white paper (DBS&A, 2002).

In the Jemez y Sangre region, residential and tourism-related uses top the list of water demands, with the exception of irrigated agriculture. With an estimated projected population growth of 17 percent over the next 20 years, a comprehensive conservation program could help meet nearly all the water needs without any increase in supply. At a minimum, however, water conservation is necessary to combat drought conditions and peak day problems. The benefits to the community for achieving water efficiency would be (1) reduced costs for infrastructure, (2) improved environmental quality, and (3) lower water bills for the public.

Studies show that an incentive water pricing structure significantly affects water use decision making and can determine the effectiveness of conservation programs. Approximate water savings potential is 15 to 30 percent for indoor use and 40 to 50 percent for outdoor use, depending on how wasteful the current uses are. Significant savings have been demonstrated in Orange County, California where an incentive pricing structure by the water utility has resulted in a 54 percent reduction in usage for landscape watering and a 12 percent reduction in indoor residential use.

Incentive rate structures implemented by water utilities and mutual domestics should therefore be a key component of a successful water conservation program in the Jemez y Sangre region. Using the market system in this manner will make end users aware of their water use habits and give them concrete incentives to modify their own water use behaviors. Appropriate incentive rates structures can (1) stabilize agency revenue, (2) send conservation messages to customers, and (3) fund all aspects of conservation programs, such as promotion, education, and rebates for customer upgrades.

To save water on a long-term and consistent basis, the local agencies need to:

- Know their customers use habits (data).
- Make water conservation important (by establishing incentive rates) and credible (use science to create customer allocations).
- Provide ongoing education and outreach to all customer groups on how to save water.
- Encourage the installation of conservation fixtures (efficient water use toilets, showerheads, sprinklers, evapotranspiration (ET) controllers, low-flow washing machines, etc.) through rebates or other incentive programs.
- Establish efficiency in new developments through regulations, and incorporate requirements for retrofitting existing development as a condition for building new development.
- Monitor and support customers' efforts to save water.

This white paper describes these program elements, their value as conservation tools, the typical costs of conservation programs, and the benefits the community can expect to gain.

2. Technical Feasibility

All across the country, water agencies have implemented a wide range of water conservation programs. Most have had short-term impacts, while a few communities have gained long-term reductions. Many water conservation programs start and stop with public education. Other programs attempt to reduce demand through ordinances, but do not supply monitoring and enforcement. The most sophisticated programs employ modern technological methods to achieve significant usage reductions. However, some of the more sophisticated technological approaches, such as determining individual water budgets for every customer, cannot be easily implemented within smaller water systems, which generally do not have adequate recordkeeping or management system capabilities to apply this approach. Financial and technical assistance will be required for such systems to achieve significant water savings with these methods.

The hope of public agencies is that education and ordinances will prompt end users to become efficient with water resources and use only what they really need. These measures have had limited success in some areas:

- Studies by the Metropolitan Water District of Southern California show that the effects of education programs last only a few months. In reviews of home water audits by the Metropolitan Water District, residents returned to pre-audit water use behaviors in less than four months. Education, without proper incentives, has not reduced water use, except for short periods.

- Conservation related ordinances have in some cases not proven to be effective at reducing water use as intended, particularly those that single out specific business areas. For example, when landscape ordinances allow watering only two days per week, residents are found to over-water on their allotted days (Georgia, Oregon, Texas

> and Colorado). The desired effect for water use reductions ends up as an overall increase in water use. When all landscape watering is banned, landscape businesses suffer, tourism is affected, and property values decrease.

However, the City of Santa Fe has effectively reduced the demand on the water system by implementing conservation ordinances that restrict watering to three days a week during stage 2 and one day a week during stage 3. While this is effective in managing a water shortage crisis, a more sophisticated approach would allow residents to maintain their gardens and reduce the water demand.

To date, conservation programs in New Mexico have included:

- School education programs
- Water-wise/xeriscape landscape education (Rio Rancho, Las Vegas, Albuquerque)
- Home water audits (Albuquerque)
- Low-flow toilet rebates (Albuquerque, Las Vegas, Rio Rancho)
- Commercial industrial programs (Albuquerque)
- General public education (Las Cruces, Albuquerque, Santa Fe, Rio Rancho)
- Inclining rates (Albuquerque, Gallup, Las Cruces)

This section outlines an integrated approach to achieving long-term water conservation. The approach seeks to (1) affect lifestyle changes in a fair and equitable manner, (2) send clear conservation signals to customers through the prices for efficient and inefficient water use, (3) provide public education to help keep water bills low, (4) provide further incentives to retrofit sites, both inside and out, (5) establish regulations for efficiency in new development, and (6) suggest monitoring water use and targeting water waste as a core public agency task.

The sequence of a suggested conservation program is:

1. Collect customer data
2. Establish incentive water rates

3. Provide public education
4. Fund retrofits and rebates
5. Set new development requirements
6. Provide user support and monitoring

2.1 Collect Customer Data

Understanding both the current community water use patterns across the different types of water user groups and the real needs of the customers is the first step in developing the best tools to save water in a given area. When the actual use of water (demand) is compared with the actual need (efficiency level), the difference is the conservation potential. The potential for water savings determines which efforts should be undertaken and when it becomes cost-effective to implement them. Once the water savings potential has been determined for a customer group, the conservation strategy comes quickly into focus.

Water use histories of individuals and of water use group type (i.e., hotels, business office, apartment, detached single-family home, etc.) must be collected and analyzed. Some billing systems may not have customer codes in place to easily identify water use patterns for customer groups. Therefore collecting and analyzing data may require field observations and customer surveys.

Major water use groups will vary by community. In Albuquerque, the commercial industrial sector is a large user of water along with landscapes. In Santa Fe, indoor use in homes, hotels, and the commercial sector accounts for 75 percent of the water on an annual basis, but only about 50 percent during summer months when landscaping demands are high, accounting for the other 50 percent. In Los Angeles, most of the water goes to interior residential use. Knowing who and how water is used is key to creating a successful conservation program.

Numerous studies funded by the American Water Works Association (AWWA) provide guidelines for how much water various user types require (Mayer et al., 1999). Efficient home and landscape water use is generally well understood. Commercial and Industrial water use is much more variable and unique to each business setting.

Standards for water use efficiency can be applied to each water use group, based on local conditions and a body of AWWA research related to actual consumptive needs. These types of standards are used to determine what the water savings potential is for the customer group and/or the community. The standards for water use needs of various customer groups include:

- *Detached single family residential need:* Interior (per capita use per resident) plus exterior (vegetation consumptive demand for irrigated area). Vegetation demand varies with type, site, and weather conditions and may be computed from real time ET station data and site-specific information on landscape vegetation types and areas for each customer

- *Multi-family/apartment residential need:* Interior (per capita use per resident)

- *Dedicated meter commercial landscape need:* Vegetation consumptive demand for irrigated area

- *Mixed use commercial need:* Interior (per capita per employee plus process water) plus exterior

- *Agricultural need:* Crop consumptive demand for irrigated area

This type of information can be used to develop an individual water budget for every customer. The water budget then provides the basis of the incentive price structure for each customer. Much of this data collection and analysis is typically contracted out by local water agencies to consultants because (1) the process requires specific skills and experience, and (2) contracting saves the local agency from creating new positions for short-term projects.

2.2 Establish Incentive Water Rates

The U.S. Bureau of Reclamation (USBR) states that, “The price of water affects the decisions regarding water use and therefore can be a key component of demand management” (USBR, 1997, p.1). Inducing lifestyle changes in terms of water use will depend upon the pricing set by the local water agency. An effective "incentive" rate structure drives all conservation activities by the agency and the community. Therefore, the first step in reducing water demand is to develop the appropriate water rate structure.

1. Collect appropriate customer data to develop water budgets and incentive water rates
2. Determine (from the collected data) where water is used and how efficiently it is used
3. Establish water use allocations (efficiency levels) for customers, prices, and rate policies
4. Test the rate structure with real-time customer data
5. Make billing system (software, hardware, etc.) changes to deliver the rate structure
6. Implement rate structure with appropriate public education and marketing, or implement rates during a drought to leverage general public awareness

When a conservation rate structure is implemented, the agency will automatically see who wastes water. The end users will automatically experience an economic incentive to reduce water use (if they waste water) and will seek the assistance of the water agency. At this point, the traditional conservation programs become most effective.

The most effective incentive rate structures meet the following goals:

- They stabilize agency revenue despite reduced water use.
- They send clear signals to customers.
- They create conservation "self-funding" from excess revenues (i.e., revenues from increasing rates for wasted water).

2.2.1 Costs to Implement Incentive Water Rates

The main costs of implementing incentive water rates are related to billing system software and any computer hardware needs to handle a more sophisticated billing system. These costs depend upon the existing billing system of the local agency. In one example agency in California (serving 150,000 people), the software development and public education costs to implement the rate structure were approximately $100,000 in 1991. However, by 2000, the rate structure had saved customers more than $30 million dollars (90,000 acre-feet) in avoided water purchases.

2.2.2 Incentive Water Rates as the Funding Mechanism for Community Conservation

A tiered rate structure, with water budget allocations for each customer, includes increased charges for water that is wasted (or water use above the given allocation). Since the fixed agency costs are automatically recovered in the service charge, any revenue collected beyond the base cost of water is excess revenue. This revenue becomes the self-funding mechanism for implementing conservation programs, including low-flow plumbing retrofits and landscape upgrades.

2.3 Provide Public Education

Along with incentive water rates, the agency needs to provide a comprehensive public education program. Customers will need assistance and information on how to save water to keep their bills low. The following public education topics are appropriate for the Jemez y Sangre region:

- Money savings possible with efficient water use
- Amounts of water use appropriate for each category of water user
- Techniques for identifying leaks
- Techniques for reducing interior water use
- Techniques for reducing landscape water use
- Rainwater harvesting
- Recycled water use / gray water use
- Business water use efficiency
- Environmental benefits of water efficiency

2.4 Fund Retrofits and Rebates

To gain water demand reductions, it is important to ensure that efficient water use appliances are distributed and installed. The greatest water savings in the Jemez y Sangre water planning region can come from upgrading the plumbing in existing homes and businesses. A single low-flow toilet (1.6-gallon flush) will save 12,000 to 16,000 gallons of water in a single year when compared to toilets that are more than 10 years old.

Reducing landscape water requirements can (1) reduce peak water problems in hot months or during water shortages, (2) reduce overall demands, and (3) reduce nonpoint source water pollution in the local area. For example, in Santa Fe, peak water demand can be reduced approximately 25 percent with efficient landscape water use. Reducing landscape water use in the short term requires two actions: (1) improving irrigation efficiency with system upgrades (fixing sprinkler leaks, reducing pressure, etc.) and (2) applying only the amount of water that landscapes require (through scheduling). Reducing water use in landscapes over the long term entails, in addition to those items listed above, changing the plant materials from species with higher water requirements to those with lower water requirements. However, regardless of plant species, efficient irrigation systems and people who apply the right amount of water in relation to weather changes constitute the best opportunity to save landscape water. Rebates can speed the upgrading of landscapes and irrigation systems to help reduce overall demand and peaking.

Water audits can be conducted to evaluate the water savings potential on a site. These can be made mandatory for all or selected groups of users, in which case a time period should be established for audits to be completed, commercial and industrial sites should be required to use a certified water auditor, and a report should be submitted to the local and state water authorities. Audits can identify where rebates can have the most impact.

The following retrofitting measures are recommended:

- For existing homes
  - Low-flow plumbing devices (all types of homes, including apartments)
  - Landscape irrigation systems, plant changes
  - Rainwater harvesting (single family homes, condos)
  - Metering
  - Sub-metering for apartments

- For existing businesses:
  - Low-flow plumbing devices
  - Process water uses
  - Cooling towers
  - Recycled water
  - Metering
  - Landscape irrigation and water-wise plant materials
  - Mandates and financial incentive programs

Retrofits can be required through “retrofit on resale” requirements that mandate the installation of low-flow plumbing devices in residences (with the cost borne by the seller or buyer) as a condition of sale. In addition, financial incentives for installing retrofits and implementing other water-saving measures can be provided through rebates, such as:

- Rebates for low-flow plumbing devices for homes and apartments

- Rebates for upgrading landscape plantings (from high water use to low water use plants)

- Rebates for irrigation system upgrades (residential and commercial)

- Rebates and/or tax incentives to install rainwater harvesting systems (residential and commercial)

- Rebates and/or tax incentives for businesses to upgrade plumbing and process water systems (particularly important in the hotel and restaurant industry, which is so prominent in this region)

In Santa Fe 75 percent of the annual water use occurs inside, suggesting that the distribution of low-flow plumbing devices could achieve significant reduction in water use. During the summer, more than 50 percent of the demand is due to outdoor irrigation, again indicating that irrigation efficiency and plant materials changes are areas where significant savings could be gained.

Analysis shows that retrofitting the sites that have the highest savings potential with low flow plumbing could save at least 25 percent of their current total annual water use. Retrofitting low-flow plumbing devices lowers overall demand and reduces peak use reliably without behavior changes. In this region, the highest potential retrofit candidates are:

- Hotels
- Apartments
- Senior apartments
- Restaurants
- Condominiums
- Detached single family homes
- Business offices

The cost to distribute such low-flow toilets and showerheads would be approximately $350 to $500 per acre-foot, as opposed to a cost for existing water of $600 per acre-foot and a cost for new infrastructure needed to serve increasing population of $675 to $1,400 per acre-foot (or more than $5000 per acre-foot if new water rights are required). Thus typical low-flow plumbing distribution/installation programs would be cost-effective for this community.

2.5 Set New Development Requirements

Planning and design guidelines are needed to ensure that all new development uses water efficiently. Since low-flow plumbing devices are a national building standard, landscaping and the use of recycled water become the main focus of these regulations. These regulations should cover:

- Grading for stormwater harvesting (parking lots, driveways, medians, etc.)

- Grading and landscape design guidelines (homes, streets, parking lots, etc.)

- Watershed management (wetlands for storm water retention) within larger development areas

- Xeriscape landscape design

- Installation of ET signal controllers and rain shut-off devices

- Installation of rainwater collection systems where paved surface areas make it feasible

- Recycled water use (mandatory for large landscapes)

- Requirements for the use of reclaimed water where available (including in offices for toilet flushing, car washes)

- Metering
  - Mandate dedicated landscape meters
  - Require all commercial sites to have separate interior and exterior water meters
  - Require all residential sites to have meters (even where wells are the source of water)

- Requirements for installation of an ET weather station in specific micro-climate areas (given to the state for ET weather network) for use in public education and billing.

- Builder mitigation options (to gain the water needed to serve new areas)
  - Conservation devices (e.g., requirement for new development to provide retrofitting of existing development as a condition for building, thus freeing up water for the new uses)
  - "New water" requirement (e.g., assisting with the funding of conservation efforts, such as recycled water programs, low-flow plumbing devices, public education, etc.] to ensure adequate water supplies for the community)

2.6 Provide Support and Monitoring

Water agency staff should be trained to educate and assist customers with water conservation issues, including using water efficiently, using weather stations, understanding computerized billing data, and other issues arising from water conservation programs.

3. Financial Feasibility

Typically, water conservation is a low-cost method to gain "new" water supplies. Its cost effectiveness is determined by comparing the cost to save water, typically $350 to $500 per acre-foot, with the cost to buy or develop new water sources.

The proper "incentive" rate structure can fund long-term conservation efforts. However, many agencies find it difficult to get started with data collection, rate design and implementation, and other measures such as rebates on low-flow toilets. A model program designed in Utah may be a solution for water agencies in the Jemez y Sangre region.

Various state and federal funding sources could be used for conservation programs. Examples include:

- State startup assistance program (zero interest revolving fund), where the state provides money to fund rate structure development. Once the local agency can implement an incentive rate structure and gain excess revenue, the State is refunded the startup money (Utah example).
- State bond issues raising money for water related projects (California example).

Financial assistance will be important for smaller water systems in the Jemez y Sangre region that otherwise lack the funding capacity to provide effective reduction measures such as low-flow retrofits.

Alternatively, implementation and long-term operational costs can be funded directly through the local incentive rate structure. The incentive rate structure was developed in California, in part, to help make local funds available for local conservation efforts. In philosophy, those who waste water pay the "marginal" costs for water (which is higher than the cost to deliver a unit of water today). This excess revenue (above the base rate cost of water per unit) is then used to help make any and all users efficient. The ability to fund conservation efforts from the incentive rate structure is a prime reason to establish incentive rates up front, before serious conservation efforts begin. If any demand reduction takes place for whatever reason, agency revenues will go down. Therefore, the effective conservation rate structure captures all the fixed revenue needs, regardless of how much water is used by the customer.

4. Legal Feasibility

There are no obvious legal barriers to individual water conservation measures such as gray water systems and other methods of increasing water use efficiency. Local governments and water service providers can, as a proper exercise of their police powers and in an effort to stretch limited water supplies, require that such conservation measures be established, as long as the costs imposed on individuals do not rise to such a level that, in effect, water service is denied entirely to people unable to afford the systems.

Each conservation program component presented in Section 2 is either in practice by some water agency in the U.S. or is being planned. For example, incentive water rates are not only recommended by the USBR, but will soon become mandated in California. Retrofit and rebate programs are commonly used to reduce water demands in every part of the country. New design requirements are commonly used by cities and water agencies, including mandating the use of recycled water (for appropriate uses) if it is available to the customer. In short, the local water agency has the legal authority to use every type of conservation method listed for the "benefit" of the community and does so in every corner of the country.

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

Based on reviews of water use in Santa Fe and surrounding communities and on program examples from around the country (i.e., those that have proven track records), the Jemez y Sangre region could gain significant water savings, as much as 30 percent, from the integrated use of the conservation program described in Section 2. The success of conservation will depend upon (1) the accuracy of the data, (2) the commitment of the local leaders, and (3) the thoroughness of the implementation. Communities that have implemented conservation programs have various levels of success; Albuquerque has reduced demand by 23 percent, Tucson by 30 percent, Los Angeles by 25 percent, Austin by 27 percent, and Irvine by 54 percent (landscape use) and 12 percent (residential use). Additionally, Santa Fe has reduced demand by 22 percent on a per capita basis since 1995.

If education and ordinances are the conservation methods of choice, conservation will be short-term and need reiteration every year. Crisis management, when water shortages appear, will be the norm. If incentive water rates are established, however, the effectiveness of conservation will be strong and persistent, and conservation will be a tool to better manage drought, peaking, or shortages.

6. Environmental Implications

Saving water among existing users through rates, retrofits, and new development guidelines is the most environmentally sound method to gain a new supply of water. No infrastructure (pipelines, reservoirs, diversions, wells, etc.) expansion is necessary to gain new water through conservation programs. Achieving water conservation in a community actually reduces the need to expand existing facilities (i.e., treatment plants, reservoirs, sewage disposal, etc.) that do have an environmental impact. Additionally, there is evidence that landscape conservation helps reduce nonpoint source water pollution.

7. Socioeconomic Impacts

Water conservation has happened in many types of communities across the country without negative impacts to business or lifestyle. The socioeconomic impacts of water conservation are largely favorable, both for residential and business customers. Water bills are reduced and more disposable income is available for other uses by the consumer. For example, it was determined that retrofitting low-flow toilets and showerheads in apartments throughout Santa Fe would reduce water bills by $300,000 per year for those customers. That money would be much more valuable by being spent in the community than it would by purchasing more of a scarce supply of imported water. With effective pricing signals and conservation incentives:

- Residential customers may make their own choices regarding how they use water, and presumably, every water user will make the right choice based on economics. If they make good choices, their water bills will be less. Indeed, conservation, particularly low-flow plumbing programs in apartment and senior communities, has a positive effect on low and fixed income homes.

- On the business side, conservation results in less need for expensive infrastructure, often funded by tax increases and/or higher water rates for all. Water conservation becomes a valuable tool for businesses to keep costs down (and profits up). For any business, a reliable supply of water is critical, and water conservation helps to ensure that water is available when customers want it and at the lowest possible cost.

Specific socioeconomic impacts of water conservation include:

- Water conservation creates jobs in a community performing efficiency services in businesses, landscaping, and plumbing.

- Water efficiency can be achieved without a diminished lifestyle (for example, through low-flow toilets, cooling towers, meters, etc.).

- Incentive rates encourage, rather than force, each end user to use water efficiently.
- Money saved by end users (avoided water purchases) benefits the individual and the local economy.
- Water conservation has a more positive impact on low-income families and seniors (i.e., the money saved through water efficiency is a greater portion of their income).
- Conservation has a positive environmental impact (which is a significant societal benefit).

Water conservation efforts cannot be completely effective without managing growth as well, and financial incentives are required to facilitate this course of action. Just a possibility of growth restrictions could be enough of an incentive to encourage developers to incorporate water saving technologies into new developments. Additionally, water users may be more likely to conserve if a growth management strategy is in place, because they will be less likely to feel that their conservation efforts are only going to support new growth.

8. Actions Needed to Implement/Ease of Implementation

Saving water requires a variety of information, skills/experience, computer hardware and software, and funding, such as:

- Willingness of decision makers
- Analysis of cost/benefits (costs of conservation programs versus existing costs of water and future infrastructure costs)
- Initial funding source(s)
- Conservation program implementation expertise

Some actions that could benefit the Jemez y Sangre region's water conservation efforts include:

- Working with the New Mexico Finance Authority and the New Mexico Environment Department to use existing water/wastewater grant funds to develop conservation programs and finance required infrastructure
- Educating agricultural users to better define actual crop water needs
- Lobbying the State Legislature to provide financial and technical assistance to smaller communities and systems for implementing efficiency improvement measures

9. Summary of Advantages and Disadvantages

Conservation can be another tool for local water agencies to use to gain “new” water supplies at a low cost. Conservation can significantly assist with groundwater management and in reducing treatment and wastewater infrastructure needs, environmental impacts from high water use, and customer water bills.

The prospects for saving water in the Jemez y Sangre region are very positive. With the exception of the City of Santa Fe, no coordinated, long-term conservation programs have been established, so the savings from rates and retrofitting will be immediate and deep. New development requirements will assist with maintaining efficient water use as population increases. This region has significant opportunity to meet the water needs of the future through integrated resource planning that incorporates conservation as a core feature.

The advantages of implementing water conservation are:

- Low-cost source of supply
- Environmentally sound

- Multiple benefits, including reduced wastewater treatment and reduced future infrastructure need
- Stretches existing supplies out into the future
- Reduces peak demand

Disadvantages of conservation programs are:

- They require data and computer technologies
- They require specific skills in landscaping, plumbing, and commercial water needs
- There are no real incentives for agricultural users to reduce usage under current state law

Many view conservation as something that has to be done, with no real alternative choice. The question is what and/or how to conduct the program.

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002. *Alternative: Efficiently convey water to reduce loss.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Mayer, P., W. DeOreo, E. Opitz, J. Keifer, W. Davis, B. Dziegielewski, and J.O. Nelson. 1999. *Residential end uses of water.* American Water Works Research Foundation, Denver, Colorado.

U.S. Bureau of Reclamation (USBR). 1997. *Incentive water rates for water agencies.*

U.S. Bureau of Reclamation (USBR). 1997. *Incentive pricing handbook for agricultural water districts.* Prepared by Hydrosphere, Boulder, Colorado.

White Paper 20

Alternative: Manage Drought

Alternative: Manage Drought

Acknowledgements: This white paper was produced by Daniel B. Stephens & Associates, Inc., with assistance from the Jemez y Sangre Water Planning Council and with input from a water planning charrette held in February 2002. Contributing authors include Michael J. Bitner, Joanne Hilton, Bob Gray, and Tom Ash (primary authors), Alletta Belin (legal), and Bonnie Colby (socioeconomic).

1. Summary of the Alternative

About 75 percent of the demand in the Jemez y Sangre region is currently met with surface water supplies, which are highly variable. When drought conditions occur, the available surface water is not sufficient to meet all of the current demands. As population and water use increase in the future, even greater discrepancies between supplies and demands are expected. Localities that rely on groundwater can also benefit from drought planning, because the demand for groundwater supplies increases when precipitation is low.

The historical record shows a recurring cycle of drought. Though it is difficult to predict the timing of droughts, it is certain that droughts will occur within the Jemez y Sangre region over a long-term planning horizon. Given this certainty, advance planning should be undertaken to avoid a crisis management situation during future droughts. A proactive planning approach to drought management is beneficial for all impacted parties. The drought management alternative consists of developing a drought management plan that will enable the region to be prepared for droughts when they do occur. Drought planning should be a foundation for all water systems, particularly those dependent on surface water for supply. Drought management does not reduce the regional demand or the projected discrepancy between supply and demand but should, however, allow communities to function well during a drought.

Some of the most important actions that can be undertaken to prepare for drought include improving storage capacity and reducing demand through efficiency and conservation. The technical feasibility of these measures is discussed in white papers on reservoir storage (DBS&A, 2002d), aquifer storage and recovery (DBS&A, 2002c), reduction of conveyance losses (DBS&A, 2002a), and demand reduction (conservation) (DBS&A, 2002b). This paper focuses on the issues involved with development of a drought management plan that addresses actions to be undertaken during various stages of drought.

Drought management plans typically include the following:

- A drought task force or other set of responsible parties is designated to oversee declarations of drought conditions and implementation of drought mitigation measures.
- "Triggers" are selected to identify various stages of drought (i.e., mild, moderate, severe). Triggers include indices that categorize levels of drought based on climatic and streamflow conditions.
- Specific mitigation measures that are to be undertaken during each drought stage are identified. Mitigation measures can include standard drought ordinances that define water restrictions, or they may include broader measures such as leasing of supplies during droughts.

Drought management can be undertaken at a regional level through cooperative agreements, or it may be undertaken by individual counties, municipalities, Acequias, Pueblos, or irrigation districts within the region. Drought planning that addresses both local and regional mitigation efforts will be most effective.

2. Technical Feasibility

This technical feasibility analysis describes the steps in developing a drought plan that encompasses monitoring, communication, and mitigation measures. In developing drought plans within the region, it is important to consider that water use during times of drought is subject to a prior appropriation system. Thus more senior water rights holders, such as the Pueblos within the region, may not need to implement mitigation measures such as water conservation to the same degree that more junior users would need to.

2.1 Drought Task Force

As noted in Section 1, the first step in developing the drought plan is to determine who within the region will be involved in development and implementation of the plan. Many drought plans rely on a task force with representatives from various water user groups such as Acequias, municipalities, counties, and irrigation districts. If drought planning is conducted by individual municipalities, Acequias, Pueblos, or irrigation districts, an employee and/or group of water users may administer the drought plan. Generally a designated municipality, agency or contractor will work with the drought task force to develop the drought plan.

2.2 Drought Triggers

Typically, standard measures such as the Palmer Drought Severity Index (PDSI), the Surface Water Supply Index (SWSI), or the Standard Precipitation Index (SPI) are used to define various stages of drought. These indices are discussed in Sections 2.2.1 through 2.2.3. Additional possible triggering parameters are discussed in Sections 2.2.4 and 2.2.5.

2.2.1 Palmer Drought Severity Index

The PDSI is an empirically derived meteorological index based on the water balance equation (i.e., precipitation is equal to evapotranspiration plus runoff and groundwater or soil moisture recharge plus or minus any change in soil moisture storage). It is computed with several formulas that incorporate precipitation and temperature data along with the available water content of a local soil type to define the terms of the water balance equation. The difference between a monthly precipitation amount and the climatically appropriate precipitation for existing conditions is multiplied by a climatic weighting factor that allows the index to have a comparable significance from location to location. The climatically appropriate precipitation and climatic weighting factors are derived from historical records. Human impacts such as irrigation usage and reservoir storage amounts are not considered.

The PDSI roughly varies between –6.0 and +6.0; values of +4.0 or more and –4.0 or less represent extreme conditions, while values close to zero represent normal conditions:

- + 4.00 or more: Extremely wet
- +3.00 to +3.99: Very wet
- +2.00 to +2.99: Moderately wet
- +1.00 to +1.99: Slightly wet
- +0.50 to +0.99: Incipient wet spell
- +0.49 to –0.49: Near normal
- –0.50 to –0.99: Incipient dry spell
- –1.00 to –1.99: Mild drought
- –2.00 to –2.99: Moderate drought
- –3.00 to –3.99: Severe drought
- –4.00 or less: Extreme drought

Weekly PDSI values for every climate division in the United States are computed by the Climate Prediction Center and are available from the National Oceanic and Atmospheric Administration's (NOAA) Drought Information Center at http://www.drought.noaa.gov.

Since its development in 1965, the PDSI has been widely used to gauge drought conditions, but it has been found to have several limitations. Some of these are related to arbitrary and simplified assumptions used in the computation of the water balance terms and the exclusion of snowfall and snow cover in the index. Researchers have suggested that the PDSI is designed for agriculture and does not accurately represent hydrological impacts from longer droughts. It also does not work well in areas with extreme variability in rainfall and runoff. Nevertheless, its frequent computation on a climate division basis and ready availability make it a useful component of drought monitoring when used in conjunction with other analyses of precipitation conditions and water supply availability.

2.2.2 Surface Water Supply Index

The SWSI was originally developed to complement the PDSI for monitoring moisture conditions in the state of Colorado. Whereas the PDSI is basically a soil moisture index for regions with consistent hydrologic conditions, the SWSI is an indicator of surface water conditions for areas in which mountain snow pack is a major component. The four parameters incorporated in the

SWSI are snow pack, streamflow, precipitation, and reservoir storage. During the winter, only snow pack, precipitation, and reservoir storage are used to compute the index, while during the summer, streamflow is used instead of snow pack.

Typically determined on a monthly basis, each parameter value is normalized (divided by the long-term average), and its probability of non-exceedance is determined by frequency analysis. Each term's probability of non-exceedance is multiplied by a weighting factor that accounts for the proportional contribution of each component to the surface water in a particular basin. The sum of the weighted components is centered on zero (by subtracting 50 percent) and divided by 12 to compress the scale to a range of –4.2 to +4.2, similar to the PDSI.

- + 4: Abundant supply
- +2: Near normal
- –1: Initiation of drought conditions
- –2: Moderate drought
- –3: Severe drought
- –4: Extreme drought

Besides Colorado, other states that have used the SWSI for drought monitoring include Oregon, Montana, Idaho, and Utah.

SWSI values are computed on a monthly basis by the Natural Resources Conservation Service (NRCS). Current SWSI values for the major New Mexico river basins are available on NRCS's web site (http://www.nm.nrcs.usda.gov/snow/forecast), along with basin outlook reports that include details on snow pack conditions and reservoir storage. This information is provided for January through May only.

2.2.3 Standardized Precipitation Index

In technical terms, the SPI for a given historical precipitation record represents the number of standard deviations away from the mean for an equivalent normal distribution with a mean of zero and standard deviation of one. Advantages of the SPI are that it can be computed for any single site with a long-term precipitation record and it can be determined for multiple time scales, typically 1, 3, 6, 12, 24, and 48 months. The application of this index to multiple climate station sites allows for a more localized definition of drought conditions than the more regional-scale PDSI and SWSI. Similarly to the PDSI and SWSI, the index is centered on zero, but extreme conditions occur at values above +2 and below –2.

- +2 or more: Extremely wet
- +1 to +1.99: Moderately to very wet
- 0 to +0.99: Near normal
- 0 to –0.99: Mild drought
- –1 to –1.49: Moderate drought
- –1.5 to –1.99: Severe drought
- –2 or less: Extreme drought

A drought event is defined as a period in which the SPI is continuously negative and reaches a value of –1.0 or less. The drought begins when the SPI first falls below zero and ends with a positive value of SPI following a value of –1.0 or less.

The ability to express conditions at multiple time scales allows the index to reflect the impact of drought on the availability of different water resources. The SPI also facilitates the definition of conditions where, for example, it is possible to simultaneously experience wet conditions on a short time scale but dry conditions on a long-term time scale. An emerging drought will first appear in short time scales, and if dry conditions persist, the drought will be reflected in longer time scales. Short-term wet periods can mask a long-term drought condition for some components of water supply, but will not appreciably affect water supply components that are responsive to longer-term conditions. For example, soil moisture conditions reflect precipitation deficits on a short time scale, while groundwater, streamflow, and reservoir storage are responsive to longer-term deficits. Thus a short-term drought would impact dryland farming conditions, but may have little effect on urban water supplies or irrigated agriculture. The use of several time scales assists in recognizing an emerging drought early on, in monitoring drought magnitudes over longer time periods that impact surface water supplies, and in anticipating an end to a drought as wetter conditions occur.

The Western Regional Climate Center computes the SPI on a monthly basis for every climate division (http://www.wrcc.dri.edu). A computer code also is available to calculate the SPI for individual sites (Guttman, 1999). DBS&A has compiled this code to run on a personal computer.

2.2.4 Reservoir Storage Levels

As an alternative to the basin-wide SWSI estimates provided by the NRCS, a more localized assessment of surface water conditions may be useful to local communities that are dependent on surface water supplies. In such cases, local reservoir storage levels may be used to define triggers for various response actions. For example, progressively greater water use restrictions might be implemented as reservoir storage drops below certain levels, such as 40 percent, 30 percent, or 20 percent of capacity. These levels would be set by the locally responsible parties who administer the drought plan based on historical usage patterns.

2.2.5 Groundwater

Some communities, notably the City of Albuquerque, have elected to use groundwater pumping rates as a drought indicator. Although Albuquerque now relies exclusively on groundwater pumping for its supply, the City plans on switching to a combined surface water-groundwater supply system soon, to reduce groundwater pumping to sustainable levels and preserve the aquifer as a drought reserve. The City anticipates that during drought conditions, per capita water use may increase and surface water may not be fully available, two conditions that when combined would result in increased groundwater pumping both to meet increased demands and to make up for decreased surface water supplies. The increased pumping represents borrowing from the drought reserve and thus serves as a metric for determining the severity of the drought conditions.

Tiered water use restrictions can be implemented to reduce over-pumping during droughts. For example, either numerical limits or type of use restrictions (e.g., no car washing) can be required to correspond to various stages of drought.

2.2.6 Drought Stages

The indices discussed in Sections 2.2.1 through 2.2.4 are used to identify various stages of drought, typically three to six divisions, with mitigation measures (Section 2.3) being implemented for each drought stage. An example of the triggers and drought stages from the *New Mexico Drought Plan* (New Mexico Drought Planning Team, undated) is shown in Table 1. Statistical analyses and correlation of the available indices to historical data are required to determine the appropriate drought triggers for any given region. Analysis of historical streamflow data is also useful in evaluating historical drought conditions. Analysis of low flow conditions within the region has been completed by Duke Engineering & Services (DE&S, 2002). Thorough technical analysis of streamflow probabilities reported by DE&S and other available data will be required to accurately determine which triggers are appropriate for the Jemez y Sangre region.

2.3 Drought Mitigation

Once the drought stages and corresponding triggers are identified, mitigation measures for each stage are identified. The technical feasibility of implementing mitigation measures is specific to the measures undertaken. Mitigation measures that may be considered in the Jemez y Sangre region include both short-term supply measures, such as leasing arrangements, and demand reduction measures.

Leasing of water rights can be arranged between willing participants with OSE approval. For example, a municipal user could lease agricultural water rights for use only during certain conditions, which could be set to correspond to specified drought triggers. Typically the agricultural user would be compensated for the value of the crop not planted. Water rights leasing requires OSE approval, and is subject to protest based on impairment and/or public welfare. Technical analysis of potential impairment issues would most likely be required to obtain OSE approval. In emergency situations, the OSE may expedite approval of a lease, as long as notice requirements have been met and no protests were filed against the transfer. However, if other water users protest the transfer, then the process can take from 6 months to 2 years; hence effective drought mitigation requires that the arrangements be in place before the water is needed during drought conditions.

Table 1. Drought Stage Triggers

Drought Status	Characteristics for a Single Climate Region
Normal	• PDSI between –0.9 and + 5.0 • 6-month SPI positive
Advisory (approaching or experiencing incipient drought)	• One month or 4 week running average PDSI is between –1.0 and –1.9 but period of less than –1.0 does not exceed 2 months. • 6-month SPI declining and less than 0.25 for 2 consecutive months.
Alert (mild drought)	• PDSI is between –1.0 and –1.9 for greater than 2 months or between –2.0 and –2.9 for 1 month. • 6-month SPI between 0 and –0.99.
Warning (moderate drought)	• PDSI is between –1.0 and –1.9 for 9 months or more, between –2.0 and –2.9 for at least 2 months, or –3.0 or less for at least 1 month. • 6-month SPI declining and between -1.00 and -1.49.
Emergency (severe to extreme drought)	• PDSI is between –2.0 and –2.9 for 9 months or more, between –3.0 and –3.9 for at least 2 months, or –4.0 or less for at least 1 month. • 6-month SPI declining and less than –1.5.
Emergency (drought receding)	• After severe to extreme drought criteria have been met, PDSI improves to greater than –2.0 for 2 consecutive months. • 6-month SPI turns in positive direction for 2 consecutive months.
Warning (drought receding)	• After criteria for moderate or worse drought have been met, PDSI improves to greater than –1.5 for 2 consecutive months. • 6-month SPI rising in positive direction and between –1.00 and –1.49 for 2 consecutive months.
Alert (drought receding)	• After criteria for mild or worse has been met, PDSI improves to greater than –1.0 for 2 consecutive months. • 6-month SPI rising in positive direction and between 0.0 and –0.99 for 2 consecutive months.
Advisory (drought receding)	• After criteria for mild or worse drought have been met, PDSI improves to greater than or equal to zero, and the 10-month running total of the PDSI is less than –10.0. • 6-month SPI is above zero.

Source: Drought Planning Team, Undated, Section 6D, Table 4 (http://weather.nmsu.edu/drought/monitoringD.htm).

PDSI = Palmer Drought Severity Index

SPI = Standardized Precipitation Index

In selecting mitigation measures, planners need to consider the priority of existing water rights. For example, some Acequias within the region that are upstream of Pueblos with senior water rights have agreed to discontinue their water use during drought conditions, thus allowing the priority users to receive the water during drought conditions.

Examples of some existing mitigation measures from the cities of El Paso and Santa Fe are shown in Table 2.

Table 2. Examples of Drought Stages and Mitigation Measures

Drought Stage [a]	Mitigation Measures
El Paso	
1	Voluntary conservation
2	• One day per week landscape irrigation • No golf course irrigation • No new landscaping
3	No new customers
All	Surcharges to recover lost revenue
Santa Fe	
1	Voluntary conservation
2	• Irrigation three days per week • Unessential uses (e.g., car washing) prohibited
3	• Irrigation one day per week • No new planting
4	• All outdoor use prohibited, except watering of large trees two days per month • No water on construction sites

[a] Stages 1 through 4 represent mild (Stage 1) to most severe (Stage 2) conditions

Long-term conservation measures help to reduce demand at all times, and hence are helpful for reducing demand during all stages of drought. Conservation measures are discussed in a separate white paper (DBS&A, 2002b). Many water conservation measures can be adopted on a permanent basis, or water managers may choose to implement conservation measures only during drought conditions. The decision on whether to implement permanent or short-term measures is based on political feasibility, water pricing issues, and the availability of the supply.

Some examples of mitigation measures focusing on demand reduction that may be most feasible for the Jemez y Sangre region, listed by category of customer group, and the stages of drought at which these measures might be applied are listed below.

- Residential

  - Disseminate educational information (how to save water at home) through billing inserts and local media, including TV, newspapers, and radio. Include weather/drought updates (e.g., drought conditions are worsening) and suggestions for saving water (e.g., take shorter showers, find leaks, use a soil probe to monitor moisture in the garden soil, use a pool cover to reduce evaporation, etc.). (Stages 1 through 4)

  - Require home water audits, either offered free by the agency or paid with a surcharge on the water bill for conservation. These could be either targeted to highest users and/or offered to all customers. Such an audit would look for leaks and inefficiencies in inside use and would check irrigation system and automatic controller schedules. The customer would receive notes or a form that describes findings and suggests tips for saving water, including how often to water the landscaping. (Stages 2 through 4)

  - Request all water users to reduce their use by a designated percentage from previous years (with the percentage increasing as drought triggers occur). (Stages 1 through 4)

  - Enact a water rate surcharge for any water use that is higher than the previous year's rate of use or higher than a specified reduction level. Implementation of the surcharge would require a software upgrade, bill notation, and/or separate letter to all customers showing the previous use and the target reduction. The increased surcharge should be based on something tangible, such as the cost to purchase new water or the cost of conservation. (Stages 3 and 4)

- Business (commercial/industrial)
  - Disseminate educational information on how to save water in commercial/industrial settings (low-flow plumbing, process water uses, leak identification, cooler tower use, landscape efficiency, etc.). (Stages 1 through 4)
  - Implement water audit program, which may take a couple of forms. For example, the program could require self-performed water audits (commercial sites), done with an agency-developed reporting form but paid for by the business. Such audits would be viewed as voluntary but with consequences if not performed. Another option would be required efficiency audits with completed efficiency forms sent to the water agency. This means that the business must pay for their own water audit, repair leaks, and report that they have done so to the water purveyor or face a surcharge until it is completed. (Stages 2 through 4)
- Business-specific recommendations (Stages 1 through 4)
  - Hotels: Laundry restriction program, price incentive on low-flow plumbing retrofits, ornamental landscape water budgeting, restaurant audit (sinks, washers, etc.)
  - Offices: Plumbing audit, repairs, and reporting; landscape water budgeting
  - Manufacturing: Site audit that identifies various water uses and recommends water savings that still maintain business/production levels
  - Service businesses (restaurants, car washes, laundromats, etc.): Site water audit and use reduction plan/efforts

Businesses generally would not be asked to reduce water compared to previous years (in order to maintain business levels). However, they would be asked to incur the costs to retrofit with low-flow plumbing and make other efficiency upgrades (cooling towers, etc.), and they may be asked to replace high water use landscapes with xeriscaping or face some type of surcharge or tax. Pricing incentives could also be incorporated in the fee structure to drive positive and long-term savings actions and yet not interrupt business activities. It is important to not develop drought plans that reduce both business and, in turn, jobs in order to save water. Instead a plan should focus on being more efficient with water while maintaining jobs, providing the local politicians with a good marketing tool, and increasing the likelihood of gaining support from the business community.

Additional mitigation measures for landscaping with dedicated meters include:

- Require site water budgets (based on local evapotranspiration and standardized use/efficiency levels) for all landscaping with dedicated meters. Water budgeting can be performed by the commercial user following a form developed by the water agency. This water budget will determine what type of landscape is present, how efficient the irrigation system is, how much water the site needs, and what plants should be saved (i.e., watered) in case of more severe drought and increasing water restrictions. A site report should be filed, using the provided forms, that identifies such items as highest value plantings (i.e., trees, other), site practices, and acres. (Stages 1 through 3)

- Alter the time of day that watering occurs to moderate morning “peak” problems. (Stages 1 through 4)

- Require all irrigation system leaks to be repaired before continued water use is allowed. (Stages 2 and 3)

- Use soil probes, read meters weekly, chart and monitor water use. (Stages 1 through 3)

- Reduce water use to a designated percentage of previous average use. (Stages 2 through 4)

- As the drought severity increases, require that high water use landscapes or irrigation systems be replaced with xeriscapes and/or drip irrigation (require evapotranspiration controller technology) to be able to continue to irrigate. (Stages 3 and 4)

- Provide some incentive for installing landscape conservation measures and technologies (rain shut-off devices, rain collection systems, evapotranspiration controllers, xeriscapes or turf removals, etc.) (Stages 1 through 4 and before and after droughts)

- Ban lawn watering (allow tree and shrub irrigation). Make some provision for public play fields and schools; however no public ornamental turf should be irrigated during stage 3 and 4 to show that government is willing to do at least as much as it asks the private sector and households to do. (Stage 4)

The potential measures described above place the burden of cost on the various users. The public agency role can be to provide detailed information and education and, in some programmatic ways, to provide financial incentives (such as incentive rates or drought surcharges). Some type of revenue generation for drought plan implementation can be incorporated into water billing rates, some portion of which could be used to develop educational materials and forms before a drought happens so that a drought plan can be quickly implemented.

3. Financial Feasibility

Development of drought monitoring and mitigation plan(s) for the region would cost approximately $100,000 to $200,000, depending on the level of detail that is included in the plan. Costs would cover items such as the technical analysis required to define drought triggers and facilitation of meetings for plan development.

Once the plan is developed, additional costs would be required to implement the plan. Staff time from various agencies and water user groups would be required for participation on a task force and implementation of mitigation measures. Costs for mitigation measures would vary depending on the measures chosen. Many of the demand reduction measures listed in Section 2.3 can be implemented at a relatively low cost. Voluntary restrictions will require funding for public education, and mandatory water restrictions will require funding for monitoring and enforcement in order to be effective. Potential costs associated with emergency water rights leasing ideally should be addressed during the planning phase, as advance arrangements with water rights purveyors are likely to be more cost-effective than last-minute deals made under stressful circumstances.

Water providers must also plan to address lower revenues resulting from water use restrictions. Tiered pricing or penalties for overuse may help to recoup lost revenue.

4. Legal Feasibility

A precise legal analysis would require knowledge of exactly what drought measures were contemplated. As a general proposition, courts will accord significant leeway to governments that are doing the best they can to address a difficult drought situation. Temporary moratoria or limitations on new development, or on high-water uses or similar measures, will likely be allowed, as long as the system imposed appears to be a rational attempt to deal with the situation. Indeed, all of the measures described in this paper should, if implemented carefully and rationally, pass legal muster. However, if any such actions cause people to go out of business or otherwise cause a huge devaluation of private property, a court might require that just compensation be paid. Similarly, if the drought plan appears to treat different classes of people very differently with no solid rational basis, then such a plan might be struck down.

With respect to limitations on exercise of water rights, such limitations must be consistent with the State Water Code, which establishes a priority water rights system. Otherwise, if exercise of water rights is prohibited or restricted to levels below the historical level of use, compensation could be required. Moreover, if a local government attempted to prohibit water rights users from exercising those rights, even if compensation were provided, such action might be found to be preempted as an interference into the arena of State Engineer authority. These provisions apply to all water rights, including domestic well rights.

Although it has only rarely happened in the past, it is likely that severe droughts in the future will prompt senior water rights holders to seek priority administration of water rights by the State Engineer or by the water rights adjudication court in an area where there is an adjudication court. What that would mean is that the State Engineer or the court would order enough junior water users to cease their diversions to supply water to all the more senior water rights holders. To date, we are unaware of the State Engineer carrying out priority administration of water rights except where such administration has been authorized by a court in an adjudication. Indeed, the Carlsbad Irrigation District has been asking the State Engineer for priority administration since 1976, so far without success. During the 1996 drought, some downstream pueblos filed motions in federal court against upstream junior water users as part of the adjudication, seeking priority administration. The filings prompted water rights owners to negotiate agreements for water management during that drought.

Many people, including the State Engineer, have argued that the State Engineer cannot administer priorities unless and until adjudication of the relevant water rights is complete. Others have argued the opposite. The issue is complex. Since adjudications in this region are unlikely to be completed for many more years, the issue will probably come to a head during the next serious drought, when senior water rights owners seek priority administration. In such a circumstance, if either a court or the State Engineer commence priority administration, there will probably be lots of litigation concerning which rights can be shut off and which cannot.

As the recent debate over possible priority administration of the Pecos River confirms, priority administration would likely cause major economic disturbance, especially to municipalities and other holders of junior water rights. This should serve as a major incentive for governmental entities to do everything possible to either plan to reduce water use during drought (thus reducing or avoiding the need for a priority call) or make plans for how to cope if there is a priority call and junior water rights are shut off.

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

Developing a drought management plan will not result in any direct increase in the water supply. The primary benefit of developing the drought plan is to identify ahead of time drought mitigation measures and parties responsible for implementing those measures. To the extent that the plan incorporates water conservation measures, which may be set to correspond to various stages of drought, significant water savings could be realized. Savings resulting from water conservation measures realized by various communities are 23 percent in Albuquerque, 30 percent in Tucson, 25 percent in Los Angeles, 27 percent in Austin, 54 percent (landscape use only) in Irvine (DBS&A, 2002b), and 22 percent in Santa Fe.

6. Environmental Implications

The impacts resulting from drought management vary depending on the drought mitigation measures chosen by the region when developing a specific plan. To the extent that water conservation measures are part of the drought plan, a positive environmental impact would generally be realized. Voluntary and mandatory conservation measures can help to sustain limited water supply resources during periods of drought, resulting in positive environmental effects such as the maintenance of river flow, which benefits wildlife and riparian habitat. Other mitigation measures, such as transfer of agricultural water to urban areas during times of drought, may result in more varied impacts. Allowing farmland to be fallow during drought seasons should not have a long-term environmental impact.

The most serious environmental impact due to drought is loss of streamflow and subsequent impacts on the riparian habitat. If there is no drought plan, generally all of the flow from the rivers will be diverted by the most senior users. Development of the drought plan would enable the region to address minimum streamflow conditions, but only if the group designated to develop the plan includes that as a priority.

7. Socioeconomic Impacts

Planning for how water will be allocated during drought conditions should result in a positive socioeconomic impact as compared to facing drought conditions with no regional plan in place. The development of the drought plan will enable the various user groups to discuss drought allocation policies when emergency conditions are not present and thus time is available for greater public participation.

Conversely, if drought restrictions are set up that affect some user groups more than others, there may be a concern about socioeconomic impacts to that user group. To avoid such impacts, a drought plan must be based on accurate data regarding community water use patterns across the different types of water user groups. Failure to do so runs the risk of not only selecting ineffective mitigation measures, but of public opposition to drought management efforts due to an inequitable focus on business sectors or users who may not be the largest or most inefficient water users. However, selective targeting of specific user groups may be difficult to avoid since fairness and water use efficiency are not necessarily compatible goals. Public education is therefore important to foster community support for such restrictions.

8. Actions Needed to Implement/Ease of Implementation

The following actions would be required to develop and implement a drought plan for the region:

- Convene a meeting of water users/stakeholders to determine who would be interested in participating in developing a regional plan or in developing their own drought plan.
- Conduct technical analyses to evaluate the correlation between historical data and drought triggers and to define appropriate triggers.
- Conduct an analysis of drought vulnerability in relation to priority dates of water rights.
- Evaluate drought vulnerabilities during a potential priority administration of the Rio Grande.
- Evaluate and adopt mitigation measures. A series of meetings would be required to develop consensus on appropriate mitigation measures.

9. Summary of Advantages and Disadvantages

The advantages of drought management planning are:

- Allows public input into development of drought planning measures
- Relatively inexpensive to complete
- Prepares the region for addressing drought conditions

The disadvantages include:

- Does not result in any new supply
- May encounter public opposition regarding water restrictions
- May result in inequities that target some user groups over others

References

Daniel B. Stephens & Associates, Inc. (DBS&A). 2002a. *Alternative: Efficiently convey water to reduce loss.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002b. *Alternative: Gaining water use efficiency (reducing water use demand) in the Jemez y Sangre region.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002c. *Alternative: Groundwater desalination.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

DBS&A. 2002d. *Alternative: Optimize reservoir management / increase allowable storage.* White paper prepared for the Jemez y Sangre Regional Water Planning Council, Santa Fe, New Mexico. July 2002.

Duke Engineering & Services (DE&S). 2001. *Water supply study, Jemez y Sangre water planning region, New Mexico.* Prepared for Jemez y Sangre Water Planning Council, Sangre de Cristo Water, and City of Santa Fe, Santa Fe, New Mexico. January 2001.

Guttman, N.B. 1999. Accepting the standardized precipitation index: a calculation algorithm. *Journal of the American Water Resources Association* 35(2):311-322, April 1999.

New Mexico Drought Planning Team. Undated. *New Mexico drought plan.* http://weather.nmsu.edu/drought/drought_plan.htm. Accessed October 18, 2001.