Supporting Document G-4

Technical Feasibility Fact Sheets

Prepared by Daniel B. Stephens and Associates

Technical and Physical Feasibility Fact Sheet
Alternative 1: Bosque Management

Acknowledgements: This fact sheet was written by James Cleverly, Ph.D., of the University of New Mexico as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

Restore Bosque habitat and manage vegetation in the Bosque to reduce evapotranspiration by selectively removing vegetation and promoting native plants.

2. Summary of the Alternative Analysis

The Middle Rio Grande Water Assembly (MRGWA) and the Mid-Region Council of Governments (MRCOG) is defining a water plan (MRGWP) to identify feasible strategies for enhancing water supply while reducing water demand. This plan will cover the Middle Rio Grande (MRG) planning region, which extends from the northern border of Sandoval County to the southern border of Valencia County. In this region, there are currently 23,000 acres of bosque, 17,000 acres of which are restorable (Coonrod, 2002). Most of this area contains cottonwood forests that have been heavily invaded by high water-using, non-native vegetation.

Removal of non-native vegetation combined with natural revegetation can restore the bosque to a cottonwood-saltgrass mosaic, resulting in water savings. Replanting generally is not a recommended restoration strategy in the planning region because of the existing cottonwood overstory. Conversely, in areas where the cottonwood overstory is absent, or where cottonwoods are dying or diseased, limited pole planting may be beneficial. A mosaic of isolated cottonwood forests, wetlands, and saltgrass meadows is the best strategy for minimizing depletions through bosque restoration.

In 1997, the action committee of the MRGWA identified water demand as five key depletions in the MRG water budget: evaporation, transpiration, municipal and industrial, groundwater recharge, and agricultural. Wherever vegetation is present, the first two depletions, evaporation

Legal Feasibility Fact Sheet

Alternative 7: Agricultural Metering

Acknowledgements: This fact sheet was written by Susan C. Kery, Esq. of Sheehan Sheehan & Stelzner, P.A. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-7: Meter and manage surface water distribution flows through all irrigation systems to conserve water.

2. Assumptions

- Metering and management would occur within and by the Middle Rio Grande Conservancy District (MRGCD)
- Metering and management would result in saved water

3. Alternative Evaluation

3.1 Federal/Compact

There are no federal or compact legal issues related to this alternative.

3.2 Tribal

There are no Tribal legal issues related to this alternative. Since Pueblo lands are located within the MRGCD, any changes to MRGCD conveyance systems could impact Pueblo lands.

3.3 State

The MRGCD has been granted broad powers by the New Legislature. Such powers necessarily include the power to meter and manage surface water distribution flows through the MRGCD system.[1] As such, there are no legal barriers to metering and managing water within MRGCD, with a resulting savings in water. The only state legal issue that arises is to determine who, or which entity, has the right to use the saved water.

This alternative anticipates that the MRGCD would meter and manage surface water distribution flows throughout its system. The purpose of using such metering and management would be to increase irrigation efficiency, and save water. To determine how the saved water could be used, an understanding of MRGCD's permitted water rights is critical.

The MRGCD has two surface water permits, numbered 0620 and 1690. On November 15, 1930, the MRGCD filed Application No. 0620 for a permit to change points of diversion from the Rio Grande. The application sought to change the diversion points of 71 old ditches diverting water from the Rio Grande and located within the MRGCD. The application proposed abandoning these 71 diversion points, and constructing six new diversion dams to replace the old diversions. The application also stated the water rights claimed by the MRGCD as totaling 123,267 acres of land, of which 80,785 acres were considered pre-MRGCD irrigated acreage, and 42,482 were described as new acreage to be irrigated. Permit No. 0620 was granted by the State Engineer on January 26, 1931. Further, the State Engineer granted MRGCD the right to store 198,110 acre-feet per year at El Vado Reservoir pursuant to Permit No. 1690, issued on August 20, 1930. This is not a water right, but a right to use storage space.

In New Mexico, beneficial use is the measure of a water right (N.M. Const. art. XVI, § 3). To show beneficial use, all water right permit holders have a duty (usually implemented through a permit condition) to file with the State Engineer a "proof of beneficial use" (PBU). The MRGCD has this duty, but has not yet filed its PBU for Permit Nos. 620 and 1690. The purpose of the PBU is to enable the State Engineer to issue a license to appropriate water. Pursuant to the Rules and Regulations Governing the Appropriation and Use of the Surface Waters of the State of New Mexico, Section II.O (Aug. 1953), a license defines the extent and conditions of use

[1] NMSA 1978, § § 73-14-39, 48 (1927)

under which a water right is granted. It is limited by actual beneficial use, and cannot be extended beyond the limits prescribed in the permit. (Id.) When issued, MRGCD's license will define its right to divert, use, and store water.

It is impossible at this time to determine the ownership of any saved water resulting from more efficient use of water within the MRGCD under this alternative. Once MRGCD's license is issued, any water saved may ultimately be available to water users within the MRGCD, if such saved water falls within MRGCD's licensed right to divert, use, and store water. By way of a very simplified illustration, if MRGCD's license allows it to divert 7.1 acre-feet per acre to irrigate 100,000 acres, and through efficiencies, it is able to irrigate the same number of acres with a diversion of 6.5 acre feet per acre, any saved water could be used by the MRGCD. Conversely, if any saved water does not fall within the parameters of MRGCD's license, under the current state of the law, any saved water would return to the system as "public water".

3.4 Local

There are no local legal issues related to this alternative.

and transpiration, are combined into evapotranspiration (ET). ET describes the process by which plants take water from the soil into their roots and transport water to the leaves, where water ultimately evaporates into the atmosphere. Because leaves are where evapotranspiration occurs, it is rightly believed that management of vegetation is a method for controlling water demand within the bosque.

The US Bureau of Reclamation (Reclamation) has pursued two methods for estimating ET in the planning region—the Blaney-Criddle estimation for the action committee's 1999 water budget, and more recently the ET Toolbox. In 1997, ET in the MRG was estimated by the Reclamation using the Blaney-Criddle method (Hansen et al., 1997). The Blaney-Criddle method relies upon monthly estimates of temperature and the number of daylight hours to estimate ET. More recently, ET in the MRG has been estimated by the Reclamation using the ET Toolbox, which uses a modified Penman formulation (Sammis et al., 1985). The Penman equation simulates evaporation from open water, estimating the amount of evaporation that results from solar energy (the energy available to evaporate water), vapor pressure deficit (the difference between actual atmospheric vapor pressure and the vapor pressure of saturated air at that temperature), and wind speed. The combination of these three terms determines potential ET, that is, the amount of water lost if there is an unlimited supply of water and no vegetation. To account for various types of vegetation, a crop coefficient curve is used to adjust potential ET into an estimate of actual ET.

In the ET Toolbox, crop coefficients for saltcedar and cottonwood were developed by Dr. Salim Bawazir from eddy covariance towers at the Bosque del Apache National Wildlife Refuge (http://www.usbr.gov/rsmg/nexrad/ ettoolbox.html). The towers at Bosque del Apache are located over a dense saltcedar stand and a seven-year-old cottonwood orchard. Wherever monospecific saltcedars occur, potential ET is converted to actual ET using the Bosque del Apache saltcedar crop coefficient; likewise, cottonwood forests are assigned the cottonwood orchard coefficient. Crop coefficients developed from the University of New Mexico's Bosque del Apache ET tower agree well with Dr. Bawazir's results. At other locations listed in the assumptions Exhibit 1A), crop coefficients show a great deal of spatial variability. Due to the inability of single-site crop coefficients to resemble natural variability in forest structure, resultant ET, and other physical and biological properties of the MRG bosque, this feasibility analysis will use the University of New Mexico (UNM) ET data and associated forest properties to predict the effects of restoration on the water budget.

The ET Toolbox is a work in progress in which crop coefficients and other parameters that are poorly understood could be estimated while providing a framework for later improving those "place-holder" variables. One such parameter is the crop coefficient for wetland, wet sand, and floodwater ET. While there is one scientific, peer-reviewed publication describing measurements of wetland ET, measurement of evaporation from wet sand and floodwater continues to evade the scientific community. Unfortunately, the basis of the wetland and marsh crop coefficients in the ET Toolbox are unavailable and thus beyond the scope of scientific review (Jensen, 1998). It is important to note that these crop coefficients provided suggest wetland ET is 15 percent greater than open water ET. This is physically impossible, for the physical structure of vegetation creates aerodynamic cavities that inhibit flux of water from the point of evaporation to free air. By creating pockets of slow moving air, the driving force for vapor flux known as vapor pressure deficit is decreased from pond surface to the free atmosphere, simultaneously decreasing wetland evaporation. In fact, the cottonwood site that floods every two years (Belen-Rio Communities) transpires less than the cottonwood site in the south valley of Albuquerque, which has not flooded in recent decades.

Most of the vegetation in the bosque is phreatophytic, meaning its roots are in contact with the water table. Because the plants always have their roots in contact with the water table, depth to the water table does not impact ET when the water table is within 3 meters of the soil surface (Horton et al., 2001). This is generally the case in the Middle Rio Grande (MRG), especially within the planning region defined below. At UNM, the hydrogeoecology group has been measuring depletions due to ET since 1999. This is done using state-of-the-art micrometeorological sensors mounted on towers above various characteristic bosque forest types, both native and non-native. This fact sheet describes the results from this research, focusing upon comparisons between cottonwood forests that have and have not been invaded by non-native species, primarily saltcedar (*Tamarix chinensis*) and Russian olive (*Elaeagnus angustifolia*). Both of these species have the ability to form dense, impenetrable thickets within cottonwood forests. It is with the resultant forest leaf area that we are most concerned. Results from saltcedar forests outside the planning region will provide a basis for predicting ET depletions due to future restoration efforts within the planning region.

Restoration efforts are well underway throughout the MRG, both within and outside the planning area. In general, this involves complete removal of the understory vegetation—saltcedar, Russian olive, willow (Goodding's and sandbar), and the herbaceous ground cover. Everything except cottonwood is rendered into mulch and removed from the site to decrease fire fuel load. When sites are burned, saltcedar often resprouts to higher ET rates than before—not only does removal of saltcedar decrease fire susceptibility, but saltcedars will not be present to benefit from fire. To avoid returning and removing re-sprouted volunteers, root rakes and root plows are used to pull out the near surface root crowns of the non-natives (Taylor, 2002). John Taylor has been leading the science of saltcedar removal at Bosque del Apache for many years, and he has developed these methods, which result in very low saltcedar recolonization rates following removal. Restoration efforts are underway to 1) decrease fire danger due to dense vegetation and excessive large woody debris and 2) reduce the water demand from bosque vegetation. This fact sheet details how these objectives are met by restoration of bosque habitat and maintenance of native bosque vegetation.

2.1 Historic and Current Conditions of the Middle Rio Grande Bosque

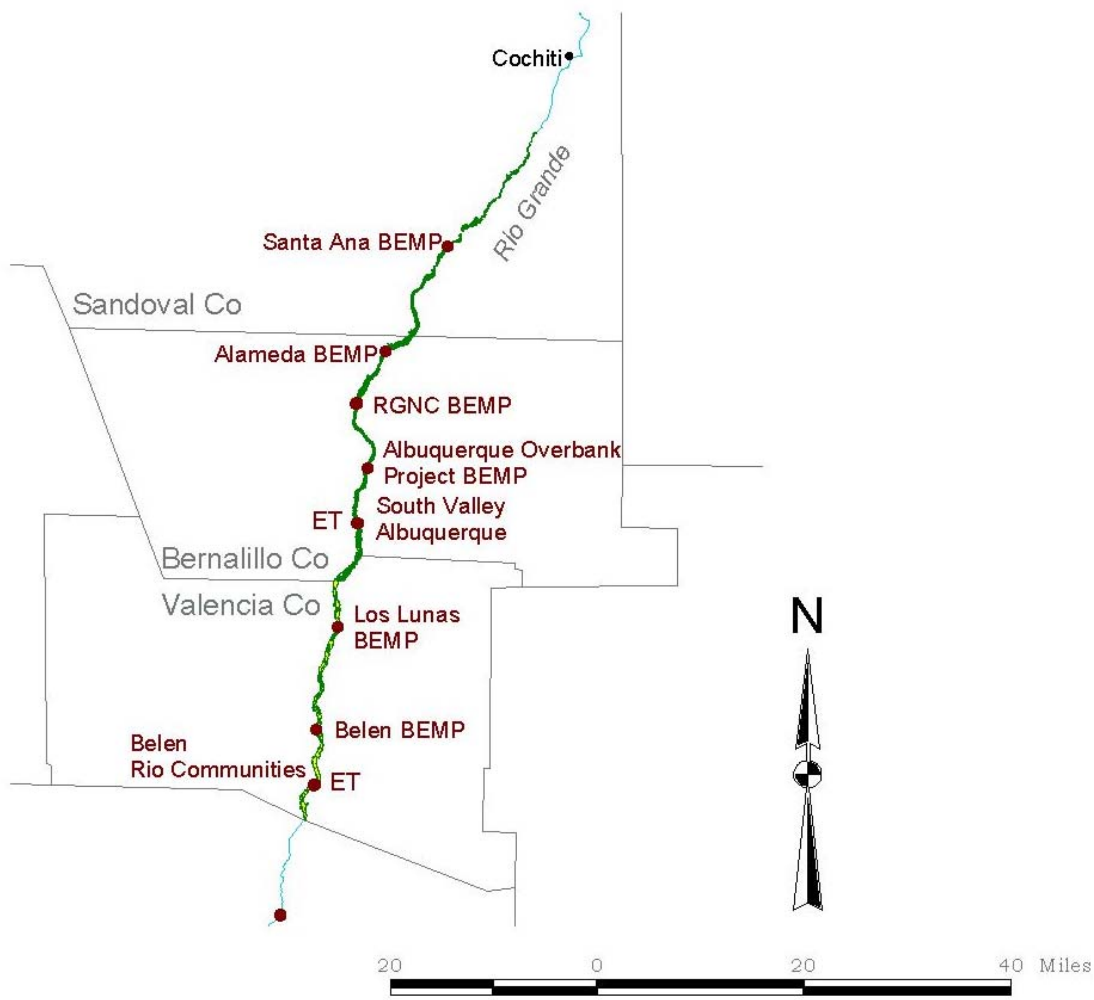
Acreage of bosque in the planning area has been provided by Dr. Julie Coonrod in association with the Middle Rio Grande Conservancy District (Coonrod, 2002). Landsat 7 ETM+ data was visually inspected to roughly identify the presence of phreatophytes in a given pixel. The Landsat scenes that were used did not extend to the extreme northern terminus of the planning region (Figure 1-1), so these results were combined with analysis of recent aerial photographs to finalize bosque acreage in the planning region. Of the estimated 23,000 acres, 17,000 acres are between the levees on the mainstem and along the Rio Puerco. The remaining 6,000 acres are not considered restorable as they are privately owned.

Dominant native species along the MRG include the Rio Grande cottonwood (*Populus deltoides* subsp. *wislizennii*), Goodding's willow (*Salix gooddingii*), sandbar willow (*Salix exigua*), seepwillow (*Baccharis salicina*), yerba mansa (*Anemopsis californica*), saltgrass (*Distichlis spicata*), and screwbean mesquite (*Prosopis pubescens*). Historically, unrestricted meandering of the MRG created a rich mosaic of variously aged cottonwood stands, isolated understory areas, dry grasslands, and wetlands (Scurlock, 1998). There are already more than enough cottonwood trees within the planning area to support restoration to historical conditions.

In Figure 1-1, vegetation composition and cover characteristics at locations marked as Bosque Ecological Monitoring Project (BEMP) sites are described in Eichhorst et al. (2001). Locations marked as ET sites contain UNM's eddy covariance ET towers. The other two ET tower sites listed in the assumptions (Exhibit 1A) are located south of the planning area. The shading

Figure 1-1. Map of the Bosque Extent within the Planning Region

Note: Green shading indicates the extent of the Middle Rio Grande bosque as shown in the 2000 Landsat data, which is abruptly cut off south of Cochiti.



around the river represents the Middle Rio Grande bosque extent as of the 2000 Landsat data, which is abruptly cut off south of Cochiti. Over 75 percent of these sites, as described in the BEMP progress report (Eichhorst et al., 2001) as well as in numerous aerial photographs, have a cottonwood overstory. Most of these trees are 30 to 50 years old and cottonwood has a maximal life expectancy of 100 years. While many of the trees will die within the next 30 years, it will take at least 40 to 50 years for the MRG within the planning area to reach cottonwood density equivalent to the late 1800s (Scurlock 1998).

Numerous exotic species have become established in the MRG bosque. Within the planning area, Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*) often form dense thickets within cottonwood forests. In the sparse forests in Valencia county, the sometimes large gaps between cottonwoods are filled with a dense cover of Russian olive and saltcedar, rather than historically low water-using saltgrass meadows. Throughout all three counties, Russian olive also forms dense thickets beneath cottonwood forests and along riverbanks.

Establishment of riparian species is dependent upon seed production during a specific flow regime, where adequate germination sites are available for these wind-dispersed seeds to land. Inundation of bars and banks, followed by declining water table in these high light environments, generally promotes establishment in many of these highly specialized riparian species, including saltcedar, cottonwood, willow, and Russian olive (Shafroth et al, 1995; Auble and Scott, 1998, Mahoney and Rood 2002). Continued reproduction of riparian phreatophytic trees within forests and on terraces is limited to clonal resprouting.

Saltcedar germinates *en masse* on sand bars and islands, producing carpets of seedlings consisting of greater than 2,000 plants m^{-2}—a density that is three times higher than that of native species (Cleverly, 1999). During the first year following germination, aboveground growth of these seedlings is very slow. Small depositional floods occurring at the end of the first growing season bury and kill most saltcedar seedlings (Gladwin and Roelle, 1998; Cleverly, 1999). Furthermore, it has been shown that these small saltcedar seedlings are vulnerable to competitive exclusion by cottonwood (Sher et al 2000). Saltcedars have established quite well in the MRG region because they can colonize these sand bars throughout the growing season, while cottonwoods only produce seeds during a 3 to 4 week window of opportunity during the late spring. Whenever saltcedar seeds germinate outside that time period, they experience no competition from cottonwood seedlings.

The distinct advantage that allows saltcedar to invade native riparian forests is its stress tolerance (Busch and Smith, 1995; Cleverly et al, 1997). Saltcedar is highly halophytic, seeming to thrive under extremely saline conditions (Kleinkopf and Wallace, 1974). After surviving short- or long-term drought and salinity, saltcedar quickly recovers its high water use physiology. In fact, stress hardening in saltcedar opens opportunities for increased dominance of floodplain ecosystems and the resultant expanded water uptake for which they are capable." (Cleverly, in review.)

Russian olive and saltcedar grow in high density, producing numerous leaves and a high leaf area index (LAI). High LAI sites like these are associated with high ET (Table 1-1). Vegetation density in these invaded sites is high due to disruptions in natural flooding regimes because the channel-bound MRG no longer meanders. Without regular inundation and drawdown, cottonwoods do not regenerate, while non-native species become more vigorous with age. This high density of vegetation contributes to increased fire danger in the bosque, following which saltcedars regenerate from underground root crowns and Russian olives regenerate by seed.

Table 1-1 summarizes information about each site, showing the dominant community, interflood interval (IFI), season length, average April through November depth to groundwater, average daily growing season (ET > 0.75) ET, and the annual cumulative ET. Error estimates are standard error of the mean.

2.2 Future Conditions without Restoration/Management

Without vegetation management along the MRG, non-native species will continue to increase their dominance while cottonwoods and other native species will decline. There are three reasons for these shifts: (1) fire favors non-native species over cottonwoods, (2) Russian olive is one of the few species riparian species that does not require flood inundation for seedling establishment, and (3) cottonwoods begin to die after 80 to 100 years.

As dominance of non-native species increases, LAI will also increase. Continually increasing vegetation density will be associated with increased occurrence of bosque fires, creating an uncontrolled spiral of depletions and property damage. If all of the 17,000 restorable acres of bosque habitat in the planning region were to increase water loss to the pre-restored South Valley of Albuquerque, depletions in the planning area would increase by up to 17,680 acre-feet.

Table 1-1. Summary Table

Site	Community	IFI	Season (days)	Depth (cm)	ET (cm/yr)	ET (mm/d)
1999 (normal spring, wet monsoon season):						
Sevilleta NWR	*T. chinensis* +	long	170	167 ± 0.1	74	3.4 ± 0.2
	Distichilus spicata					
Bosque del Apache NWR	*T. chinensis*	short	183	199 ± 0.3	122	5.4 ± 0.2
2000 (normal to dry spring, very dry monsoon season:						
Albuquerque	*P. deltoides* +	long	236	139 ± 0.1	123	5.2 ± 0.1
	T. chinensis, E. angustifolia					
Belen—Rio Communities	*P. deltoides* + natives	short	215	120 ± 0.1	98	4.6 ± 0.1
Sevilleta NWR	*T. chinensis* +	long	215	193 ± 0.1	76	3.5 ± 0.1
	Distichilus spicata					
Bosque del Apache NWR	*T. chinensis*	short	223	227 ± 0.1	111	5.0 ± 0.2
2001 (normal to wet spring, normal monsoon season):						
Albuquerque	*P. deltoides* +	long	233	138 ± 0.1	115	4.9 ± 0.1
	T. chinensis, E. angustifolia					
Belen—Rio Communities	*P. deltoides* + natives	short	236	131 ± 0.1	106	4.5 ± 0.1
Sevilleta NWR	*T. chinensis* +	long	192	198 ± 0.1	69	3.6 ± 0.1
	Distichilus spicata					
Bosque del Apache NWR	*T. chinensis*	short	214	223 ± 0.2	106	5.0 ± 0.2

Natives: Anemopsis californica (Yerba Mansa), Baccharis sp. (Seepwillow), Salix exigua (Coyote Willow), Equisetum sp. (Horsetail)

IIFI = Interflood interval cm/yr = Centimeters per year ET = Evapotranspiration mm/d = Millimeters per day
NWR = National Wildlife Refuge

2.3 Future Conditions with Understory Restoration/Management

Numerous restoration projects have been performed or are currently underway. Some of the projects south of the MRG planning region have had poor success due to poor planning; these projects did not include root crown removal. Success rates, indicated by failure of non-native species to re-establish, have improved since use of root crown removal or cut-stump applications of herbicide have become more common. The basis for projecting the future conditions with understory restoration and management will be drawn from in-progress projects that are occurring with in the planning region. These projects all take advantage of the findings of the Albuquerque overbank project and Bosque del Apache's pioneering efforts. Within the planning region, restoration and management projects are now underway in Sandoval County (Pueblo of Santa Ana and the U.S. Army Corps of Engineers [USACE]), Bernalillo County (the Middle Rio Grande Conservancy District [MRGCD], and the City of Albuquerque), and Valencia County (USACE).

The USACE projects in Santa Ana (Sandoval County) and Los Lunas (Valencia County) both include extensive modifications to surface water flow in addition to removal of non-native species. At Santa Ana, the Pueblo is placing in-stream gradient structures, thus creating habitat for the endangered silvery minnow. In Los Lunas, the USACE is cutting additional channels through the restoration site to mimic the success of the Albuquerque Overbank Project.

The Albuquerque Overbank Project (AOP) was an experiment performed by Dr. Cliff Crawford to test restoration of on-site hydrological processes as a method for creating self-managing native ecosystems. This small-scale study included removal of Russian olive and saltcedar thickets along the riverbank in association with placement of channels to facilitate establishment of native cottonwood and willow gallery forest.

Vegetation recovery at the AOP site followed a well-documented succession from initial establishment of sunflowers (most likely *Helianthus annuus* and *H. cilaris*), followed within a few short years by sandbar willow, Rio Grande cottonwood, and a few Russian olives. None of the vegetation that recurred on these experimental sandbars was planted; re-vegetation proceeded naturally under near-ideal conditions.

Considerably much less time has occurred since the implementation of the not-yet completed restoration project at Santa Ana Pueblo. Even less time has elapsed since the burgeoning restoration projects in the South Valley of Albuquerque and in Los Lunas. Some post-restoration infilling by Russian olive is possible in suitably cool and moist microclimates beneath the cottonwood canopy. Saltcedar, once root crowns are successfully removed, is slow to fill in following restoration because saltcedar establishes following inundation and drawdown as native species do. Replanting generally is not a recommended restoration strategy in the planning region because of the existing cottonwood overstory. Conversely, in areas where the cottonwood overstory is absent, or where it is needed to replace dying or diseased trees, pole planting may be beneficial. A mosaic of isolated cottonwood forests, wetlands, and saltgrass meadows is the best strategy for minimizing depletions through bosque restoration.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Two primary methods of non-native vegetation removal are being practiced in the MRG: herbicide use and mechanical removal. Often, these two methods are combined, as with the "cut-stump" method, in which non-native vegetation that was removed mechanically is treated with a direct application of herbicide onto the cut stem. Herbicide-based restoration is less expensive (approximately $180 per acre at Bosque del Apache) but is generally not as successful as mechanical removal. Mechanical removal is more expensive (approximately $600 per acre), but use of root rakes, root plows, and other methods that extract the root crowns of Russian olive and saltcedar is much more successful after 5 to 10 years (Taylor, 2002). Combination methods can be the most expensive (approximately $2,500 per acre) and have varying success rates. Mechanical removal is favored at sites where cottonwood trees are to be retained due to the toxic effect of general-use herbicides on cottonwoods. All restoration sites within the planning area contain cottonwood trees. Although root crown removal is not being used in many of the restoration projects throughout the planning region, the technology to combine a root plow with the large cranes already in use in the South Valley of Albuquerque is straightforward.

Infrastructure Development Requirements

This alternative action requires no infrastructure development. Contractors have already been identified through the numerous projects in the MRG.

Total Time to Implement

Complete implementation of this alternative will require at least 10 years and possibly up to 25 years. The City of Albuquerque has been restoring bosque habitat in the south valley of Albuquerque at a rapid rate since August 2002. This rapid restoration employs removal of understory vegetation without associated modifications to site hydrology. This project is working closely with the fuel reduction–restoration study by the MRGCD. The MRGCD's project began in 1999, actual restoration has begun in 2002, and the study will continue for 5 years. This project involves removal of non-native species, replanting of native species, and controlled burning of post-restoration sites. More hydrologically ambitious restoration projects, such as the Los Lunas project undertaken by the USACE, proceed much more slowly. However, the Los Lunas restoration project is more likely to succeed because it is modifying the on-site hydrology. Such modifications improve the probability of native species establishments and increase leaching of salts from the vadose zone.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

From a basin perspective, savings due to removal of riparian vegetation are interpreted as a decrease in water demand. In the water budget, restoration within the planning area is acknowledged as a reduction in water demand.

Effect on Water Supply (surface and ground water)

Because surface water and groundwater are immediately connected in the riparian corridor, change in ET is experienced directly as a change in surface water supply. Any impacts on the shallow alluvial aquifer are generally assumed to affect surface water supplies immediately. Therefore, restoration within the planning area is acknowledged as an increase in water supply of the same magnitude as the reduction in water demand.

Water Saved/Lost (consumption and depletions)

The total water savings due to restoration and management of all bosque habitats in the planning region is *17,680 acre-feet per year*, an average savings of 1.04 acre-feet per acre of restoration. This amount was estimated on a county-by-county basis, as described below.

LAI is an important factor in determining the effect of restoration projects upon the water budget. LAI preceding restoration is fairly well known throughout the planning region. LAI following restoration is being measured in some pilot projects, and is projected from the density of cottonwood at other sites and throughout the planning region. The change in ET is computed from the relationship between LAI and ET. Figure 1-2 shows the functional relationship between LAI and ET from monthly data taken during 2001. The equation represents the least squares regression line, and it was used to calculate the percent change in ET following a given change in LAI due to restoration activities. The LAI at the South Valley Albuquerque site following restoration activities is 2.5.

Sandoval County. The bosque community in Sandoval County consists of a narrow band of dense cottonwood forest (Figure 1-1). The Santa Ana Pueblo restoration forest is located upon a high terrace and contained a high-density Russian olive understory prior to vegetation removal. Sites like this throughout the county most likely have an unrestored LAI equivalent to the South Valley Albuquerque site, but the high density of cottonwoods sustained at this site limits the ET savings due to removal of non-native vegetation by 20 percent, from 3.9 acre-feet per acre to 3.1 acre-feet per acre restored. This represents a savings of 0.8 acre-feet per acre.

Bernalillo County. The bosque community in Bernalillo County consists of a wider band of sparser cottonwood forests. A great deal of Russian olive and saltcedar exists between the cottonwoods and chokes the forest beneath the canopy. These sites, representing 80 percent of the bosque in Bernalillo County, are characterized by the South Valley ET site maintained by UNM and the AOP site (Eichhorst et al., 2001; Dahm et al., 2002). Since restoration efforts began at the South Valley site, LAI has declined from 3.5 to 2.5, creating a projected 25 percent decline in ET, from 3.9 acre-feet per acre to 2.9 acre-feet per acre. This is a water savings of 1 acre-foot per acre.

Locations such as the Rio Grande Nature Center and Alameda account for 15 percent of the bosque in Bernalillo County. These sites maintain a savannah-like mosaic of cottonwood trees, open spaces, and non-native species (Eichhorst et al., 2001). Leaf production by cottonwoods at these sites has been steadily declining for over a decade (Molles et al., 1998). Low LAIs at these unfavorable sites limit the potential savings achieved by restoration and management. Under this alternative, sites as these would be transformed into forest mosaic savannahs, which would reduce ET by 13 percent, from 2.5 to 2.2 acre-feet per acre. This is a water savings of only 0.3 acre-feet per acre. Restoration of sites such as these, which already have sparse vegetation, will not appreciably reduce vegetative water loss in Bernalillo County.

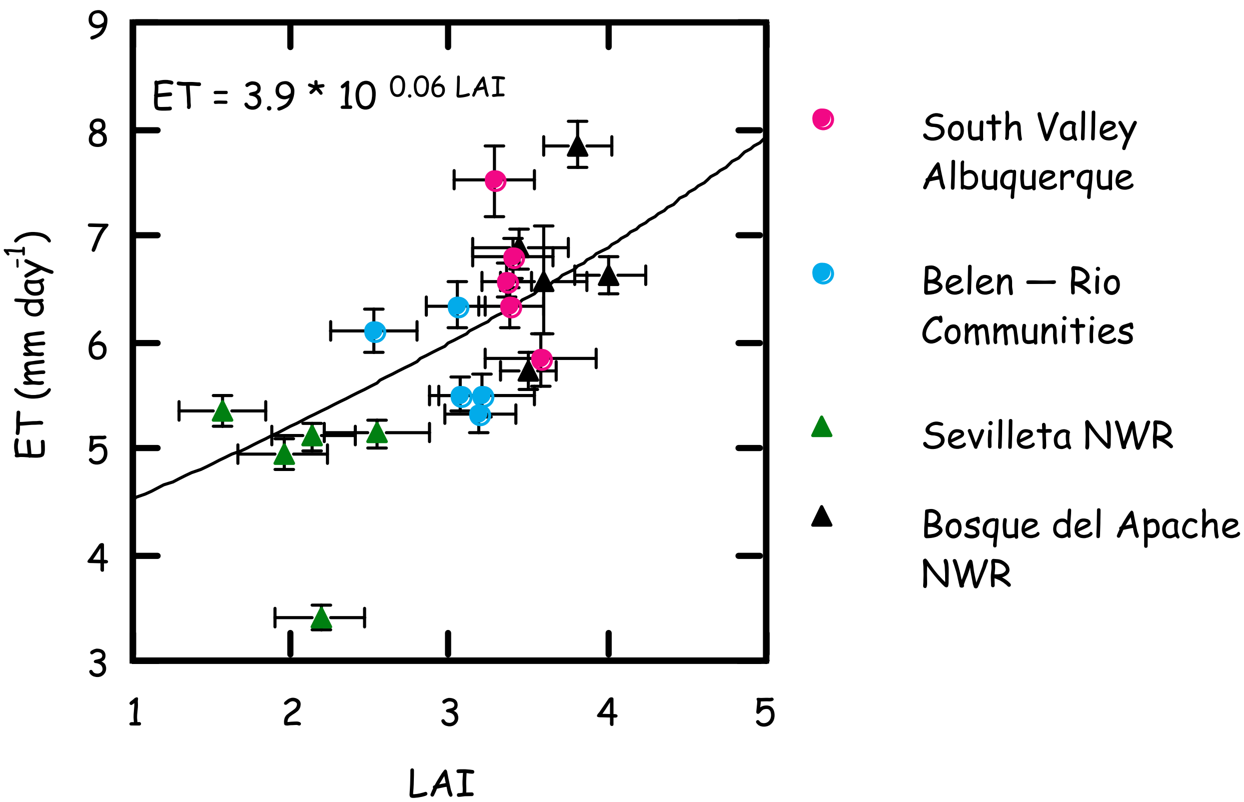


Figure 1-2. Functional Relationship Between Leaf Area Index and Evapotranspiration

The remaining 5 percent of the bosque in Bernalillo County consists of constructed wetlands and wetland restoration projects. Typically, these wetlands are located near the river, where non-native species often grow very dense. ET from a wetland can be as much as 50 percent of the water lost from a dense cottonwood or saltcedar forest (Burba et al., 1999). Wetland restoration will reduce ET by 50 percent, from 3.6 acre-feet per acre to 1.8 acre-feet per acre. This is a water savings of 1.8 acre-feet per acre.*Valencia County*. Dominance of Valencia County by shrubs and non-native species is much greater than in the other two counties (Eichhorst et al., 2001). Large spaces beneath and between cottonwoods are taken up by Russian olive and saltcedar. Restoration at such sites would produce largely cottonwood savannahs—a patchwork of cottonwood copses, saltgrass meadows, and re-vegetated willow stands in the lower terraces. Restoration of these densely invaded cottonwood forests will reduce ET by 40 percent, from 3.3 acre-feet per acre to 2.0 acre-feet per acre. This is a water savings of 1.3 acre-feet per acre.

Impacts to Water Quality (and mitigations)

This alternative has a minor effect on water quality.

Most plants cannot tolerate saline soils and will exclude salt from entering the plant at the roots. If the soil is too saline, these intolerant plants will decrease evapotranspiration until they die from lack of water. Saltcedars, however, thrive on saline soils, taking up the salts and delivering them to the surface of their leaves. While saltcedar is known for its association with saline soils, soils are not salty due to the presence of saltcedar. Saltcedars cannot “create” saline soils—the salts must already be present in the system and the presence or absence of saltcedars has very little effect on water quality.

Russian olives are known to convert atmospheric nitrogen to nitrate; Russian olive roots act as hosts to nitrogen-fixing bacteria. The presence of Russian olive does impact water quality by increasing nitrate concentration in alluvial groundwater, but it is unknown exactly how much soil nitrate concentrations might change immediately following removal of Russian olives.

Watershed/Geologic Impacts

There are no known watershed/geologic impacts caused by this alternative action.

3.1.2 Environmental Impacts

Impact to Ecosystems

The intent of all restoration projects is to impact ecosystems for the better. The greater diversity of habitats generated by restoring a mosaic of forests, wetlands, and grasslands is expected to promote a greater diversity of organisms that can use the bosque.

Implications to Endangered Species

Decreasing depletions, which is the focus of this alternative, increases the probability that the river can remain wet. Any means of increasing surface water reliability provides better assurance that the endangered silvery minnow will survive in the MRG. While the endangered willow flycatcher has been found nesting in saltcedar, maintenance of sandbar willow communities does not affect the feasibility of bosque restoration. Sandbar willow is historically limited to wet banks at the river's edge (Scurlock, 1998), and such vegetative growth is consistent with the AOP restoration model.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Costs for the projects discussed in Section 2.3 are as follows:

- Los Lunas: Mark Horner, USACE, $20,000 per acre
- Albuquerque: Ondrea Hummel, City of Albuquerque
- Albuquerque: Sterling Grogan, MRGCD, $2,500 per acre, 450 acres
- Other estimates: John Taylor, Bosque del Apache National Wildlife Refuge, $180 to $1,000 per acre

Costs for pole planting are approximately $10 per tree with labor costs on the order of $10 per hour (Means, 1999). These costs can be reduced if volunteer labor is used to plant the poles. In some cases, poles may be available (such as from the Bosque del Apache) for no cost is volunteers cut and re-plant the poles.

3.2.2 Potential Funding Source

The sources shown in Table 1-2 have provided or currently are providing funding for bosque restoration:

Table 1-2. Funding Sources for Bosque Restoration

Source	Already Funded	County
U.S. Budget, Senator Pete Dominici	$ 75,000,000	Bernalillo
City of Albuquerque	unknown	Bernalillo
Middle Rio Grande Conservancy District	$ 1,500,000	All
Bosque Initiative	unknown	All
ESA Workgroup	unknown	All

3.2.3 Ongoing Cost for Operation and Maintenance

The cost of restoration provided by Taylor (2002) includes the ongoing cost for operation and maintenance for five years. Removal of saltcedar and Russian olive root crowns, along with restoration of on-site hydrology (as with the AOP and the nascent USACE projects) greatly reduces the ability of saltcedar to return following removal. Because the success rate of non-native removal projects in the planning area range from less than 10 percent (South Valley of Albuquerque) to 50 percent (Valencia County) to nearly 100 percent (AOP), maintenance costs are estimated at 50 percent of the initial costs. These costs are incurred approximately every five years, since this is typically when full-scale removal becomes necessary again . The restoration projects from which these costs are estimated involved multiple years of minimal management. Maintenance costs in the planning region are, however, expected to be larger due to recurring costs for removing regrowth sooner at approximately half of the sites in the region..

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Technical and Physical Feasibility Fact Sheet
Alternative 9: Agricultural Conveyance

Acknowledgements: This fact sheet was written by Michael McGovern of Bohannan Huston, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-9: Develop conveyance alternatives for water transportation in agricultural irrigation systems.

2. Summary of the Alternative Analysis

This alternative analysis examines "off-farm" irrigation conveyance system efficiency and strategies for its improvement both in the Middle Rio Grande Conservancy District (MRGCD) and the smaller community ditch systems in Sandoval County (Saavedra, 1987), referred to in this fact sheet as the "small Sandoval systems". Tables 9A-1 and 9A-2 in Exhibit 9A present irrigated area and flow data for the MRGCD system. Table 9A-3, also in Exhibit 9A, illustrates the same for the 21 smaller systems in Sandoval County. As noted in the fact sheet for Alternative 7, *Agricultural Metering*, data from Wilson (1999), the MRGCD (2000), and the recent MRGCD metering study carried out by SS Papadopulos & Associates (2002) are used as the basis for this alternative analysis. Also as discussed in the analysis of Alternative 7, using irrigation efficiency indicators as the only means to measure MRGCD overall efficiency may be misleading. Implementation of off-farm conveyance efficiency measures would reduce diverted irrigation water quantities. However, reduction in diversions will not result in "new" water.

On Table 9A-1 (Exhibit 9A), the number of farms listed (USDA and NMASS, Undated) appears to be much lower than the currently estimated number of farm turn-outs that are billed by MRGCD. This is probably related, but not fully explained, by the number of farmers who have listed their occupation as full-time farmers on their federal tax returns as opposed to the number of farmers who have other primary income jobs within the study area. Table 9A-3, which contains data from Saavedra (1987), has not been field checked; however Wilson (1999) notes non-MRGCD irrigated areas of similar total acreages in Sandoval County.

It is assumed, as for Alternative 7, *Agricultural Metering*, that this analysis applies to irrigation systems that rely on both groundwater and surface water within the MRGCD. Wilson (1999) notes that groundwater is used as a water source in the three-county MRGCD region as (1) a stand-alone source and (2) in conjunction with surface water as both a primary source and as a secondary source to surface water. In the MRGCD region, surface water is used exclusively on 71 percent of all acreage, groundwater only on less than 1 percent, surface water supplemented with ground water on 21 percent, and groundwater supplemented by surface water on less than 7 percent. (Wilson, 1999). Also, as for Alternative 7, reliable flow and physical irrigation infrastructure facility and control system data are difficult to obtain. Sources of off-farm conveyance data are listed in Exhibit 9A. As no discernable reduction in irrigated acreage has been noted over the past 10 years within the MRGCD system, it is assumed in this analysis that the acreage under irrigation today will remain constant over the next 40 years.

Irrigation flow accounting in the MRGCD is complex, as system drainage water or "return flow" from upstream canal units is used as diversion water for downstream canal units. This occurs from the Cochiti Division all the way through the system to the Socorro Division. Although it is not discussed at all in the OSE water reports (Wilson, 1997 and 1999), it is a feature of the water accounting exercise presented in the SSPA (2001) report. Each of these two reports present estimated data for off-farm conveyance efficiency (E_c) in the MRGCD system, however the values presented are widely different. E_c is the factor that allows estimation mainly of water "lost" to seepage in the off-farm conveyance system. For MRGCD's irrigation system, the relationship and interplay between accounting for estimated return flow downstream from diversions and the system's E_c estimates is a major issue as a large fraction of all diverted water that flows through the system results in either drainage water return flow and/or seepage. Seepage water might be reduced and is the subject of this Alternative 9 analysis. Drainage water return flow used as downstream diversions is beyond the scope of this analysis.

To minimize the effect of this issue on the analysis and focus more on possible seepage reduction, a value of 64 percent is used as the conveyance efficiency (E_c) for MRGCD canal units located in Sandoval, Bernalillo, and Valencia Counties. This value was adopted based on general information given in Wilson (1997), who states that overall in New Mexico, 36 percent of irrigation water is lost in off-farm conveyance.

There are several ways to improve off-farm conveyance efficiency (E_c). Most involve improvements to irrigation management systems that ensure water deliveries are scheduled and measured. Such management improvements keep water in the right farming units at the right time and ensure measured deliveries with minimal wastage. A second category of enhancements to irrigation conveyance systems is through improvements to the physical infrastructure (i.e., canals). Various canal lining and piping systems have been proposed, tested, and are in use today all over the world. The most common "improved" canal lining system employs simple non-reinforced concrete lining or reinforced concrete lining on larger canals. Other materials already in use in the project area include gunite (shotcrete) and geo-membranes. Compacted clay and/or clayey soils are also employed, and combinations of each of these are sometimes used together depending on the application, the size of the canal, the local geology, maintenance requirements, and cost.

Canal lining systems, their costs, and their effectiveness at eliminating seepage have been extensively studied recently by the U.S. Bureau of Reclamation (Reclamation) Pacific Northwest Region, Water Conservation Field Services Program (2002). Over the past ten years Reclamation has constructed and evaluated over 30 test sections and canal lining projects that have addressed various materials and efficiencies. Although this work has been in a region with different geological characteristics, the experience can be useful in evaluating this alternative. Table 9A-6 (Exhibit 9A) summarizes some of the major findings of the program and provides cost information from the summary report produced as part of this study. It also includes an explanation of unit canal lining costs that are used in this analysis to project a conceptual canal lining project/program for MRGCD and the 21 small Sandoval systems.

Tables 9A-4 and 9A-5 (Exhibit 9A) summarize the diversion water reduction that would result if a canal lining project/program were to be funded and implemented on MRGCD canals and the small Sandoval systems. Note that for the MRGCD system in the three-county area, the conceptual program proposes to line only 50 percent of all main and lateral canals. This is to allow for seepage and to allow for watering of canal riparian flora in certain stretches of the canal system. The exercise takes incidental losses into account. It assumes the percentage of incidental loses (evapotranspiration) reported to be present today (U.S. BOR, 2002; Wilson, 1997) will remain after lining sections of the canal system. It is important to remember that incidental depletions are not diversions. Another major benefit that will accrue as a result of this work would be additional water available for canal "tail end" users within the MRGCD.

Seepage/lining studies need to be carried out to determine where and how much seepage is required, what type(s) of canal lining systems (concrete, liquid applied, and or geo-membrane) can be employed, and to establish the actual local unit costs that will be involved. Based on the findings of such a study, the "best choice" canal linings can be installed in appropriate areas of the Middle Rio Grande (MRG) region. Seepage studies, which are needed for both the MRGCD and the small Sandoval systems, should be based on a full hydraulic model of the intake, canal, farm, and drainage system. The cost of such studies is provided in Tables 9A-7 and 9A-8 (Exhibit 9A).

Other initiatives that could be implemented with this program include removing unwanted riparian vegetation along earthen-lined canals; straightening some sections of canal; improving canal structures; and retiring canals with few remaining users, where losses far exceed actual water deliveries. Farmers situated on retired canals could be converted to groundwater at additional savings of diverted surface water. The cost for these three activities in the MRGCD system is added in Table 9A-7 (Exhibit 9A).

The use of piping as a method to control seepage and evapotranspiration has been reviewed as part of this analysis. Although both seepage and evapotranspiration are positively affected, unless the irrigation water is free of silt and debris, there can be significant operations and maintenance (O&M) problems with the use of off-farm conveyance pipes. Pipes might be used at the tail ends of some laterals and farm canals or on-farm, but because of the O&M issues, they have been excluded from this analysis.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Table 9A-6 (Exhibit 9A) summarizes the results of Reclamation's large canal lining study in the Pacific Northwest (U.S. BOR, 2002). Other canal lining studies that include cost benefit analysis and verify the diversion water savings estimates used in this analysis have been carried out in Texas through the Texas Cooperative Extension Program's District Management System Program (TCE, 2001). For this analysis, concrete is used as the primary lining material in the MRG region; however, more study is needed on this subject. Materials and methods of construction are well known. What might be seen as new is an approach to lining that does not seek simply to minimize seepage and losses, but to control and optimize it.

Infrastructure Development Requirements

Canal lining should occur in conjunction with a developed, system-wide water budget to ensure that the desired amount of seepage occurs in planned locations. Hydraulic studies for major existing canals and systems are also needed.

Total Time to Implement

For the small Sandoval systems, this program could be implemented over a five-year period. For MRGCD, such a program might last for 15 to 20 years.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

The amount of diverted water required for irrigation will be reduced as a result of this alternative. See "water saved/lost" below for a discussion of consumptive use.

Effect on Water Supply (surface and groundwater)

The amount of water diverted for irrigation would be reduced. The question of what happens to the water that is no longer being diverted would be determined by legal considerations. From a practical perspective, fewer water diversions would mean more water stays in El Vado reservoir since water used for irrigation in the MRGCD is stored there. If less water is needed for irrigation in the MRGCD, the result would be a reduction in the quantity of water released from the reservoir. Additional water in the reservoir could be used to extend the irrigation season and provide farmers with a full water supply. Administrative changes would likely be required before any water made available through efficiency improvements in the MRGCD could be acquired, leased, or purchased by other entities.

The consumptive irrigation requirement (CIR) for the small Sandoval systems was just over 1 acre-foot per acre in 1999. Lining canals in these systems will allow for more diverted water to reach the farms. It will extend the irrigation season, thereby raising the CIR closer to or above 2.2 or 2.4 acre-feet per acre. Therefore, while the Tables 9A-4 and 9A-5 (Exhibit 9A) seem to indicate a higher conveyance efficiencies (E_c) resulting from lining, in reality such projects allow more diverted water to be delivered to system farms, especially to "tail end" farms. This would increase CIR, crop yields, and economic gain. However, Tables 9A-4 and 9A-5 do not reflect this; they simply project higher off-farm conveyance efficiencies.

This analysis projects that 25 percent of MRGCD canals and 35 percent of small Sandoval system canals will be lined to decrease seepage. Groundwater levels may be affected by this alternative through a reduction in seepage, however, the degree to which it would be affected is difficult to quantify in overall supply terms, Effects on surface water supply would seem to be substantial considering the quantity of diversion water that might be reduced.

Implementation of this alternative might result in a reduction of approximately 71,000 acre-feet of diverted water in MRGCD and the small Sandoval systems. Based on the OFWM program costs listed for the MRGCD in Table A9-7, it would cost approximately $1,700 to save 1 acre-foot of diverted water. In the small Sandoval systems, the cost to save 1 acre-foot of diverted water would be approximately $5,300.

Water Saved/Lost (consumption and depletions)

As discussed above, this alternative will primarily affect diversions. Some very minor reduction in consumptive use could occur because of slight reductions in riparian evapotranspiration on the order of 1,500 acre-feet per year (SSPA, 2003). Conversely, to the extent that this alternative results in an extension of the irrigation season, consumptive use could increase due to reservoir evaporation and additional crop irrigation.

In considering savings in seepage losses, it is important to note that water which seeps from canals is a source of recharge to the shallow groundwater in the area. With the exception of the slight reductions in riparian evapotranspiration described above, changes in seepage do not affect depletions.

Impacts to Water Quality (and mitigations)

Water quality impacts are unknown over the long term. Manageable impacts from increased silt may occur during construction.

Watershed/Geologic Impacts

Under this alternative, more water would be stored in El Vado reservoir or possibly available for other beneficial uses. Seepage reductions need further study to evaluate their impact on the Rio Grande bosque.

3.1.2 Environmental Impacts

Impact to Ecosystems

These impacts should be minimal if lining project is planned to minimize impacts. Reductions in canal seepage could potentially affect the Rio Grande bosque and vegetation along canals. Impacts would need to be evaluated for specific canals. Overall, this impact could be mitigated by selective lining.

Implications to Endangered Species

Conserved water stored in upstream reservoirs would increase operational flexibility and may, therefore, increase management alternatives for maintaining endangered species habitat.

Financial Feasibility

3.1.3 Initial Cost to Implement

Tables 9A-7 and 9A-8 (Exhibit 9A) summarize the capital costs for canal-lining projects/programs in the MRGCD and in the 21 small Sandoval systems. These programs are normally funded through bonding and user fees in irrigation districts that are focused on large-scale production agriculture. Canal lengths for MRGCD and the Sandoval systems have been extrapolated from data obtained from SSPA (2002) and from actual acequia reconnaissance surveys conducted by DBS&A in 2001 and 2002 (DBS&A, 2002).

3.1.4 Potential Funding Source

For the MRGCD, financing could be obtained through federal government agencies and/or state of New Mexico agencies. Considering the large reduction in diversion water that might be realized, the costs may appear attractive. Participation from MRGCD users and city and county residents (non-users) who enjoy the benefits of the “valley garden” should be considered. See fact sheet for Alternative 59, *Severence Tax*.

The small Sandoval systems can obtain external funding now through the U.S. Army Corps of Engineers (USACE) irrigation system rehabilitation program as funded through the Water Resources Development Act of 1986 (Public Law 99662) and the NM Interstate Stream Commission Acequia Restoration Program funded through the state of New Mexico's Irrigation Works Construction Fund. The USACE program provides a federal grant that will cover 85 percent of costs with a 15 percent local entity participation requirement. The NM state program also allows for additional grant monies to be applied to the same project lowering the local share to 5 percent of the total construction and overall project cost.

3.1.5 Ongoing Cost for Operation and Maintenance

Because lined canals are less costly to maintain than earthen canals, this alternative should result in a lower annual maintenance cost for the system. This item has not been costed separately as it would be a net decrease in maintenance costs. In any irrigation system, however, operation and maintenance costs should be recouped from the beneficiaries of the irrigation system and its operation

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Alternative 9

Exhibit A
Calculation Spreadsheets

TABLE 9A-1: MRGCD Irrigation System, Rio Grande Drainage Basin, Sandoval, Bernalillo, and Valencia County, New Mexico

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1	Reported Irrigated Acreages	MRGCD Handout, *Estimated Irrigated Acreage as of July 2000*, MRGCD, 4/2001
2	Reported Irrigated Acreages	Gore, C., et. al., *New Mexico Agricultural Statistics 2000*, USDA (number of farms from 2000 Census data [probably full time farms])
3	Reported Irrigated Acreages	Wilson, B., Water Use by Categories in NM Counties and River Basins and Irrigated Acreage, NM OSE, 1999
4	Reported Irrigated Acreages	S.S. Papadopulos & Assoc., Inc. (SSPA), *MRGCD Efficiency and Metering Program*, NM ISC, Table 4.4, December 2002
5	Number of MRGCD Customers	13,000 (12000 - 14,000 from MRGCD Billing Records)
6	Consumptive Irrigation Requirement	2.2 acre-feet/acre S.S. Papadopulos & Assoc. *(CIR values should be viewed as estimates, not measured values)*
7	It is assumed that all irrigated areas include fallow but not idle lands. Incidental depletions are not broken out in this exercise.	

#	County	Reported Irrigated Area[1] (2000)	Reported Irrigated Area[2] (less non MRGCD systems) (2000)	Reported Irrigated Area[3] (1999)	Reported Irrigated Area[4] (2001)	Number of Farms (see Note #2)	Number of Billed Customers (see Note #5)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
		acres	acres	acres	acres	#	#
1	Sandoval	6,733	4,712	6,075	8,008	353	3,143
2	Bernalillo	12,870	9,190	8,760	9,291	468	4,167
3	Valencia	30,938	23,674	20,798	28,459	639	5,690
	Totals	**50,541**	**37,576**	**35,633**	**45,758**	1,460	13,000

TABLE 9A-2: MRGCD Irrigation System Characterization

Notes and Assumptions

1 MRGCD Irrigation system diversion, incidental loss, consumptive use, and return flow accounting is complicated by the use of return flows for source irrigation diversions in downstream canals. ***For the purpose of this exercise, use MRGCD acreage data, at a CIR of 2.2 acre-feet per acre, use Wilson B., 1999 conveyance efficiency and incidental depletion coefficients. Use 64% as on-farm efficiency, assuming that there is a straight 36% losses to seepage as reported as average in New Mexico in Wilson (1997).***

This exercise then attempts to exclude to the extent possible any return flow from upstream irrigated areas being counted as diversion water for downstream irrigated land.

#	County	Reported Irrigated Area[1] (2000)	On-farm Irrigation Efficiency (E_f)	Farm Delivery Requirement	Off-farm Conveyance Efficiency (E_c)	Total System Diversion Requirement	System Diversion Requirement per Acre
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
		acres	%	acre-feet	%	acre-feet	acre-feet
1	Sandoval	6,733	48%	30,860	64%	48,218	7.2
2	Bernalillo	12,870	48%	58,988	64%	92,168	7.2
3	Valencia	30,938	50%	136,127	64%	212,699	6.9
		50,541		**225,974**		**353,085**	**7.0**

TABLE 9A-3: Non MRGCD Irrigation Systems, Rio Grande Drainage Basin Sandoval County, New Mexico

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1	All NM OSE Data:		Saavedra, Paul, *Surface Water Irrigation Organizations in New Mexico*, NM Office of the Sate Engineer, Santa Fe, New Mexico, March 1987
2	Average ditch data from 14 ditches reporting		
3	Consumptive Irrigation Requirement (CIR)	1.13 acre-feet/acre	Wilson, B., *Water Use by Categories in NM Counties and River Basins and Irrigated Acreage*,
	(CIR values should be viewed at estimates not measured values)		1999
4	No data in OSE reference:		

#	Name of Community Ditch or Acequia	Source	Reported Irrigated Area	Largest Farm Unit	Smallest Farm Unit	Farms	Avg. Farm Size	Est. Consumptive Irrigation Requirement
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
			acres	acres	acres	#	acres	acre-feet
1	Upper West Ditch	Jemez River	53.40	39.40	0.90	8	6.68	60
2	East Lateral	Jemez River	10.60	5.40	1.00	4	2.65	12
3	Jemez Spring Ditch	Jemez River	43.90	6.20	0.10	37	1.19	50
4	West Side Ditch	Jemez River	9.12	1.50	0.20	19	0.48	10
5	West Ditch	Jemez River	9.80	8.10	0.06	4	2.45	11
6	South Upper Ditch	Jemez River	15.60	9.80	0.04	7	2.23	18
7	San Ysidro Ditch	Jemez River	484.50	99.90	0.06	54	8.97	547
8	East and West Sandoval Ditch	Jemez River	30.50					34
9	La Jara Ditch	La Jara Creek	1,400.00	150.00	10.00	63	22.22	1,582
10	Placitas Community Ditch	Las Huertas Creek	150.00					170
11	Lagunitas Community Ditch	Nacimiento Creek	92.00					104
12	Nacimiento Comm. Ditch Assoc.	Nacimiento Creek	713.50	34.00	0.04	101	7.06	806
13	Ponderosa Community Ditch	Paliza Creek (Vallecitos Ck.)	319.10			101		361
14	Canon Community Ditch	Rio Guadalupe	192.50	26.00	0.40	48		218
15	Vallecitos Ditch	Rio Puerco	117.00	24.00	5.00	9	13.00	132
16	Rio Puerco Ditch	Rio Puerco	100.00					113
17	Ortiz Ditch	Rio Puerco	7.00	34.10	0.04	101	0.07	8
18	Garcia Lucero Ditch	Rio Puerco	400.00					452
19	Acequia De Los Utes	Rito los Utes	40.00					45
20	Los Pinos Ditch	Rito los Pinos	397.00	75.00	8.00	12	33.08	449
21	La Cueva Ditch	La Jara Creek	53.40	39.40	0.90	8	6.68	60
		Total Irrigated Acreage	**4,638.92**					**5,242**
		Total Number of Ditches	21					
		Total Number of Ditches w/complete data	14					
		Average Ditch Data	**220.90**	**39.49**	**1.91**	**34**	**7.63**	250
		Total Number of Farms (est.)				608		

TABLE 9A-4: MRGCD Irrigation System, Off-Farm Conveyance Efficiency Estimate - 2001

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1	Estimated consumptive irrigation requirement	2.2	acre-feet *(CIR values should be viewed at estimates not measured values)*
2	% of canals proposed to be lined	20%	
3	Assumed seepage reduction	40%	(Worst seepage problems are in areas of most permeable soils. Seepage does not occur uniformly along all canal length.)
4	Concrete lining	75%	efficient
5	In column 11 incidental off-farm depletions (ID) are subtracted from possible diversion water reduction. ID coefficient from Wilson, B. (1999)		
6	It is assumed that irrigated areas include fallow but not idle lands		
7	For off-farm canal length, see Table A9-7		

						Existing		Proposed		
#	County	Reported Irrigated Area	Off-Farm Canal Length	Consumptive Irrigation Use	Farm Delivery Requirement	Losses in Off-Farm Canals	System Diversion Requirement	Losses in Off-Farm Canals	System Diversion Requirement	Possible Diversion Water Reduction
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
		acres	feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet
1	Sandoval	6,733	911,545	14,813	30,860	17,359	48,218	7,811	38,671	**9,261**
2	Bernalillo	12,870	1,061,775	28,314	58,988	33,180	92,168	14,931	73,919	**17,702**
3	Valencia	30,938	1,541,063	68,064	136,127	76,572	212,699	34,457	170,584	**40,851**
	Totals	**50,541**	3,514,382	**111,190**	225,974	127,111	**353,085**	57,200	**283,174**	**67,813**
	miles		*665.6*							

Est. Existing Diversion (acre-foot per acre)	7.0
Est. New Diversion (acre-foot per acre)	5.6

	Before	After
Total System Irrigation Efficiency (E_i)	31.5%	39.3%
Off-farm conveyance efficiency (E_c)	**64.0%**	**79.8%**
On-farm irrigation efficiency (E_f)	49.2%	49.2%

TABLE 9A-5: Non MRGCD Irrigation Systems, Off-Farm Conveyance Efficiency Estimates, Sandoval County, New Mexico

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1	Total system main-canal length estimated at	89	ft per acre of irrigated land [1]	[1] McGovern, M; Marez, J., *Assessment Report for the Santa Cruz Irrigation*
2	Total system D-canal length estimated at	54	ft per acre of irrigated land [1]	*District Acequias*, DB Stephens & Assoc., July 2002 (Adjusted est. of
3	Off-farm conveyance efficiency (E_c)	70%	Ref [2]	acequia canal lengths measured from aerial photos for 15 acequias.
4	On-farm irrigation efficiency (E_f)	50%	Ref [2]	[2] Wilson, B., *Water Use by Categories in NM Counties and River Basins*
5	Estimated consumptive irrigation use	1.13	acre-feet Ref [2]	*and Irrigated Acreage,* 1999
6	In column 11 incidental off-farm depletions (ID) are subtracted from possible diversion water reduction. ID coefficient from Wilson, B. (1999)			
7	% of canals proposed to be lined	35%	to reduce seepage by 60%	(estimate)
8	Concrete lining	75%	efficient	

#	Name of Community Ditch or Acequia	Reported Irrigated Area	Off-Farm Canal Length	Consumptive Irrigation Use	Farm Delivery Requirement	Existing: Losses in Off-Farm Canals	Existing: System Diversion Requirement	Proposed: Losses in Off-Farm Canals	Proposed: System Diversion Requirement	Possible Diversion Water Reduction
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
		acres	feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet
1	Upper West Ditch	53	7,636	60	121	52	172	16	136	**35**
2	East Lateral	11	1,516	12	24	10	34	3	27	**7**
3	Jemez Spring Ditch	44	6,278	50	99	43	142	13	112	**29**
4	West Side Ditch	9	1,304	10	21	9	29	3	23	**6**
5	West Ditch	10	1,401	11	22	9	32	3	25	**6**
6	South Upper Ditch	16	2,231	18	35	15	50	5	40	**10**
7	San Ysidro Ditch	485	69,284	547	1,095	469	1,564	141	1,236	**319**
8	East and West Sandoval Ditch	31	4,362	34	69	30	98	9	78	**20**
9	La Jara Ditch	1,400	200,200	1,582	3,164	1,356	4,520	407	3,571	**921**
10	Placitas Community Ditch	150	21,450	170	339	145	484	44	383	**99**
11	Lagunitas Community Ditch	92	13,156	104	208	89	297	27	235	**61**
12	Nacimiento Comm. Ditch Assoc.	714	102,031	806	1,613	691	2,304	207	1,820	**469**
13	Ponderosa Community Ditch	319	45,631	361	721	309	1,030	93	814	**210**
14	Canon Community Ditch	193	27,528	218	435	186	622	56	491	**127**
15	Vallecitos Ditch	117	16,731	132	264	113	378	34	298	**77**
16	Rio Puerco Ditch	100	14,300	113	226	97	323	29	255	**66**
17	Ortiz Ditch	7	1,001	8	16	7	23	2	18	**5**
18	Garcia Lucero Ditch	400	57,200	452	904	387	1,291	116	1,020	**263**
19	Acequia De Los Utes	40	5,720	45	90	39	129	12	102	**26**
20	Los Pinos Ditch	397	56,771	449	897	385	1,282	115	1,013	**261**
21	La Cueva Ditch	53	7,636	60	121	52	172	16	136	**35**
	Totals	**4,639**	663,366	5,242	10,484	4,493	14,977	1,348	11,832	**3,051**

Est. Existing Diversion (acre-foot per acre)	3.2
Est. New Diversion (acre-foot per acre)	2.6

	Before	After
Total System Irrigation Efficiency (E_i)	35.0%	44.3%
Off-farm conveyance efficiency (E_c)	**70.0%**	**88.6%**
On-farm irrigation efficiency (E_f)	50.0%	50.0%

TABLE 9A-6: Canal Lining Technologies and Cost Estimates

Notes and Assumptions

1 Data Source:

this analysis sh [1] Swihart, J., Haynes, J., *Canal Lining Demonstration Project, Year 10 Final Report*, Bureau of Reclamation
Denver Technical Service Center Civil Engineering Services, Pacific Northwest Region, November 2002
(unit costs have been increased by 75% to account for initial costs in 1990 and other tech. service costs)

2 Construction Cost Includes:
- a contractor mobilization/demobilization
- b supply of liner materials
- c subgrade preparation
- d installation
- e contractor OH and profit

Type of Lining	Construction Cost	Maintenance Cost	Seepage Reduction	Durability
	$/sq.ft.	$/sq.ft.	%	years
Fluid Applied Membrane	$ 5.02	$ 0.01	90%	12.5
Concrete Alone	$ 4.08	$ 0.01	75%	50
Exposed Geomembrane	$ 2.68	$ 0.01	90%	17.5
Geomembrane with Concrete Cover	$ 4.45	$ 0.01	95%	50

Chose Concrete lining technique because:

1 known technology
2 low cost, good seepage efficiency, long life, easy to repair
3 ditch shapes can be made standard for easy maintenance

A MRGCD Main Canals (concrete lining)

Canal Shape	Trapezoidal
Typ. Canal Dimensions	bottom w = 25 ft., height = 8 ft., side slopes are 3:1
Sq ft. per foot	41.5
Cost per foot	$ 169.22

B MRGCD Lateral Canals (concrete lining)

Canal Shape	Trapezoidal
Typ. Canal Dimensions	bottom w = 6 ft., height = 4 ft., side slopes are 3:1
Sq ft. per foot	14.5
Cost per foot	$ 59.12

C Non MRGCD Main Canals (concrete lining)

Canal Shape	Trapezoidal
Typ. Canal Dimensions	bottom w = 10 ft., height =5 ft., side slopes are 3:1
Sq ft. per foot	20.5
Cost per foot	$ 83.59

D Non MRGCD D-Canals (concrete lining)

Canal Shape	Trapezoidal
Typ. Canal Dimensions	bottom w = 4 ft., height = 4 ft., side slopes are 3:1
Sq ft. per foot	12.2
Cost per foot	$ 49.75

TABLE 9A-7: MRGCD Irrigation System, Proposed Off-Farm Canal and Conveyance Improvements

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1 Canal Lengths (acres per mile of canal) — S.S. Papadopulos & Assoc., Inc., *MRGCD Efficiency and Metering Program*, NM Interstate Stream Commission, December 2002

County	Total (acres served per mile of canal)	Total footage	Main Canal -ft (assume 40% of total)	D-Canal -ft (assume 60% of total)
Sandoval	**39**	911,545	364,618	546,927
Bernalillo	**64**	1,061,775	424,710	637,065
Valencia	**106**	1,541,063	616,425	924,638

2 Percentage of canals to be lined — 25%

3 Cost estimates include no project financing costs

4 It is assumed that irrigated areas include fallow but not idle lands

#	County	Source	Approximate Irrigated Area	Off-Farm Main Canal Length	Off-Farm D-Canal Length	Cost to Line Main Canals	Cost to Line D-Canals	Total Cost to Line Canals
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
			acres	feet	feet	$	$	$
1	Sandoval	Rio Grande	6,733	364,618	546,927	$ 15,424,816	$ 8,084,090	**$ 23,508,907**
2	Bernalillo	Rio Grande	12,870	424,710	637,065	$ 17,966,958	$ 9,416,418	**$ 27,383,376**
3	Valencia	Rio Grande	30,938	616,425	924,638	$ 26,077,284	$ 13,667,010	**$ 39,744,294**
			50,541					**$ 90,636,577**

Capital Project Cost Estimate

Item	$	Amount	%	
Total of MRGCD Lining (construction only)	$	90,636,577		
Add cost of new diversions/structures	$	13,595,487	15.0%	(includes other activities to reduce diversions [vegetation removal, retirement of canals])
Add Contingencies	$	4,531,829	5.0%	
Add Feasibility Studies	$	906,366	1.0%	
Add Environmental Studies (CWA, NEPA, ESA, e.g.)	$	453,183	0.5%	
Add Engineering, Surveying, other services	$	10,876,389	12.0%	
Grand Total	**$**	**120,999,831**		
Possible Diverted Water Savings (acre-feet)		**67,813**		
Cost per acre foot of diverted water reduced	**$**	**1,784**		
15 Years to Implement Program	**$**	**8,066,655**	per year	

TABLE 9A-8: Non MRGCD Irrigation Systems, Proposed Off-Farm Conveyance Improvements

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1	Total system main-canal length estimated at	89	ft per acre of irrigated land
2	Total system D-canal length estimated at	54	ft per acre of irrigated land
3	Percentage of canals to be lined	35%	

#	Name of Community Ditch or Acequia	Source	Approximate Irrigated Area	Off-Farm Main Canal Length	Off-Farm D-Canal Length	Cost to Line Main Canals	Cost to Line 65% D-Canals	Total Cost to Line Canals
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
			acres	feet	feet	$	$	$
1	Upper West Ditch	Jemez River	53.4	4,753	2,884	$ 139,042	$ 50,206	$ 189,249
2	East Lateral	Jemez River	10.6	943	572	$ 27,600	$ 9,966	$ 37,566
3	Jemez Spring Ditch	Jemez River	43.9	3,907	2,371	$ 114,306	$ 41,274	$ 155,581
4	West Side Ditch	Jemez River	9.1	812	492	$ 23,747	$ 8,575	$ 32,321
5	West Ditch	Jemez River	9.8	872	529	$ 25,517	$ 9,214	$ 34,731
6	South Upper Ditch	Jemez River	15.6	1,388	842	$ 40,619	$ 14,667	$ 55,286
7	San Ysidro Ditch	Jemez River	484.5	43,121	26,163	$ 1,261,536	$ 455,522	$ 1,717,058
8	East and West Sandoval Ditch	Jemez River	30.5	2,715	1,647	$ 79,416	$ 28,676	$ 108,091
9	La Jara Ditch	La Jara Creek	1,400.0	124,600	75,600	$ 3,645,305	$ 1,316,266	$ 4,961,571
10	Placitas Community Ditch	Las Huertas Creek	150.0	13,350	8,100	$ 390,568	$ 141,028	$ 531,597
11	Lagunitas Community Ditch	Nacimiento Creek	92.0	8,188	4,968	$ 239,549	$ 86,497	$ 326,046
12	Nacimiento Comm. Ditch Assoc.	Nacimiento Creek	713.5	63,502	38,529	$ 1,857,804	$ 670,826	$ 2,528,629
13	Ponderosa Community Ditch	Paliza Creek (Vallecitos Ck.)	319.1	28,400	17,231	$ 830,869	$ 300,015	$ 1,130,884
14	Canon Community Ditch	Rio Guadalupe	192.5	17,133	10,395	$ 501,229	$ 180,987	$ 682,216
15	Vallecitos Ditch	Rio Puerco	117.0	10,413	6,318	$ 304,643	$ 110,002	$ 414,646
16	Rio Puerco Ditch	Rio Puerco	100.0	8,900	5,400	$ 260,379	$ 94,019	$ 354,398
17	Ortiz Ditch	Rio Puerco	7.0	623	378	$ 18,227	$ 6,581	$ 24,808
18	Garcia Lucero Ditch	Rio Puerco	400.0	35,600	21,600	$ 1,041,516	$ 376,076	$ 1,417,592
19	Acequia De Los Utes	Rito los Utes	40.0	3,560	2,160	$ 104,152	$ 37,608	$ 141,759
20	Los Pinos Ditch	Rito los Pinos	397.0	35,333	21,438	$ 1,033,704	$ 373,255	$ 1,406,960
21	La Cueva Ditch	La Jara Creek	53.4	4,753	2,884	$ 139,042	$ 50,206	$ 189,249
		Totals	**4,638.9**	412,864	250,502	$ 12,078,771	$ 4,361,466	**$ 16,440,237**

Total of non MRGCD lining (construction only)	$	16,440,237		
Add cost of new diversions/structures	$	2,466,036	15.0%	
Add Contingencies	$	822,012	5.0%	
Add Feasibility Studies	$	246,604	1.5%	
Add Environmental Studies (CWA, NEPA, ESA, e.g.)	$	82,201	0.5%	
Add Engineering, Surveying, other services	$	1,972,828	12.0%	
Grand Total	**$**	**22,029,918**		(includes no annual financing costs)
Possible Diverted Water Savings (acre-feet)		**3,051**		
Cost per acre foot of diverted water reduced	**$**	**5,389**		
7 Years to Implement Program	**$**	**3,147,131**	per year	

Technical and Physical Feasibility Fact Sheet
Alternative 10: Irrigation Efficiency

Acknowledgements: This fact sheet was written by Michael McGovern of Bohannan Huston, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-10: Develop and employ alternatives to maximize irrigation efficiency on all irrigated land in the region.

2. Summary of the Alternative Analysis

The measures introduced and outlined in this fact sheet as part of the Alternative 10 analysis offer the potential for relatively large reductions in total water diverted for irrigation purposes in the study area. However, coordinated planning is needed to ensure that, together with the measures outlined in the fact sheets for Alternative A-7, *Agricultural Metering*, and A-9, *Agricultural Conveyance*, these improvements are feasible at the farm level. Also, the planning of all irrigation system improvements should start with an examination of expected responses from and impacts to farmers and farms.

This alternative examines on-farm water efficiency and conservation measures that can reduce the quantity of water that must be delivered to a farm in order to satisfy crop water requirements (farm water delivery requirement [FDR]). Reduction of farm water deliveries will reduce diverted irrigation water quantities at the system level (intake point of diversion). It does not, however, result in "new" water because the irrigation consumptive requirement (CIR) does not change unless irrigated acreage is reduced or lower water use crops are introduced. However, on-farm efficiencies will slightly reduce incidental depletions.

The study area for this alternative includes the MRGCD system and the smaller community ditch and acéquia systems in Sandoval County, referred to in this analysis as "small Sandoval systems." From interviews with farmers and agricultural professionals in the planning region, it is likely that many large and some small farmers in all three counties have already implemented some of the measures proposed in this fact sheet. Therefore projected efficiency gains presented in this analysis are only estimates and should not be considered hard data. Much additional study of on-farm water management, farming methods, and farm infrastructure should be completed to determine which on-farm improvements would be most suitable for the different types of irrigation that occur within the MRGCD as well as the small Sandoval systems.

Acreages used to develop this alternative analysis are taken from existing publications. For the small Sandoval systems, Saavedra (1987) was used. MRGCD 2000 data is used as the basis for acreages within the MRGCD system. Table 10A-1 (Exhibit 10A) lists available data and also shows the estimated number of farms in the MRGCD and in the small Sandoval systems. This estimate is extrapolated from uncertain data and should only be viewed as a best guess.

2.1 On-Farm Water Efficiency

On-farm water efficiency (E_f) is a simple ratio of the quantity of water taken up or consumed by crops, including evapotranspiration (ET), divided by the quantity of water delivered to a farm. Both SS Papadopulos & Associates, Inc. (SSPA, 2002) and Wilson (1997 and 1999) report on-farm efficiencies throughout the planning region at 50 percent. This means that 50 percent of water delivered to a typical farm turn-out is taken up by crops, while the remaining 50 percent resulting in incidental on-farm losses (consumption), deep percolation seepage, and drainage away from the farm that returns to source.

On-farm efficiency is affected by several factors (Kay, 1986):

- *Farm layout*: The shape and slope of the farmed areas used in basin (flood), and border irrigation systems affect the farm's ability to promote efficient root zone saturation without deep percolation loss.
- *Soil types*: Differing soil types in a farm or in several basins can cause uneven watering effectiveness and extremely high deep percolation losses.
- *Land preparation practices*: Land leveling needs to be done every five to ten years to ensure that water does not pond and that water flows freely in basins.

- *Farm canal condition*: Large amounts of water can be lost to seepage in on-farm canals.

- *On-farm water management (OFWM):* A broad term that means supplying crops with the right amount of water at the right time, without wasting water and as economically possible.

- *Irrigation scheduling*: Scheduling of on-farm water deliveries can help maximize crop yields.

- *Methods of irrigation:* These include flood (basin), border, furrow, or micro-irrigation.

On-the-job training for farmers also contributes to improved on-farm water efficiency (FAO, 1990).

On-farm water conservation is also related to the type of crop that is being grown, as crops have different water requirements and some crops lend themselves more readily to efficient irrigation methods than others. Within the planning region, much of the irrigated agricultural land is planted in forage crops such as alfalfa and hay; basin (flood) and border irrigation are the most common methods of irrigation for these crops. Although flood irrigation is generally considered wasteful compared to furrow or other micro-irrigation methods, border irrigation can be as much as 80 percent efficient, while flood or basin on-farm irrigation can be as much as 90 percent efficient (Kay, 1986). In other words, with border or flood irrigation, 80 to 90 percent of the FDR could be taken up in crop ET (consumption) with 10 to 20 percent of the FDR resulting in seepage or drainage.

2.2 On-Farm Water Efficiency in the MRG Planning Region

A more realistic "best case" on-farm efficiency target for the MRGCD and the small Sandoval systems is probably between 65 to 70 percent. In general, operators of large "production agriculture" type farms are better able to invest resources into improving on-farm infrastructure that result in high efficiency rates. However, the MRG region has many "part-time" farmers who are less likely to have sufficient capital to make the investments needed to maximize efficiency, thus, the overall expected efficiency will be lower.

Table 10A-2 (Exhibit 10A) summarizes possible diverted water savings that might accrue as a result of on-farm water management improvements. These include improved land preparation activities, laser leveling, on-farm metering, and improved on-farm water management practices such as on-farm canal lining and/or piping. Sources for estimated on-farm efficiency gains that might be achieved are provided in Table 10A-2.

In addition to availability of water and water use, other factors that influence the feasibility of implementing on-farm efficiency in the study area include:

- *Farm and farmer data*: A profile of farming and farmers in the region is needed to understand which measures are most feasible, would likely produce the most diverted and/or consumptive water reduction, and would be most cost-effective. For example, in the MRGCD system irrigation is provided for production farms, supplemental-income generating farms, and other uses such as landscaped areas and non-agricultural field watering. Feasible on-farm and on-site efficiency and conservation measures are likely to be different for each of these types of irrigation

- *Agricultural markets*: In addition to factors such as crop water usage, agricultural markets must be considered. Although alfalfa, one of the major regional crops, has a relatively high crop water requirement, it also has a strong local and regional market. In 1999, alfalfa sales alone netted the study area close to $11 million (USDA and NMASS, date unknown). Whether other lower consumptive use type crops could be grown on smaller farms in the planning area is discussed in fact sheet for A-11, *Low-Water Crops.*

- *Farm labor*: Farm labor is both scarce and expensive in the study area. Conservation and efficiency measures might change the manner in which irrigation occurs requiring more farm labor to prepare the land, plant the seed, irrigate, apply fertilizers and pesticides, maintain on-farm canals and earthen structures, and generally manage irrigation and drainage water flows. Production farmers in the region may have more access to and can more easily afford additional labor. Smaller farmers will be unable to readily locate or afford this labor.

Table 10A-3 (Exhibit 10A) outlines an OFWM project that could be funded and implemented within the planning area to address many of the technical on-farm issues as well as some of the other feasibility issues mentioned. The goal of such a project would be improve water management in a manner that sustains agriculture in the MRG planning region (MRGCD and the 21 small Sandoval systems).

For purposes of this fact sheet, known on-farm water conservation and irrigation efficiency measures (Kay, 1986, CNA, IMTA, and IWRA, 1994; Vickers, 2001) have been applied to both the MRGCD and the small irrigation systems in Sandoval County (Tables 10A-2 and 10A-3 in Exhibit 10A). These measures include on-farm irrigation technologies (NMSU and WRRI, 2001; Hulsman, 1983; Garcia et al., 1999) and improved OFWM techniques such as:

- Improving flood and border irrigation practices
- Lining and or piping on-farm conveyance canals
- On-farm metering
- Land leveling and improved land preparation

Such initiatives must be tailored for each of the three following categories of farms/farmers as each views farming and onsite infrastructure in a separate manner.

- Production farms (farming provides a primary income source). Farmers better understand investment for future return as part of their business.

- Supplemental-income generation farms (farming is carried out by users who have other jobs or who are retired individuals). Farmers depend on income from small farms to support their families and/or way of life, but in general, they do not view farming and farm system investments as a business decision.)

- Non-agriculture areas (users apply irrigation water to landscaping or grass).

Assistance from the New Mexico Acéquia Association might be sought in developing such an OFWM program. The success of such a program in the small Sandoval systems may relate as much to the social and economic well-being of the rural communities and people who live in these areas as well as to the ability to save and use water more efficiently (see social and cultural fact sheet for A-10 alternative in *Evaluation of Alternative Actions for Social and Cultural Implications*).

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

The technology exists to carry out this program. The program does, however, require what might be viewed as thinking "out of the box" to focus more attention on farms and farmers. New Mexico State University and associated agricultural extension agencies would also be able to offer technical assistance in this area as well. Two universities that have extensively researched the methods used to achieve on-farm efficiencies are Colorado State University and Utah State University.

Infrastructure Development Requirements

An organization that can provide farm and farmer assistance is required. MRGCD is one entity that could oversee this program. If a different entity were created, it should be set up as a regional entity, not part of a federal or state agency.

Total Time to Implement

The proposed OFWM program introduced is for five years, although this will not be enough time to implement all needed activities. As the program moves forward, additional subsidized activities will be required.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

If successful, this program would reduce the water required to be diverted into irrigation systems in the study area, which provides more water supply management options to the region. As shown in Table 10A-2 (Exhibit 10A), about 42,000 acre-feet of diversion water could be saved.

Effect on Water Supply (surface and groundwater)

The amount of water diverted for irrigation would be reduced. The question of what happens to the water that is no longer being diverted would be determined by legal considerations. For practical purposes, it is assumed that fewer water diversions would mean more water stays in El Vado reservoir since water used for irrigation in the MRGCD is stored there. If less water is needed for irrigation in the MRGCD, the result would be a reduction in the quantity of water released from the reservoir. Additional water in the reservoir could be used to extend the irrigation season and provide farmers with a full water supply. Administrative changes would likely be required before water, which is made available through efficiency improvements in the MRGCD, could be acquired, leased, or purchased by other entities.

Water Saved/Lost (consumption and depletions)

The consumptive use of irrigation water varies, mainly according to crop. Consumptive use changes due to crop changes are discussed in alternative A-11, *Low-Water Use*. Assuming that on-farm incidental depletions are about 5 percent of the total diversion savings of 42,000 acre-feet, on-farm incidental depletion savings are estimated to be 2,400 acre-feet per year (Table 10A-2 in Exhibit 10A). This estimate is based on a reduction in incidental on-farm depletions, which are a component of FDR.

Impacts to Water Quality (and mitigations)

Water quality impacts are difficult to predict but less water might mean higher concentrations of salt and agricultural chemical constituents in drainage water and in the soils. This needs further study.

Watershed/Geologic Impacts

Seepage will be reduced through the reduction of deep percolation and incidental losses on farms, and this will affect groundwater levels and recharge. Table 10A-4 (Exhibit 10A) examines a "before" and "after" scenario; the "after" scenario assumes that all of initiatives presented in Alternatives 7, 9, and 10 are implemented and indicates that there would still be significant water available for seepage.

3.1.2 Environmental Impacts

Changes in recharge to the shallow aquifer due to changes in flows through on-farm canals may impact the bosque and the types of ecosystem that may be established in the canals and drains of the MRGCD. However, flows in the system are already intermittent due to the seasonal nature of irrigation.

Increased water in storage could be released to enhance ecosystem functions, depending on ownership of the water.

Impact to Ecosystems

Ecosystem impacts should be minimal if on-farm projects are planned and designed to avoid impacts to on-farm ecosystems.

Implications to Endangered Species

Increased water supply management flexibility will provide more options for supporting endangered species habitat.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Table 10A-3 provides estimated costs for an initial five-year OFWM project and the design study necessary to develop it. This cost is estimated at nearly $27 million. The cost per acre-foot to reduce water diversions is approximately $620.

3.2.2 Potential Funding Source

Both federal and state funding assistance should be available for the measures described in this fact sheet. The most applicable federal program for funding on-farm activities is the Natural Resources Conservation Service Environmental Quality Incentives Program. However, this program is significantly understaffed, which could increase the time needed to process applications and disburse funding. Federal funding sources are not available for operation and maintenance costs.

3.2.3 Ongoing Cost for Operation and Maintenance

A group that focuses increased attention on farming should be one of the outcomes of the five-year OFWM project. Such an organization should have a staff of 12 to 15 professionals and an equal number of support staff and technicians (as well as vehicles, offices, and other support). This organization would also manage the introduction of new technology and lead an on-going information dissemination program, stimulating agricultural education, and monitoring and evaluating farm and farmer inputs in terms of water savings (conservation) and reduced use (efficiency). Costs could be around $700,000 to $2,000,000 per year to operate depending on the number of employees and the types of work carried out. The cost for this operation could be paid for through user charges and the local tax mill levy, which is how the MRGCD currently funds its operations.

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Alternative 10

Exhibit A
Calculation Spreadsheets

TABLE 10A-1: Middle Rio Grande Irrigation Systems: Irrigated Areas and Numbers of Farmers

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1 Data is arranged and presented to highlight On-Farm irrigation activities in MRGCD's system split by the three counties in the study area and all of the small community ditch systems in Sandoval County as a fourth group.
2 Reported Irrigated Acreages — MRGCD Handout, *Estimated Irrigated Acreage as of July 2000*, MRGCD, 4/2001
3 Reported Irrigated Acreages — Gore, C., et. al., *New Mexico Agricultural Statistics 2000*, USDA
4 Reported Irrigated Acreages — Wilson, B., *Water Use by Categories in NM Counties and River Basins and Irrigated Acreage, 1999*
5 Reported Irrigated Acreages — S.S. Papadopulos & Assoc., Inc., *MRGCD Efficiency and Metering Program*, NM ISC, Table 4.4, December 2002
6 Reported Irrigated Acreages — Saavedra, Paul, *Surface Water Irrigation Organizations in NM*, NM OSE, Santa Fe, New Mexico, March 1987
7 Number of Customers — 13,000 estimate (12000 - 14,000 from MRGCD Billing Records)
8 It is assumed all irrigated areas include fallow but not idle lands. Incidental depletions are not broken out in this exercise.

#	Irrigator Groups	Reported Irrigated Area[2] (2000)	Reported Irrigated Area[3] (less non MRGCD systems) (2000)	Reported Irrigated Area[4] (1999)	Reported Irrigated Area[5] (2001)	Reported Irrigated Area[6] (1987)	Number of Reported Farms (see Note #3)	Avg. Farm Size	Number of Billed Customers (see Note #7)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
		acres	acres	acres	acres	acres	#	acres	#
1	Sandoval-MRGCD	6,733	4,712	6,075	8,008		353	22.69	2,275
2	Bernalillo-MRGCD	12,870	9,190	8,760	9,291		468	19.85	2,640
3	Valencia-MRGCD	30,938	23,674	20,798	28,459		639	44.54	8,085
	Sub Totals	**50,541**	**37,576**	**35,633**	**45,758**		1,460	31.34	13,000
4	Sandoval-Small Systems					**4,639**	*608*	**7.63**	
	Totals	**50,541**				**4,639**			

1 Assume average size of all farms = 7.63 acres
(includes MRGCD and non-MRGCD farms)
2 Assume Reported Farms are full time farms. Assume Sandoval Reported Farms in MRGCD = 80%
2 All farm numbers would be:

Systems	All Farms	Reported Farms	Small Farms and other irrigators	Production Farms
	#	#	#	%
Sandoval MRGCD	1,050	282	767	26.9%
Bernalillo-MRGCD	1,218	468	750	38.4%
Valencia-MRGCD	3,730	639	3,091	17.1%
Sandoval-Small Systems	608	71	537	11.6%
	6,605	**1,460**	**5,145**	**22.1%**

TABLE 10A-2: Middle Rio Grande Irrigation Systems: On-Farm Water Use Characteristics and Possible Improvement

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1	Consumptive Irrigation Requirement	2.2 acre feet/acre	**For MRGCD**: *ibid,* S.S. Papadopulos & Assoc.; *ibid,* Wilson, B.,
	(CIR values should be viewed at estimates not measured values)	1.13 acre feet/acre	**for Small Sandoval systems**: *ibid*, Wilson, B.,
2	On Farm Efficiency (Ef)	48%	*Wilson, B. 1999 - Sandoval, Bernalillo - MRGCD*
3	On Farm Efficiency (Ef)	50%	*Wilson, B. 1999 - Valencia - MRGCD, small Sandoval systems*
4	Border Irrigation Max Efficiency	90%	*ibid, Kay, Melvin*
5	Eff. Improvement possible due to proper land prep (leveling)	7%	*ibid, Kay, Melvin (10%)*
6	Eff. Improvement possible due to improved water management	15%	*on-farm conveyance improvement, canal lining and piping*
7	Eff. Improvement possible due to on-farm water metering/control	8%	Vickers, Amy, *Handbook of Water Use and Conservation*, the Waterplow Press, June 2002 (10%)
8	In column 9 incidental off-farm depletions (ID) are subtracted from possible diversion water reduction. ID coefficient from Wilson, B. (1999)		
9	**Exercise assumes total farm coverage**		

#	Irrigator Groups	Consumptive Irrigation Requirement	Farm Delivery Requirement	Improvement due to: Better Land Prep	Improvement due to: Improved Water Management	Improvement due to: On-Farm Water Metering	New Farm Delivery Requirement	Systems Diversion Water Reduced
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
		acre-feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet	acre-feet
1	Sandoval-MRGCD	14,813	30,860	2,019	4,025	2,286	22,530	7,080
2	Bernalillo-MRGCD	28,314	58,988	3,859	7,694	4,369	43,065	13,534
3	Valencia-MRGCD	68,064	136,127	3,605	12,824	4,832	114,867	18,071
	Sub Totals	**111,190**	**225,974**	**9,482**	**24,543**	**11,487**	**180,462**	**38,685**
4	Sandoval-Small	5,242	10,484	2,692	988	372	6,432	3,444
	Total	**116,432**	**236,458**	**12,175**	**25,530**	**11,859**	**186,894**	**42,130**

New On-Farm Irrigation Efficiency (Ef)	**62%**
Possible Diverted Water Reduction (acre-feet)	**42,129.6**

TABLE 10A-3: Middle Rio Grande Irrigation Systems: Details of Proposed On-Farm Water and Agricultural Support Project

Notes and Assumptions

1	**Carry Out Studies**	a	Catalog and characterize all farmers and farmer/farm institutions in 3 county region		$ 250,000
	this analysis should be viewed as conceptual only and not as factual.		Catalog farm and farmer types: Production farmers, supplemental Income farmers, other irrigators		
		b	Carry out OFWM studies: How is water used on local farms in study area?		$ 150,000
		c	Carry out crop and market studies: What is grown? Why? What else can be grown?		$ 125,000
			How can we help local farmers be more productive? Support farmers? **Other existing markets?**		**$ 525,000**
2	Assume that farmer assistance can be delivered through a five year outreach program that provides more qualified professional staff to work with local farmers				
	Develop and implement a Middle Rio Grande On-Farm Water Management Project (MRGOFWM)				
	Implementers: MRGCD, USDA/NRCS, NMSU, Ag. Extension Service, Farm Bureau, Consulting Firms				
3	Project Goals	a	Promote **profitable, sustainable, vital** agriculture in Sandoval, Bernalillo, and Valencia Counties		
		b	Form and institutionalize a MRG farmer assistance agriculture program and office as part of MRGCD		
		c	Develop on-line and other farmer information systems and linkages to MRGCD, NRCS, NMAg. Ext.		
		d	Develop and formalize MRGCD linkage to all farmers in the three county area		
		e	Strengthen Farm Bureau, build farmer trust		
		f	OFWM Goals		
			i	Train 1,500 farmers in efficient on-farm water use; agrimet data, water application	
			ii	Promote efficient land preparation practices	
			iii	Promote land leveling	
			iv	Increase on-farm lined and piped conveyance systems	
			v	Increase MRGCD and small Sandoval systems E_f from 50% to 76%	
		g	Other agricultural and farmer goals		
			i	Train farmers in agriculture and horticulture (crop diversification)	
			ii	Train farmers in marketing (maximize farm revenue)	
			iii	Train farmers in land reform (maintain farm size)	
		h	Develop and implement 3 county area farming education program (middle and high schools)		
4	**Project Inputs**	a	Provide 9 senior and 6 junior professional staff members to implement program		**Estimated Five Year Input Costs**
			i	1-Director, 1-Training Spec., 1-Market Spec's, 2-OFWM Spec's, 3-Hoticulturalists, 1-Agricultural Engineer	
			ii	6 - Farm Outreach Technical Specialists	$ 9,000,000
		b	Matching land preparation grants (90%) - 1,000 farms		$ 2,500,000
		c	Matching land leveling grants (90%) -1,000 farms		$ 3,500,000
		d	60 demonstration High Value Crops (HVCs) demonstration farms		$ 1,500,000
		e	60 demonstration high efficiency OFWM farms		$ 1,500,000
		f	Matching OFWM grants - lining/piping/meters (90%) -1,000 farms		$ 5,000,000
		g	120 computers, software, web pages, training materials		$ 730,000
		h	15 study tours - 20 farmers each		$ 750,000
		i	250 farmers trained at external training courses		$ 500,000
		j	20 On-site Farmer and Farming seminars		$ 400,000
		k	Middle and High school curricula		$ 400,000
		l	Monitoring, Reporting, Evaluation		$ 300,000
	Possible On Farm Water Savings (acre-feet)	**42,130**	Reduction in Farm Delivery Requirement		**$ 25,780,000**
	Cost per acre foot of water saved	**$ 624**	Includes project cost and study cost		

TABLE 10A-4: Middle Rio Grande Irrigation Systems: Possible Seepage Effects of Changes to Systems

All land, water, crop and cost numbers presented in this table are based on published documents or data from agencies, many of which use estimates or placeholder assumptions to assign values. These values are based in part on empirical data (measurements, studies) however, they should not be considered as measured data. Therefore, the results of this analysis should be viewed as conceptual only and not as factual. Specific, more accurate data needs include, cropped acreages, crop irrigation requirements, on- and off-farm efficiency coefficients. References for all source documents have been provided.

Notes and Assumptions

1 Assume Programs outlined in Alternatives Analyses A-7, A-9, and A-10 are feasible and implemented with total farm and system coverage

2 All conceptual plans noted in A-7, A-9, and A-10, assume that for MRGCD, return flows have been to the extent possible, factored out, of analysis accounting as possible diversions used in downstream irrigated areas.

EXISTING

#	County / System	Reported Irrigated Area	Consumptive Irrigation Requirement	Total System Diversion Requirement	System Irrigation Efficiency (Ej)	Total Diversion Per Acre	Total Diversion Water Reduction From A-7, A-9, A-10
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
		acres	acre-feet	acre-feet	%	acre-feet	acre-feet
1	Sandoval (MRGCD)	6,733	14,813	48,218	30.7%	7.2	21,601
2	Bernalillo (MRGCD)	12,870	28,314	92,168	30.7%	7.2	41,633
3	Valencia (MRGCD)	30,938	68,064	212,699	32.0%	6.9	84,787
4	Small Systems - Sandoval County	4,639	5,242	14,977	35.0%	3.2	7,776
	Totals	**55,180**	**116,432**	**368,062**	**31.6%**	**6.7**	**155,797**

POSSIBLE

#	County / System	Reported Irrigated Area	Existing Consumptive Irrigation Requirement	New Total System Diversion Requirement	New System Irrigation Efficiency (Ej)	New Total Diversion Per Acre	Existing Volume of Water - Incidental Depletions, Deep Percolation, and Off-Farm Conveyance Seepage	New Volume of Water - Incidental Depletions, Deep Percolation, and Off-Farm Conveyance Seepage
1	*2*	*3*	*4*	*10*	*11*	*12*	*13*	*14*
		acres	acre-feet	acre-feet	%	acre-feet	acre-feet	acre-feet
1	Sandoval (MRGCD)	6,733	8,820	26,617	33.1%	4.0	33,405	17,797
2	Bernalillo (MRGCD)	12,870	28,384	50,535	56.2%	3.9	63,854	22,151
3	Valencia (MRGCD)	30,938	74,389	127,912	58.2%	4.1	144,635	53,523
4	Small Systems - Sandoval County	4,639	5,242	7,201	72.8%	1.6	9,735	1,959
	Totals	**55,180**	**116,835**	**212,265**	**55.0%**	**3.8**	**251,630**	**95,430**

Results

1 Irrigated acreage remains the same

2 Consumptive Irrigation Requirement (CIR) remains the same

3 Total system Diversion is reduced by **155,797** acre-feet or by **42%**

4 Irrigation system efficiency in the study area improves from **31.6%** to **55.0%**

5 Seepage is not curtailed

Technical and Physical Feasibility Fact Sheet

Alternative 11: Low-Water Crops

Acknowledgements: This fact sheet was written by Brian McDonald, Ph.D., private economic consultant, as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-11: Develop markets for locally-grown produce, and low-water alternative crops.

2. Summary of the Alternative Analysis

In 2000 there were 41,494 irrigated acres in the Middle Rio Grande (MRG) planning region, with 21,200 acres in alfalfa and another 10,020 acres in pasture. Almost 60 percent of the alfalfa and pasture acreage was located in Valencia County. Other forage crops included corn (2,196 acres) and other hay (2,100 acres). Fruit crops included fruit orchards (600 acres), grapes (600 acres), and melons (25 acres). Vegetable crops included chile (980 acres), miscellaneous vegetables (1,510 acres), and dry beans (11 acres) (USDA, 2001) (Table 11-1).

Alfalfa is a water-intensive crop, using 28.20 inches annual consumptive use of water per acre in the Belen area (Blaney and Hanson, 1965). This compares to 17.94 inches per acre for sorghum, which is also grown in the MRG region. Switching 5,000 acres from alfalfa to sorghum would reduce consumptive water use by an estimated 4,275 acre-feet per year of water. There are also varieties of alfalfa that use less water, which local farmers turn to during sustained periods of drought. Switching all current alfalfa acreage to an alfalfa variety that uses 15 percent less water over the growing season would reduced annual consumptive water use by 7,473 acre-feet in the MRG planning region.

Under current irrigation and institutional practice there is no economic incentive for local farmers to switch to lower water using crops. Farmers in the Middle Rio Grande Conservancy District (MRGCD) face a zero marginal price for agricultural water. Reducing consumptive water use does not lower the farmer's dollar cost of irrigation water. By switching crops the farmer will likely incur additional business costs that cannot be recovered out of reduced outlays for irrigation water. Thus, the benefit/cost ratio for switching to lower water-using crops is negative Though some farmers within the region have chosen to grow produce or other lower water use crops, the negative benefit/cost ratio indicates that widespread changes in crop patterns is not likely to occur unless incentives are implemented or market changes occur.

Table 11-1. Irrigated Crop Acreage, 2000 in the Middle Rio Grande Planning Region

Crop	Bernalillo	Sandoval	Valencia	Total
Alfalfa	4,600	4,100	12,500	21,200
Chile	500	400	80	980
Corn	700	425	1,071	2,196
Fruit orchards	130	410	60	600
Grapes	200	35	25	260
Other hay	400	---	1,700	2,100
Melons	---	---	25	25
Miscellaneous field crops	200	400	15	615
Miscellaneous small grains	160	100	500	760
Miscellaneous vegetables	400	1,000	110	1,510
Nursery stock	---	---	50	50
Pasture	1,600	2,370	6,050	10,020
Pecan orchard	---	---	2	2
Dry beans	---	10	1	11
Rye	20	---	---	20
Sod	---	---	230	230
Sorghum	200	50	35	285
Wheat	80	50	500	630
Total	9,190	9,350	22,954	41,494

Source: U.S. Department of Agriculture, New Mexico Agricultural Statistics Service. 2001 New Mexico Agricultural Statistics. Las Cruces, New Mexico.

Furthermore, in the MRGCD there is no on-farm metering of irrigation water **use**. This means that even if a marginal price were charged for irrigation water, there is currently no mechanism to measure the quantity of water applied to irrigated crops. Under current irrigation practices, saving water does not economically benefit the individual farmer.

In fact, there is a disincentive or impediment to the use of lower water-use crops under current institutional arrangements. Under the prior appropriation water right system, water must be put to beneficial use. If agricultural water is conserved but not used, it may be subject to forfeiture. The local farmer's water right is limited to the actual consumption of water by the crop grown, and not by the water diverted. Thus, switching to a lower water use crop financially undermines the local farmer in a region where water rights currently sell for approximately $5,000 per acre-foot. Water rights attached to the land are part of the wealth of the farmer. Switching to lower water use crops has the potential to reduce the farmer's right to water, and thus reduce his future wealth.

There are other obstacles to the implementation of this alternative. A change of crops may require a different business infrastructure in the agricultural sector than is currently available. Vegetable and fruit crops are more labor-intensive, requiring periodic weeding and hand-harvesting in many cases. Farm labor is generally not available in the MRG planning region, since the predominant alfalfa crop does not require such farm labor. Different planting and harvesting equipment will be necessary. Crop storage and processing facilities would have to be built and different marketing and distribution networks would have to emerge. New farm cooperatives and marketing associations would be needed to achieve the necessary volume to successfully market other crops. Such cooperatives would also be needed for the grading and sorting of agricultural produce as well as the leasing of necessary capital equipment.

Other crops would have different business risks associated with them. Orchard fruit, for example, can be a total loss due to a late spring frost. Vegetable crops may be a total loss if sufficient water is not available throughout the entire growing season. Crop yields for many vegetable crops can be improved by a more deliberate application of water, taking into account the quantity of necessary water, timing, and meteorological conditions. The latter will require metering of irrigation water.

According to the Valencia County Extension Office, farmers in the MRG planning region are at a competitive disadvantage in the market for fresh produce serving local consumers. Compared to southern New Mexico, this region has a shorter growing season, lower yields, no established infrastructure for food processing, inadequate farm labor, and smaller farms so that economies of scale cannot be easily attained in crop production. International competition for New Mexico's chile crop is now a concern, since New Mexico cannot compete with the low cost labor in Mexico. Capital-intensive chile harvesting techniques are now under development in an attempt to maintain the competitiveness of New Mexico chile production. Similar international competition can be expected in the production and marketing of other vegetable crops.

3. Alternative Evaluation

Alfalfa, the predominant crop in the MRG region's agricultural sector today, is a water-intensive crop. However, alfalfa is well-suited economically to the region's agricultural marketplace. It is a drought tolerant crop whose demand comes from local cattle ranchers, recreational horse owners, and dairies. It can be grown with less business risk by part-time farmers on small land plots.

Switching to low water-use crops would be one alternative to conserve water in the MRG planning region. However, such a water conservation strategy presents obstacles. Crop production for consumer markets would face intense regional and international competition. A different business infrastructure for local farmers would have to be developed to include seed and fertilizer suppliers, planting and harvesting equipment, the availability of farm labor, processing and sorting facilities, marketing and distribution networks, and even agricultural research and training.

Finally, economic incentives must be found to encourage local farmers to switch to low water-use crops and to offset current disincentives and impediments. Farmers currently pay zero marginal price for irrigation water and there is no on-farm metering of water use. Thus, farmers would have no cost savings from the use of less irrigation water. Farmers could lose water rights by shifting to crops with lower consumptive use under current water rights laws, resulting in a diminution of farmer wealth. Thus, legal and institutional practices would also have to change.

3.1 Technical Feasibility

Enabling New Technologies and Status

No new agricultural technologies would be required.

Infrastructure Development Requirements

New business infrastructure in the agricultural sector would be necessary. This would include seed and fertilizer suppliers, availability of farm labor for planting and harvesting crops, agricultural machinery, processing facilities, and marketing and distribution arrangements.

Total Time to Implement

Time needed would be based upon the economic viability of changing crop patterns and the provision of financial incentives to local farmers.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

This alternative has great potential to reduce water demand in the agricultural sector. Current crop patterns are water-intensive in an arid climate.

Effect on Water Supply (surface and groundwater)

None anticipated.

Water Saved/Lost (consumption and depletions)

This depends upon the amount of irrigated acres switched to low water-use crops. For example, switching 5,000 acres from alfalfa to sorghum would reduce consumptive water use by an estimated 4,275 acre-feet.

Impacts to Water Quality (and mitigations)

None anticipated.

Watershed/Geologic Impacts

None anticipated.

3.1.2 Environmental Impacts

Impact to Ecosystems

Water savings would be available for other water uses, including the maintenance of riparian habitat.

Implications to Endangered Species

Water savings would be available for other water uses, including instream flow to maintain habitat for the silvery minnow.

3.2 Financial Feasibility

Local farmers have no financial incentive to implement this alternative. A farmer's marginal cost of irrigation water is $0, since there presently is no on-farm metering and water pricing is based on a flat per acre assessment. Thus, any water savings would not reduce a farmer's annual cost of production. Furthermore, if agricultural water is conserved and not used, it may be subject to forfeiture under the prior appropriation water right system. Switching to lower water-use crops has the potential to reduce the farmer's right to water and thus his personal wealth.

3.2.1 Initial Cost to Implement

Unknown, but this alternative would require large, up-front expenditures to establish new business infrastructure and to provide financial incentives to farmers to switch crops.

3.2.2 Potential Funding Source

The federal government is the primary governmental organization that subsidizes agriculture in the U.S. Because of the importance of water management in New Mexico, state government should have a significant interest in financing this alternative. State government must also make statutory changes to water laws so that water savings become the water right of the farmer. Local organizations such as the MRGCD must implement water metering and acre-foot water charges to provide financial incentive for farmers to switch to low water use crops.

3.2.3 Ongoing Cost for Operation and Maintenance

Unknown. Ultimately this would be determined by the market for alternative, low water use crops.

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Technical and Physical Feasibility Fact Sheet

Alternative 18: Urban Conservation

Acknowledgements: This fact sheet was written by Myra Segal Friedman of EJJ Associates as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-18: Adopt and implement local water conservation plans and programs in all municipal and county jurisdictions, including drought contingency plans.

The first part of this alternative, "adopt and implement local water conservation plans and programs. . ." is covered in Sections 2 through 3, below. Drought contingency plans are covered in Section 4.

2. Summary of the Alternative Analysis

Important Note: *Water use and savings estimates in this analysis (summarized in Tables 18-2 and 18-3) reflect a very high level of conservation—a "best case" conservation scenario. Savings estimates are based on a complete implementation, phased in over 20 years, of major conservation measures leading to significantly reduced water usage rates (see Table 18-1). Outdoor conservation goals are based on recommended subdivision guidelines from the Office' of the State Engineer (OSE) , which assume a major reduction of irrigated landscape area to a maximum area of 800 square feet per residential unit for new construction and phased in reduction for existing residential landscapes. Indoor savings are based on national case studies of a conserving home with conserving appliances and lifestyle. If these goals are not reached, water savings will be significantly lower than the estimates shown in Tables 18-3 and 18-4. As such, the numbers presented in Tables 18-3 and 18-4 should be treated as a best-case scenario for conservation and not treated as a forecast about future water use and savings in any conservation scenario. A significant financial, lifestyle and political investment is needed to achieve these savings. If conservation levels are lower than the best case effort scenario, the water savings figures must be decreased accordingly.*

The analysis of this alternative draws on water conservation plans and data found in a variety of implemented programs, publications, and case studies. Sources include Office of the State Engineer Technical Reports (Morrison, 2000; NM OSE, 2001; Wilson, 1997), a textbook by

Vickers (2001), the water conservation programs and associated activities developed and implemented by the City of Albuquerque and other jurisdictions in the region (City of Albuquerque, 2002a; Witherspoon, 2002a; NM OSE, 2001), water use data in a report commissioned for this water planning region (JSAI, 2000) Mid-Region Council of Governments (MRCOG) planning documents (MRGCOG, 2000 and 2002) and ideas on these alternatives documented by MRCOG and the Water Assembly.

Water uses analyzed in this section are non-agricultural. Agricultural water use alternatives are covered in A-7, A-9, A10, A-40, and A-60.

Estimates of potential conservation savings are calculated based on current water use in the Middle Rio Grande (MRG) water planning region and shown in Table 18A-1 (*Estimated Current Water Use by Public Water Supplies and Domestic Wells in Bernalillo, Sandoval, and Valencia Counties*) in Exhibit 18A. As Albuquerque water customers use approximately 74 percent of the planning region's municipal, residential, industrial and commercial water, attention to conservation efforts in Albuquerque can yield the most savings.

To project potential conservation savings, goals were established for reduced per capita use, as shown in Table 18-1. Water use is characterized in gallons per capita per day (gpcd), derived by dividing the total water pumped/withdrawn per year (in gallons) by population, then dividing the quotient by 365 days. This method allows for a comparable index to be developed when only total water delivered and population data are available. Total water use includes usage by residential, commercial, industrial, and institutional customer classes, as well as unaccounted-for-water (UAW). The usage goal assumes installation of water conserving devices and landscape and water-conserving lifestyle changes.

A residential-only usage (gpcd) is estimated. Monitoring of actual usage is possible if enough data is available to extract all other uses (i.e., industrial, municipal, and commercial) and to examine the differences between winter and summer use so that outdoor and indoor use can be determined. The established goals are based on estimated indoor usage for a "conserving home" and outdoor usage for a home with a landscape of 800 square feet, using drip irrigation. For further detail, see Table 18A-2 (*Estimate of Gallons per Person per Day Before and After Proposed Water Conservation Measures Implemented and Reduction from Current Use*) and

Table 18A-3 (*Estimated Savings and Costs Attributed to Installation of Water Conserving Fixtures and Appliances*) in Exhibit 18A.

Table 18-1. Proposed Conservation Goals for the Middle Rio Grande Regional Planning Area

	Public Water System Usage (gpcd)					
	Composite Usage			Residential-Only Usage		
Year	Total	Indoor [a]	Outdoor [b]	Total	Indoor [a]	Outdoor [b]
2000	200 [c]	120	80	104	62	42
2010	160	96	64	81	51	30
2020	135	80	55	68	48	20
2050	120	80	40	65	45	20

[a] Indoor water use goals are based on water use in a "conserving" house with water-efficient fixtures and appliances (Vickers, 2001)
[b] Outdoor water use goals are based on reduced landscape area and watering rates (Wilson, 2002a and 2002b)
[c] The estimated gallons per day (gpd) is generalized to provide a starting point. Some locations may have already achieved a lower gpd.

gpcd = Gallons per capita per day

To reach target per capita use rates, various conservation measures were analyzed. In order to target the highest uses, water use was analyzed to establish where conservation can make the biggest difference. Target water uses included residential outdoor, residential indoor, and large irrigated green spaces (e.g. golf courses, parks, and medians).

Estimates of potential savings resulting from reduced per capita use were calculated. The Sandia National Laboratories computerized water model ran conservation scenarios for the low and high population projections through 2050. Results are shown Table 18-2. The model offers the ability to calculate potential savings using other assumptions and variables.

Table 18-2. Estimated Water Use, Savings, and Return Flow Assuming High Level of Conservation for the Middle Rio Grande Planning Region

Category	Regional Estimates (acre-feet) [a]						
	Total	Residential Indoor	Residential Outdoor	Commercial	Industrial	Institu-tional	UAW
2000 (Population = 725,000)							
Water use [b]	158,890	47,667	31,778	41,311	3,178	17,478	17,478
Return flow [c]	87,215	46,714	636	23,134	2,701	4,544	1,049
2010 Low Projection (Population= 830,000) [d]							
Water use [e]	146,432	43,930	29,286	38,072	2,929	16,108	16,108
Water savings [e]	148,697	44,609	29,739	38,661	2,974	16,357	16,357
Return flow [c]	64,070	30,710	811	21,238	6,970	3,427	914
2010 "High Projection (Population = 892,000) [d]							
Water use [e]	156,475	46,943	31,295	40,684	3,130	17,212	17,212
Water savings [e]	195,413	58,624	39,083	50,807	3,908	21,495	21,495
Return flow [c]	77,580	46,004	626	22,783	2,660	4,475	1,033
2020 Low Projection (Population = 940,000) [d]							
Water use [e]	139,507	41,852	27,901	36,272	2,790	15,346	15,346
Water savings [e]	109,390	32,817	21,878	28,441	2,188	12,033	12,033
Return flow [c]	69,168	41,015	558	20,312	2,372	3,990	921
2020 High Projection (Population = 1,005,000) [d]							
Water use [e]	156,173	46,852	31,235	40,605	3,123	17,179	17,179
Water savings [e]	120,284	36,085	24,057	31,274	2,406	13,231	13,231
Return flow [c]	77,431	45,915	625	22,739	2,655	4,467	1,031
2050 Low Projection (Population = 1,150,000) [d]							
Water use [e]	154,331	46,299	30,866	40,126	3,087	16,976	16,976
Water savings [e]	238,351	71,505	47,670	61,971	4,767	26,219	26,219
Return flow [c]	76,517	45,373	617	22,471	2,624	4,414	1,019
2050 High Projection (Population = 1,500,000) [d]							
Water use [e]	200,263	60,079	40,053	52,068	4,005	22,029	22,029
Water savings [e]	292,211	87,663	58,442	75,975	5,844	32,143	32,143
Return flow [c]	99,290	58,877	801	29,158	3,404	5,728	1,322

[a] Based on gallons per capita per day (gpcd) rates provided in Table 18-1

[b] Distribution of water use by end-use category is based upon the following data:
- Wilson, 2002c (Table 4: Summary of water use in acre-feet, in New Mexico counties, 2000)
- City of Albuquerque, 2000
- Witherspoon, 2001
- Rio Rancho, 2000
- Skeie-Campbell, 2002

[c] Return flow is based on historical rates provided by John Shomaker & Associates, Inc., 2000 (Tables 21 and 29). The return flow rates used in this table assume a constant return rate by category of use: Residential Indoor = 98%, Residential Outdoor = 2%, Commercial = 56%, Industrial = 85%, Institutional = 26% and UAW = 6%.

[d] Population projections based on MRGCOG, 2000.

[e] Projected water use and savings (calculated using a baseline of 2000) results were computed using the Sandia National Laboratories Water Model computer model by Vince Tidwell and Howard Passel, November 15, 2002.

UAW = Unaccounted-for water

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Water-conserving technologies for indoor and outdoor uses are available in the current market. Within the 50-year timeframe of this regional water plan, new technologies for fixtures, appliances, and irrigation systems will potentially increase water use efficiency.

Water savings attributed to conservation presented in this analysis result from a coordinated, concentrated effort to implement conservation measures. Reduced efforts will yield results lower than the saving estimates discussed under Section 3.1.1, *Physical and Hydrological Impacts*.

Outdoor Water Use. Water conserving guidelines based on the subdivision guidelines issued by the NM OSE (Wilson, 2002a) set a ”low-water-use” scenario for landscaping. Guidelines include reducing irrigated landscape areas to 800 square feet and reducing watering levels to 0.5 acre-feet per year per lot. Low water use plants and drip irrigation is encouraged.

Even if phased in over ten years, water savings can be very significant. Reducing the size of irrigated residential landscapes from the current averages of 3,500 square feet (Albuquerque), 1,700 square feet (Rio Rancho), and 1,500 square feet (semi-urban areas in other parts of the region) can save an estimated 34,000 to 74,000 acre-feet per year (Tables 18-3, 18A-4, and 18-A-6 *[Estimated Water Savings from Reducing the Size, Plantings and Water Rate for Residential Landscapes After 100% Implementation of OSE Conservation Subdivision Guidelines* in Exhibit 18A]). Table 18-3 presents a "best possible outcome" for conservation rather than a conservative estimate, as discussed at the October 26, 2002 meeting that reviewed the assumptions for this alternative.)

Indoor Water Use. Assumptions of savings attributed to water-conserving measures and the 45 gpcd goal for indoor use are based on the "conserving house" as described in case studies reported by Vickers (2001). Savings from fixture replacement are summarized in Table 18A-3 (*Estimated Savings and Costs Attributed to Installation of Water Conserving Fixtures and Appliances*) in Exhibit 18A.

Infrastructure Development Requirements

Repair, rehabilitation, and ongoing maintenance of existing water-related infrastructure are essential to achieve and maintain water conservation goals. UAW losses are directly related to the rehabilitation and repair of water and sewer lines. To reduce UAW losses, a significant investment (up to $20 million/year for Albuquerque alone) is needed to repair and rehabilitate water infrastructure. Irrigation systems would need to be converted from sprinklers to drip on a landscape-by-landscape basis at an estimated cost of $2.00 per square foot.

Total Time to Implement

The time needed to implement water conservation is contingent on the commitment of the public and elected officials and the financial resources available. A significant reduction of water use can be achieved in 10 to 20 years if conservation measures are implemented in a timely manner and water consumers and providers subscribe to the effort. Fostering implementation requires commitment to ongoing publicity, education, and other programs to maintain a high level of awareness and participation in conservation activities.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Conservation can effectively reduce the demand for water on a regional basis. Tables 18-2 and 18-3 summarize the estimated water use and savings associated with reduced per capita water use. Even though population is projected to grow, conservation can lead to significant savings in water use.

Table 18-2 summarizes water use and savings as conservation efforts increase based on population forecasts. Projected water use and conservation-based savings were computed using the Sandia National Laboratories water model. This computer model assumes that the target gpcd levels shown in Table 18-1 are achieved. Results show that if significant indoor and outdoor conservation measures are fully implemented (i.e., phased in over 10 to 20 years), total annual water demand for an increased population can resemble current demand levels. However, if the region grows at the highest projected rate, between 2020 and 2050 water demand will surpass 2000 levels by an estimated 26 percent. Note that a key element in achieving these savings is the large reduction of landscape area and high-water-use plants and turf. The savings projected in Tables 18-2 and 18-3 will be achieved only if these reduction measures are fully incorporated into policy and practice.

As stated in the introductory note in Section 2, *Summary of the Alternative Analysis,* the numbers presented in Tables 18-2, 18-3, and 18-4 (see Part II) should be treated as a best-case scenario for conservation and not as forecasts for future water use and savings in any conservation scenario. A significant financial, lifestyle, and political investment is needed to achieve these savings. If conservation levels are lower than the best case effort scenario, the water savings figures must be decreased accordingly.

Table 18-3. Estimated Water Use and Savings in the Middle Rio Grande Planning Region

	Population [a]		Water Usage [b] (acre-feet)		Water Savings [c]	
	Low Projection	High Projection	Low Projection	High Projection	Low Projection	High Projection
2000	725,114	NA	158,890	NA	NA	NA
2010	829,434	892,000	146,432	156,475	148,697	155,143
2020	939,606	1,005,364	139,507	156,173	109,390	120,284
2050	1,150,331	1,500,000	154,331	200,263	238,351	292,211

[a] Population projections are based on MRGCOG (2000), which uses forecasts from the University of New Mexico Bureau of Business and Economic Research (BBER) and the Regional Economic Models, Inc. (REMI) model calibrated by REMI for State Planning and Development District 3 (SPDD3).
[b] Calculations were based on rates provided in Table 18-1 and combinations of data sources cited throughout this document.
[c] Savings is calculated using a baseline of 2000. Return flow is based on rates provided in John Shomaker & Associates, Inc. (JSAI) (2000), Tables 21 and 29.

NA = Not applicable

Effect on Water Supply (surface and ground water)

Conservation could ease the pressure on limited water supplies.

Water Saved/Lost (consumption and depletions)

Table 18-2 provides estimates of water use, savings, and return flow between 2000 and 2050 using the MRCOG "low" and "high" population projections. Water use, savings, and return flow are shown by end-use categories (proportional use by end-use category is based on rates in John Shomaker & Associates, Inc. [JSAI], 2000 [Table 21]).

Important factors to note include:

- Estimated total return flow, after conservation is implemented, resembles current rates (44 to 55 percent of water use). The estimated volume (acre-feet) of return flow is between 73 and 114 percent of current levels, depending upon achieving conservation goals and population growth. Note that return flow will be better retained through outdoor conservation measures, as outdoor uses do not readily return water back to the river.

- Because both state and City policy emphasize the conservation of non-renewable groundwater and encourage the optimal use of renewable surface water, we assume that the City might reduce its groundwater diversion to match any reduction in demand. Thus, conserved water potentially could be considered as augmenting the groundwater drought reserve and would be available for use in accordance with the City's Proposed Drought Plan, which suggests that withdrawal from the river for drinking water would cease in times of drought (City of Albuquerque, 2002c).

Impacts to Water Quality (and mitigations)

Conversion of landscapes from sprinkled turf to drip-irrigated xeriscapes will reduce non-point source pollution by reducing runoff and erosion. However, if landscapes are not replanted with low-water-use plantings to stabilize soil, erosion and silting could result.

Watershed/Geologic Impacts

Water conservation will help preserve and postpone permanent damage to the aquifer and postpone the threat of land subsidence due to over-pumping of the aquifer.

3.1.2 Environmental Impacts

Impact to Ecosystems

Pumping of non-renewable groundwater and indirect withdrawal of surface water will be reduced, thereby reducing the risk of or extending the time before the aquifer would suffer permanent damage or subsidence. In addition:

- Runoff and soil erosion will be reduced when landscapes are converted from turf using chemicals and spray sprinklers to low-water-use plants with drip systems.

- Energy use and air emissions associated with landscape maintenance will be reduced.

Implications to Endangered Species

As shown in Table 18-2, projected return flow estimates range from 73 to 114 percent of current return flow rates. Based on this:

- The water flow available to the silvery minnow in the Rio Grande may be slightly impacted by conservation, depending upon how return flow rates change after implementing indoor and outdoor conservation measures.

- Ownership of water saved under this alternative will be determined by legal considerations. If water saved is available and the owner is willing to lease or sell the water for the purpose of promoting endangered species, this alternative could be beneficial for endangered species such as the silvery minnow.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

The cost of an acre-foot of conserved water can be computed on an annual basis (e.g., public education programs), or amortized over the life of the conservation measure (e.g., conversion of landscape and irrigation system). However, conservation may preserve water that cannot be replaced through the purchase of water rights (if these rights are not available on the market), and the computed costs for an acre-foot of conserved water are probably not comparable to the permanent consumptive-use water right (approximately $4,500/acre-foot on current market). Rather than make a cost comparison, this discussion summarizes potential conservation costs.

- Publicly and privately funded costs associated with conservation include (1) public education campaigns, (2) staff to administer the program, (3) labor and materials to convert landscape plantings, and (4) labor and materials to convert existing fixtures to low-water use fixtures.

- The City of Albuquerque estimates that approximately 56.6 billion gallons of water (17,186 acre-feet) were saved between 1994 and 2001 through conservation measures. These savings cost the utility $72 or $152 (depending upon how it is calculated) for every acre-foot of water that has been conserved. The City's conservation program budget has averaged $2.2 million per year or $15.4 million for the seven years (1995 through 2001) (Witherspoon, 2002a, p. 26.) Note that this estimate does not include private funds invested to install conserving fixtures, landscapes or irrigation systems.

- For the MRG planning region, a unified approach to public education efforts (i.e., public relations efforts on radio, television, and printed media) is possible because the water planning area is a single media market. Public education efforts can be overseen and coordinated by a staff person designated to work with the conservation efforts of all jurisdictions within the region. This individual would assemble, duplicate, and disseminate existing public education and outreach materials to utilities and customers throughout the region.

- Cost for a mid-level professional full-time employee is estimated at $60,000 (including benefits and overhead). The employee's time would be divided among tasks associated with A-18, A-22 and A-56 of this feasibility analysis.

- Cost for additional services by a public relations, education, and outreach consultant is assumed to range from $180,000 to $2.2 million per year, based on current expenditures for existing programs (Rio Rancho and Albuquerque, respectively).

- The conversion of existing landscapes to xeriscapes costs an average of $2.00 per square foot and can add up to a significant investment. Further detail can be found in Exhibit 18A, Table 18A-7 (*Estimated Cost to Reduce the Area and Change-Out Plantings and Irrigation Systems for Residential Landscapes, Golf Courses and Parks/Medians*). If high-water-use landscapes are reduced (by 30 percent for parks and golf courses and to an average of 800 square feet per residential unit), the public and private investment would approach $520,000,000. Indoor fixture replacement can range from $25 to $600 per household, or an estimated $400,000 to $9,600,000for the region as a whole. Further detail can be found in Exhibit 18A, Table 18A-6 (*Estimated Savings and Costs Attributed to Installation of Water Conserving Fixtures and Appliances*).

3.2.2 Potential Funding Source

The costs of implementing a public program are generally shared among the customers of the water supplier/utility. Individual water users pay for installation of water conservation measures. Customers' investments can be offset by a rebate on a portion of the expense.

3.2.3 Ongoing Costs for Operation and Maintenance

- Staff and/or contractors would be needed on a long-term basis to coordinate water conservation efforts to encourage water users to continually find new ways to reduce water use.

- Public education efforts would need to continue on a long-term basis to keep water conservation in the public's consciousness. Ongoing public education efforts will help conservation rates increase and prevent users from reverting to higher water use.

- Leak detection and repair of public water supply infrastructure is essential to reduce water waste. Irrigation systems need ongoing maintenance to prevent over-watering and water waste, and to keep systems in good repair.

4. Drought Contingency Planning

A regional Drought Task Force should be convened with representatives from each area of the region and from various water use sectors to meet, discuss, and recommend a regional drought plan. Task force members would include representatives from each jurisdiction in the water planning area, such as government officials, administrative staff familiar with water conservation program, ditch masters, commercial, industrial and institutional leaders, agricultural/ livestock owners, and community members. The task force would help assure that the drought plan corresponds to the needs and abilities of local users. It also would foster broad ownership, better acceptance, and the development of a community network to help with implementation. This regional Drought Task Force should coordinate with the Drought Task Force convened by the State of New Mexico and other task forces in the region (e.g., the City of Albuquerque).

The regional drought plan would address various levels of drought, based on severity (Table 18-4):

- Stage I: Drought Advisory
- Stage II: Drought Warning
- Stage III: Drought Emergency

Table 18-4. Proposed Water Use Goals to Be Met With Drought Response Measures

Drought Stage	Water Use Goals (gpcd)					
	Composite			Residential Only		
	Total	Indoor	Outdoor	Total	Indoor	Outdoor
Drought Stage I	120	80	40	65	45	20
Drought Stage II	100	60	40	50	40	10
Drought Stage III	90	54	36	45	40	5

gpcd = Gallons per capita per day

A drought plan would include:

- Drought indicators
- Drought response measures
- Implementation strategies

Estimated savings of drought mitigation measures are based on experience with conservation measures, the results of which are compared with the average water use in the region. Combined totals of drought response measures should be reduced, as appropriate, to account for overlap of measures (i.e., public education and limits on outdoor watering).

A highly effective water conservation program may reduce the potential savings of a drought mitigation plan because some of the drought recommendations have already been implemented. Also, the public may fail to distinguish the difference between drought mitigation measures and water conservation measures they have already been asked to perform. One major difference is that drought measures require a short-term response time while conservation measures can change things in a more fundamental way for long-term savings.

Estimates of water saved through the implementation of drought measures are based on savings achieved by replacing non-conserving fixtures, appliances, and landscapes with the appropriate water-saving counterparts. Water use goals associated with the various drought stages goals can be changed over time as the region achieves and reshapes its conservation goals. For example, drought goals may strive for greater reduction as overall usage rates are lowered over time.

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Alternative 18

Exhibit A
Detailed Tables

Exhibit 18A: Detailed Discussion of Alternative 18—Urban Conservation

Acknowledgements: This discussion, which follows the same basic format as the fact sheet it accompanies, provides additional details and information that support the conclusions presented in the fact sheet. It was written by Myra Segal Friedman of EJJ Associates as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc.

This exhibit contains some of the detail behind the findings reported in the A-18 analysis.

The estimate of total water saved through conservation is based on an assumption that the gallons per capita per day (gpcd) is reduced according to the goals presented in Table 18-1. Reduced water consumption can be realized through a combination of efforts including reduced use for residential indoor, residential outdoor, parks, golf courses, repair of leaky infrastructure, and changes in lifestyle. The tables in this exhibit are an estimate of savings that could result from these efforts.

Table 18A-1. Estimated Current Water Use by Public Water Supplies and Domestic Wells In Bernalillo, Sandoval, and Valencia Counties

		Estimated Current Water Use		
Regional Water Supplies [a]	Population [b]	Ac-Ft/Yr	% of Use in MRG Planning Region	Gallons per Person per Day [c]
Bernalillo County				
Albuquerque	483,053	110,388	73.9	204
Other Public Water Supply	36,588	11,836	5.3	289
Total Public Water Supply	519,641	118,377	79.2	203
Domestic wells [d]	49,413	5,573	3.7	100
Total Bernalillo County	569,054	123,950	82.9	194
Sandoval County				
Rio Rancho	51,765	10,744	7.2	185
Other Public Water Supply	12,346	1,743	1.2	126
Total Sandoval Public Water Supply	64,111	12,487	8.4	174
Domestic wells [d]	25,797	2,829	1.9	100
Total Sandoval County	89,908 [e]	20,910	14	152
Valencia County				
Belen	6,901	1,473	1.0	191
Other Public Water Supply	26,073	4,994	3.3	171
Total Valencia Public Water Supply	32,974	6,467	4.3	175
Domestic wells [d]	33,178	3,716	2.5	100
Total Valencia County	66,152	10,183	6.8	137
Total Public Water Supply Use	616,726	141,178	91.9	204
Total Domestic Wells [d]	108,388	12,118	8.1	100
Estimated Total Use in Region	**725,114**	**149,449**	**100.0**	**184**

General Sources: *Historical and Current Water Use in the Middle Rio Grande Region*, prepared for the Middle Rio Grande Council of Governments and the Water Assembly, by John Shomaker & Associates, June 2000
- Summary of water use in acre-feet, in New Mexico counties, Table 4, 2000, October 4, 2002, Compiled by Brian Wilson, Office of the State Engineer
- Public Water Supply. Withdrawals and depletions in acre-feet, in New Mexico counties, 2000 Compiled by Brian Wilson, Office of the State Engineer, October 29, 2002

[a] Domestic (self-supplied) Withdrawals and depletions in acre-feet, in New Mexico counties, 2000. Complied by Brian C. Wilson, New Mexico Office of the State Engineer, October 29, 2002
[b] Census Population For Incorporated Cities, Towns, Villages And CDPs (Census Designated Places, Areas Defined to Identify Non-Incorporated Places) , U. S. Census 2000
[c] Divide total water use by population
[d] Domestic (self-supplied) Withdrawals and depletions in acre-feet, in New Mexico counties, 2000. Complied by Brian C. Wilson, New Mexico Office of the State Engineer, October 29, 2002 (data sent directly from Brian Wilson)
[e] 2000 Census http://www.mrgcog.org/2000socioeconomic/2000econmhmpg.htm

Table 18A-2. Estimate of Gallons per Person per Day Before and After Proposed Water Conservation Measures Implemented and Reduction from Current Use

	Albuquerque Usage **Before** Plan (2002) [a]		Albuquerque Usage **After** Plan Fully Implemented (at 2002 Population)		**Reduction** From Current Use to 100% Conservation Implementation	
Category	gpcd	%	gpcd	%	gpcd	%
Total non-ag use	204	100	120	100	84	41
Residential outdoor	40	20	20	17	20	50
Residential indoor	60	29	45	38	15	25
Industrial	5	2	4	3	1	20
Commercial [b]	53	26	21	18	32	60
Parks & golf courses and other institutional uses	23	11	12	10	12	50
Unaccounted-for Water	23	11	18	15	5	22

[a] Distribution of use is based on Albuquerque billing data as follows: 204 gpcd is comprised of the following elements: 100 gpcd for residential use + 23 gpcd for institutional/municipal public spaces + 33 gpcd for commercial + 20 gpcd for multi-family + 23 gpcd for unaccounted for water + 5 gpcd for industrial. Source: City of Albuquerque Public Works water billing data, personal communication with Jean Witherspoon, October 14, 2002

[b] Albuquerque data often accounts for water use by multi-family residences in the commercial category (COA, 2003). Multi-family usage accounts for approximately 40% of commercial billing amounts (Witherspoon, 2001).

Table 18A-3. Estimated Savings and Costs Attributed to Installation of Water Conserving Fixtures and Appliances

Non-Conserving Fixture From Installed From 1980-1990: Water Use Rating	Average Use	Estimated Use of Older Fixtures	Estimated Water Use of Conserving Fixture in Gallons/Use and gpcd for Fixture [a]	Estimated Water Savings When Replaced With a Water Conserving Fixture (gpcd)	Estimated Cost of Replacement [b]
Toilet 3.5 gal/flush [c]	5.1 flushes/ person/day	17.9 gpcd	1.6 gpf (gal/flush) = 8.2 gpcd	9.7	$100
Toilet 5.0 gal/flush [c]	"	25.5 gpcd	(1.6 gpf = 8.2 gpcd)	17.3	$100
Showerhead 4.0 gal/minute [c]	5.3 minutes/ person/day	14.1 gpcd	1.8 g/m (gal/minute) for 3.5 gpm rated = 9.5 gpcd	5.3	$25
Faucets 3.0 gal/minute [c]	8 minutes/ person/day	16.2 gpcd	1.0 g/m = 8 gpcd	8.1	$100
Dishwasher 14gal/load [a]	322 loads /year	4.8 gpcd	7 gal/load = 2.4gpcd	0.7	$500-$1,000 $100-500 more than standard model
Clothes washer 51 gal/load [c]	392 loads /year	21	27 gal/load = 11.2 gpcd	8.9	$600-$1,100 $200-$700 more than standard model
Misc. (leaks, guests, etc.) [c]			5.7 gpcd		
Total potential savings of low-water-use indoor fixtures & lifestyle			45 gpcd	40.3 gpcd	
Evaporative cooling [d]	10,758 gal. for 1,130 cooling season = 29 gal/day spread over yr.	11.3 gpcd	6 gpcd w/reduced use and eliminate bleed-off coolers		

[a] Assume average of 2.6 persons/household (http://www.mrgcog.org)
[b] http://www.waterwiser.org and associated links
[c] Source: Amy Vickers & Assoc Inc, Handbook of Water Use & Conservation[1]
[d] Source: B. C. Wilson, P.E. Office of State Engineer Technical Report 48[2]

Table 18A-4. Estimated Water Savings from Reducing the Size, Plantings and Water Rate for Residential Landscapes After 100% Implementation of OSE Conservation Subdivision Guidelines [a]

Municipality	Single Family Units [b]	Multi-Family Units [b]	Estimated Average Yard Size per Household in 2000 (ft^2) [c]	Estimated Yard Size Single Family After Conservation Plan Fully Implemented (ft^2)	Annual Gal/ft^2 for Bluegrass[d]	Gal/ft^2 Yr for Buffalo Grass or Xeriscape[d]	Low-Water Landscape Gallons /Dwelling Unit/ Person/ Day [d]
Bernalillo County							
Albuquerque	126,643	63,285	3,500	800	50	25	21
Los Ranchos	1,252	103	4,000	800	44	15	13
Tijeras	143	0	100	100	45	15	2
Bernalillo County Total	158,115	65,084					
Sandoval County							
Bernalillo town	1,276	126	1,250	800	43	15	13
Corrales	2,462	247	900	800	45	15	13
Cuba	137	34	100	100	45	15	2
Jemez Sp	133	9	900	800	45	15	13
Rio Rancho	17,641	2,152	1,750	800	45	15	13
San Ysidro	51	2	100	100	45	15	2
Sandoval County Total	28,646	2,469					
Valencia County							
Belen	1,828	431	1,500	800	48	15	13
Bosque Farms	1,076	4	900	800	45	15	13
Los Lunas	2,670	467	1,500	800	45	15	13
Valencia County Total	14,913	1,124					
Three County Total	201,674	68,677					

Source: 2000 census on mrgcog.org, Office of State Engineer, Technical Report 48, By Brian Wilson, Personal Communication with Claude Cisneros, City of Albuquerque Conservation Office

[a] Recommended Guidelines for County Subdivision Regulations for Water Supply and Demand, Brian Wilson, P.E., New Mexico Office of the State Engineer, May 2000

[b] 2000 Census as reported on www.mrgcog.org summaries for member counties

[c] Personal Communication with Claude Cisneros, xeriscape and rebate specialist, City of Albuquerque Public Works, October 30, 2002

[d] Recommended Guidelines for County Subdivision Regulations for Water Supply and Demand, Brian Wilson, P.E., New Mexico Office of the State Engineer, May 2000

Parks and Golf Courses

- Assumptions: new acreage of green space is not added; savings estimate is at 100% implementation; changes are phased in over 10 years.

- Assume the cost per square foot is the same for changing out public or privately-owned landscapes. Cost would include labor, low-water plantings, mulch and conversion of the irrigation system. Assume cost to reduce grass to mulch involves labor and materials for removal of grass and excavating down so mulch will not slip off.

- Assume current water use for high-water horticulture and turf is 43 and 50 gallons/square foot, respectively. Low water landscape would use 13 and 21 gallons/square foot for drip irrigated horticulture and buffalo grass, respectively[3].

Table 18A-5. Estimated Water Savings by Reducing the Amount of Watering and Reducing Turf Areas for Parks and Golf Courses in Albuquerque

	Estimated Water Use in 2000(ac-ft/yr)	Estimated Water Savings with Turf Area Reduced 30% and Water at 32 in/ft^2 [a]	Estimated % Savings Reduce Turf Area and Reduce Amount of Watering
Private Golf Courses in Albuquerque	3,060	1,480	48%
Public Golf Courses in Albuquerque	1,850	920	50%
Parks and Medians in Albuquerque	5,090	1,390	27%
Estimated Total	10,000	3,790	38%

Source: Jean Witherspoon, City of Albuquerque Conservation Office Billing Data, April 2001

[a] Water use at the three types of listed golf courses/parks is currently 46, 45 and 35 inches per ft^2, respectively) (ac-ft/yr)

Table 18A-6. Estimated Water Savings Resulting from Reduced Residential Landscape Area and Watering Rates

	Single Family Dwelling Units [a]	Multi-Family Units [b]	Estimated Existing Average Area of High Water Use Residential Landscape Per Household [c]	Estimated Best Case Potential Savings (ac-ft/yr) [d]
Albuquerque	126,643	63,285	3500	90,344
Rio Rancho	17,641	2,152	1250	2,396
Other Locations in Water Planning Area	57,390	3240	100 to 1,250	1,899
Regional Total	201,674	68,677		94,639

[a] 2000 census on mrgcog.org
[b] Wilson, 1997. Technical Report 48, Appendix C
[c] Personal Communication with Claude Cisneros, City of Albuquerque Conservation Office, October 29, 2002
[d] Obtained by reducing new and existing irrigated landscape from current average area (in 4th column) to 800 ft^2 and converting to low-water-use plants and irrigation at suggested rates in Table 18-4A (Wilson, 1997, Technical Report 48)

Estimated Cost to Reduce Existing High Water Use Turf, Landscaping and Sprinkler Systems to Low Water Plantings or Mulch and Drip Irrigation System

The following Table (18A-7) estimates the existing acreage of high–water-use landscapes in the region. Landscape area covered in this table includes Albuquerque golf courses, parks and irrigated medians and residential landscapes in the water planning region. Reductions are assumed to be as follows:

- Parks and golf courses reduce their high-water turf by 30 percent. Residential landscapes reduce their irrigated area to an equivalent of 800 ft^2. The cost to change out landscape and irrigation systems for these areas is assumed to be $2.00/$ft^2$. It is assumed that reduction in turf area results in planting of low-water drought-tolerant plants and drip irrigation systems (not "zeroscape").

Table 18-7. Estimated Cost to Reduce the Area and Change Out Plantings and Irrigation Systems for Residential Landscapes, Golf Courses, and Parks/Medians

Cost to implement	Existing area in acres	Number of acres to convert from high water use to low or no water use (30%)	Estimated cost (at $2.00/ft^2.) to change out plantings & irrigation system for converted acreage [a]
Residential Landscaping	21,700	16,735	$433,000,000
Private Golf Courses	850	255	$22,000,000
Public Golf Courses	500	150	$13,000,000
Parks	2000	600	$52,000,000
Total	**25,050**	**17,740**	**$520,000,000**

[a] Estimated cost/ft^2 as provided by City of Albuquerque Conservation Office and Office of the State Engineer Conservation Office. One acre = 43,560 ft^2.

Conversion Factors Used for A-18

1 acre-foot =	325,851	gallons
1 inch of water =	27,200	gal/acre
1 acre =	43,560	sq ft
Average household =	2.6	persons

[1] *Handbook of Water Use and Conservation, pages 25,27,88,103,118,128*
[2] *Water Conservation and Quantification of Water Demand in Subdivision, A Guidance Manual for Public Officials and Developers Technical Report 48;* Prepared by Brian C. Wilson, P.E., Office of the State Engineer, May 1996
[3] *Technical Report 48*, B. Wilson, Office of the State Engineer, Appendix C

Technical and Physical Feasibility Fact Sheet

Alternative 21: Urban Water Pricing

Acknowledgements: This fact sheet was written by Brian McDonald, Ph.D., private economic consultant, as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-21: Examine a variety of water pricing mechanisms and adopt those that are most effective at conserving water. The mechanisms to be examined include: a) price water to reflect the true value; b) institute a moderately increasing block price schedule; c) institute a steeply increasing block price schedule; and d) other feasible incentives and subsidies for conserving water.

2. Summary of the Alternative Analysis

If prices are increased by 100 percent, urban water pricing mechanisms can effect a 10 percent decrease in water demand. However, the use of price increases as a strategy to conserve water can lead to revenue enhancement for public and private water systems, which is inconsistent with present utility regulatory policy. Under current regulations, revenues from price increases must be reinvested in water projects and programs. Because drastic increases in price are required to affect demand, this alternative may not be the most appropriate for reducing water demand. Other non-price conservation mechanisms such as water conservation and xeriscaping may provide more feasible, lower-cost approaches for demand reduction.

2.1 Understanding the True Cost of Water

In the ideal competitive world the price of a commodity such as water would be set at its true economic value, determined by the interplay of demand and supply among many competing buyers and sellers. However, in the Middle Rio Grande (MRG) planning region the true value of water is unknown and indeterminate, since the market for water is not competitive.

Irrigation water is provided to farmers by the Middle Rio Grande Conservancy District (MRGCD) on a per-acre charge basis, and the marginal price of irrigation water is zero since there is no metering. Urban water use in the City of Albuquerque is priced on a cost of service basis, where water prices are set so that the city recovers the operating and capital cost to provide water service. Private water utilities, such as New Mexico Utilities, must get New Mexico Public Regulatory Commission approval of water prices, which are generally set to recover the cost of service and a fair rate of return on invested capital. Competitive market forces do not set water prices in this region.

As further evidence of the lack of a competitive market for water in the MRG region, consider that the acquisition of new water rights today costs approximately $5,000 per consumptive acre-foot of water. This reflects the value to acquire the permanent right to consume water in the region from another water user. Assuming a discount rate of 5.25 percent,[1] a $5,000 cost to acquire a permanent water right today represents an annual $262.50 cost[2] per consumptive acre-foot cost. The City of Albuquerque and other water users in the region also have rights to San Juan-Chama Project water, the cost of which has been determined by the U.S. Bureau of Reclamation based upon the capital and operating cost of this project. It is estimated that the annual cost of the San Juan-Chama Project water to the City of Albuquerque is $45 per acre-foot. The City of Albuquerque has recently leased San Juan-Chama water back to the Bureau of Reclamation at an annual cost of $45 per acre-foot, as provided for in the San Juan-Chama Project agreement. However, at the same time the City is paying $5,000 per acre-foot to acquire permanent water rights, which is an annual $262.50 cost. In a competitive market, the marginal price of water would be the same price for all uses, but this is not true in the planning region.

Groundwater that is mined as a source of water supply represents a special case for the true value of water. Such groundwater not only provides the usual “extractive services” to municipal, industrial, commercial, and agricultural water users. In addition, it provides “in situ services” such as supporting the water table in the riparian zone, preventing the subsidence of the land surface, providing reserves in case of drought, and reducing water treatment costs.[3] The value of these in situ services are not reflected in the current price of mined groundwater, which is based upon the cost to drill, pump, and treat mined groundwater.

Other impediments to a functioning competitive water market in the MRG region include the difficulty of transferring water among users because of institutional and legal constraints. In a competitive market the transfer of water would be relatively frictionless. Water within this region is also not well-defined as a private property right because of the lack of adjudication of water rights, including the resolution of native rights for the Pueblo Indians. There are many more paper water rights in the MRG region than there are wet water rights.[4] There are also new demands for water in this region, which have not previously existed and which have been imposed by the courts, such as instream flow for endangered species. Thus, in no sense does a true value of water exist today in the MRG region, and what this value would be under competitive economic market conditions is impossible to determine.

2.2 Correlation Between Price and Demand

Water is not exempt from the laws of economics. As an economic commodity, the demand for water is responsive to the price of water. As the price of water increases, the quantity demanded falls. The effectiveness of increasing the price of urban water as a strategy to conserve water in the MRG planning region, however, depends on exactly how responsive demand for water is to increased price. Economists refer to this relationship between the quantity demanded and the price as the "price elasticity of demand."

Michelsen et al. (1998) provided an extensive analysis of the effectiveness of residential water conservation price and non-price programs for the American Water Works Association. This research explored the feasibility of using higher water prices to alleviate temporary water shortages, to avoid the need for increased water supply, treatment, and water system expansion, and to extend the ability of existing water supplies to meet current and growing future demand for water. Specifically, Michelsen et al. (1998) focused on the consumer response to price and non-price conservation measures in different urban areas of the southwest including Los Angeles, San Diego, Denver, Albuquerque, Las Cruces, and Santa Fe. The statistical analysis covered the 1984 to 1995 time period and examined residential water consumption, rate structure, and price and non-price conservation programs.

According to their research, non-price water conservation programs appear to be effective, if the water utility achieves a critical mass of such water conservation programs. Although they were not able to determine the effectiveness of a specific non-price water conservation program, their research did indicate that a combination of water conservation programs, implemented in unison, can be effective in reducing the demand for residential water use (Michelsen et al., 1998). The feasibility of such non-price water conservation programs is explored more completely in the economic fact sheet for Alternative A-22, Conservation Incentives.

Over time, a water price increase coupled with extensive non-price, conservation programs can lead to reduced revenues due to a reduction in water use. Revenue projections as well as short- and long-term effects on water demand must be part of a study to fully evaluate the implications of this alternative on the operations of any individual public or private utility.

Typically, urban water rates are set to recover the cost of providing water service to residential and non-residential customers. Rate structures include a fixed monthly charge, which may or may not include some minimum usage of water, and a water commodity charge, which may be a constant price per unit of water or an increasing block rate structure in which the price per unit increases as water consumption increases. The increasing block rate structure is oriented toward water conservation and attempts to use the market mechanism to reduce water use, particularly among high volume water users. Michelsen et al. (1998) found that in 1986 only 8 percent of residential water providers in the U.S. used an increasing block rate structure. However, by 1994 this had increased to 22 percent.

Although Michelsen et al. concluded that a higher water price has the expected negative impact on water use, they noted that water demand is very price inelastic: "Consumers are very unresponsive to price increases under current rate structures, requiring large increases in price to achieve small reductions in demand" (Michelsen, et al., 1998). For summer water use, they found that the price elasticity of demand for water was approximately –0.20, which means that for a 100 percent increase in water prices, water demand decreases 20 percent. On an annual basis, however, they concluded that the price elasticity of demand for water was only –0.10, meaning that a 100 percent increase in water prices will reduce water demand by only 10 percent (Michelsen et al., 1998).

Urban water prices are set within a utility regulatory environment, whether it is a public utility or private water utility. In the latter case, however, the price allows recovery of the operating and capital cost of the water utility and a fair rate of return. Revenue enhancements through price increases are allowed, if the water utility can document that it has increased operating cost of service or additional capital expansion needs.

Price increases for water conservation goals alone will result in revenue enhancement for water utilities. Public water utilities must be operated on an enterprise fund basis, and excess revenue may not be shared with the general fund. Private water utilities operate on a cost of service plus a fair rate of return basis. Revenue enhancement from a water conservation pricing strategy would result in excess profits to the private water utility or excess reserve funds to the public water utility. However, if these revenues are reinvested in water projects and programs, the utility can implement the price change while complying with existing regulations.

2.3 Existing Water Rate Structures in Selected Southwestern Cities

Tucson, Arizona has the highest increasing block rate water price structure in the southwest. For a single-family residential customer, Tucson charges $1.03 per unit[5] for the first 15 units, $3.50 per unit for the next 15 units, $4.92 per unit for the next 15 units, and $6.97 per unit for water usage over 45 units. In contrast, the City of Albuquerque charges $1.1934 per unit with a 50 percent surcharge ($1.7901 per unit) in summer (April through October) for water usage exceeding 200 percent of the winter average. A second tier surcharge of an additional 50 percent ($2.3868 per unit) is applied to water usage exceeding 300 percent of the winter average. In Albuquerque, the typical residential customer uses 10 units in the winter; this means that in summer only, the city charges $1.1934 per unit for the first 20 units, $1.7901 per unit for the next 10 units, and $2.3868 per unit for water usage over 30 units.

Both Albuquerque and Tucson have a fixed-base charge that does not include any minimum water usage; however, Phoenix charges a fixed base charge, varying by meter size, that does include a minimum water usage—6 units during October through May, and 10 units during June through September. Consequently, in Phoenix, the minimum water user faces a zero marginal price of water. For water usage beyond the minimum, Phoenix uses an increasing block rate structure that varies by season. In the low use months of December through March, the water commodity charge is $1.24 per unit. In the medium use months of April, May, October, and November, the water commodity charge is $1.47 per unit. Finally, in the high use months of June, July, August, and September, the water commodity charge is $1.87 per unit. Phoenix also imposes a flat $0.08 per unit environmental charge in all months in addition to the water commodity charges above.

Colorado Springs has a water price structure similar to Albuquerque, with a fixed base charge and no minimum usage. In the winter months (November through April), there is a constant water commodity charge of $1.52 per unit. In the summer months (May through October) there is an increasing block rate structure. The water commodity charge is $1.52 per unit for the first 10 units of water, $1.91 per unit for the next 20 units of water, and $2.27 per unit for water use over 30 units.

Salt Lake City has the lowest water rates among the southwestern cities surveyed. Salt Lake City has a fixed base charge, which includes the first 5 units of water use. It also has an increasing block rate structure like Phoenix, which varies by the season than by usage. During the low use season of October through May, the water commodity charge is $0.61 per unit, while during the high use season of June through September, the water commodity charge is $0.93 per unit.

There are several small private water utilities in the MRG planning region. Residential water rates for three of these are presented in Table 21-1; however, as a condition of releasing this rate information, these private water utilities wished to remain anonymous. Water utilities A and B both charge a fixed monthly base amount, which includes a minimum usage of the first 900 gallons. For monthly water usage over 900 gallons, these two private water utilities charge a fixed commodity charge: $2.53 per 1,000 gallons and $3.08 per 1,000 gallons, respectively.

Water Utility C charges no fixed monthly base amount, and derives water revenues only from a commodity charge per 1,000 gallons. This commodity charge increases as monthly usage increases, ranging from $3.38 per 1,000 gallons on the first 1,000 gallons to $5.84 per 1,000 gallons for usage over 20,000 gallons. Thus, Water Utility C already has imposed an increasing block rate structure, while the other two have not.

Table 21-1. Water Rates for Small Private Utilities in the Middle Rio Grande Planning Region

Private Water Utility[a]	Service Charge	Rate per 1,000 Gallons		
		0 to 900 Gallons Used	901 to 20,000 Gallons Used	Over 20,000 Gallons Used
Water Utility A	None	$12.50	$2.53	$2.53
Water Utility B	$11.25	$3.08	$3.08	$3.08
Water Utility C	None	$3.38	$4.61	$5.84

[a] These small utilities have between 500 and 2,000 connections each.

It is important to note that the water commodity charge of these small private water utilities is much higher than the commodity charge of large public water utilities such as Albuquerque, Salt Lake City, Colorado Springs, and Phoenix. Increasing the water rates from present levels at these small private water utilities as a means of encouraging water conservation will impose a greater financial burden on these rate payers than on those of a large public water utility such as the City of Albuquerque.

Santa Barbara, California is an interesting case study of the urban water pricing and water conservation policy. In 1990 and 1991, Santa Barbara was faced with a severe drought and had actual physical limitations on the amount of water available for consumption. Urban water use was reduced by 50 percent during this time period. In response to the drought and water shortage, Santa Barbara embarked on a $34 million desalination water project to expand the city's water supply. To pay for this project, water rates were doubled and an increasing block rate price structure imposed.

At first glance, it may appear that Santa Barbara was able to achieve a 50 percent reduction in urban water use for a 100 percent increase in water prices. However, this would be an incorrect analysis of the price elasticity of the local demand for water. Although water usage undoubtedly fell because of higher water prices, the decrease in usage was primarily caused by the physical shortage of water—water could not be had for any price.

Santa Barbara raised water prices in response to the drought emergency, not only to discourage water demand and but also to raise revenue to pay for the $34 million desalination plant. The need for revenue enhancement to pay for expanding the city's water supply was a major driving force behind the water rate increase.

Interestingly, Santa Barbara does not currently use the desalination plant, but maintains it as a drought reserve. Due to ample rainfall in recent years and cheaper available water from the State Water Project, it is not cost effective to run this plant at this time. Between 1993 and 1999 Santa Barbara kept its water rates unchanged, while the statewide average residential water price increased 20 percent. Santa Barbara did approve a 3 percent water price increase in 1999 and 2000 to fund major water construction for the City's Sheffield Reservoir. Thus, even in Santa Barbara, water price increases appear to be tied for the need for revenue enhancement rather than water conservation.

Water consumption data from the City of Santa Barbara indicates that, prior to the drought emergency in 1990, water system production was approximately 16,000 acre-feet per year. During the drought, water system production fell to near 10,000 acre-feet per year and today, water system production has leveled off at approximately 14,500 acre-feet per year, "reflecting an estimated permanent reduction in water usage of about 10 percent as a result of measures taken during the drought" (City of Santa Barbara, 2002).

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Urban water pricing mechanisms with increasing block rate structures already have been implemented in many U.S. cities. Thus, this alternative is technically feasible.

Infrastructure Development Requirements

For a public water utility, a water rate increase would usually be initiated by the water utility department, as needed, to fund increased operating costs or capital expenditure needs of the public water system. The new water rate structure would be designed by city staff, perhaps with the assistance of an outside consultant. Water utility department staff must document that the proposed water rates would raise enough water revenue to cover operating cost and debt service on water revenue bonds without generating excess cash reserves. The proposed new water rates would be presented to the city council for review and approval, and the mayor must sign off on the rates, after city council approval. The city council and/or the mayor can also initiate a water rate increase as part of a city water policy strategy to conserve water, with increased water revenues dedicated to fund water conservation programs or new water supplies for the city.

For a private water utility, the manager of the private water utility typically would bring a proposal for a water rate increase to the New Mexico Public Regulatory Commission (NMPRC) for approval. The proposal would first be prepared by the financial staff of the private water utility, with or without the assistance of outside consultants. In many cases the private water utility hires an outside lawyer, who is an expert in administrative proceedings before the NMPRC, to assist in this process. This proposal must document that the proposed rate structure would raise sufficient revenue to cover the operating cost of the private water utility as well as provide a fair rate of return on the utility's invested capital. The NMPRC staff would review the proposed new water rate structure and recommend approval of the commissioners. The new water rates would not go into effect until it was approved by the five-member NMPRC.

Total Time to Implement

Administrative implementation of a new water rate structure could be completed within six months; however, it may require consultation on water rate design, which could require from six months to two years to complete.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

A 100 percent increase in water rates, on average, would decrease total urban water use by 10 percent. Total urban consumptive water use in the MRG planning region is estimated at 84,880 acre-feet in 1995 (Wilson and Lucero, 1997).

Effect on Water Supply (surface and groundwater)

None.

Water Saved/Lost (consumption and depletions)

This alternative would result in a 10 percent reduction of urban water demand for every 100 percent increase in the water rate.

Impacts to Water Quality (and mitigations)

None.

Watershed/Geologic Impacts

None.

3.1.2 Environmental Impacts

Impact to Ecosystems

Water savings, if legally available, could be transferred to other water uses that support riparian habitat.

Implications to Endangered Species

Water savings, if legally available, could be transferred to other water uses that support the endangered species such as the silvery minnow.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

For a public water utility, the administrative costs include staff time to develop, manage, and implement a water rate increase initiative, estimated at six months of one full-time employee's time. The public water utility likely would contract out for a water rate study, which would cost approximately $50,000 depending on the scope and complexity of the study. City council staff would review the proposed water rate increase, estimated at one month of a full-time employee's time. Staff from the mayor's office would also review the final water rate proposal, requiring an estimated two weeks of a full-time employee's time. This alternative could cost from $100,000 to $300,000 to implement, depending on employee salaries and/or unanticipated costs. Assuming a 100 percent increase in the average price of urban water ($0.00193 per gallon including surcharges; City of Albuquerque, 2002) the cost to save 8,488 acre-feet (10 percent of total urban consumptive use in the three counties in the region) is approximately $6,300 per acre-foot.

For a private water utility the administrative costs would likely be of the same magnitude, except the total cost is more likely to be at the high end of the range. This is because an outside attorney specializing in administrative hearings before the NMPRC would likely be hired on a contract basis.

Potential Funding Source

Water users would pay for the increased rates. Public and private utilities pay salaries and the cost of outside consultants from revenues, therefore these costs would also be funded by water users.

3.2.2 Ongoing Cost for Operation and Maintenance

None.

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[1] Current interest rate on municipal bonds rated AAA.

[2] $5,000 times 5.25%.

[3] For a more complete discussion of these groundwater issues see *Valuing Ground Water: Economic Concepts and Approaches*, Commission on Valuing Ground Water, National Research Council, The National Academies Press, 1997.

[4] "Paper" water rights exist on paper and may not have a proof of beneficial use to substantiate their existence. In certain areas, paper water rights may exceed the available water supply or "wet water."

[5] One unit is 748 gallons of water or 100 cubic feet of water.

Technical and Physical Feasibility Fact Sheet
Alternative 22: Conservation Incentives

Acknowledgements: This fact sheet was written by Myra Segal Friedman of EJJ Associates as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-22: Provide local government programs that offer subsidies for adoption of water efficient technologies and utilization of water saving devices.

2. Summary of the Alternative Analysis

This analysis examines implementation of subsidy programs to promote installation of low-water-use technologies that can be administered through regional or local governments or water suppliers and can build on current local and national programs. Existing programs serve as a model for public water supply systems to initiate incentive programs to encourage consumers to reduce water usage. Rebates or "give-aways" demonstrate a commitment by water utilities and policy makers that they think it is important to change water wasting fixtures, appliances and landscapes. These incentives provide a balance to mandatory requirements the utility or jurisdiction may impose.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Water-efficient technologies and water saving devices are available in the general market. Reduction in household water use since the mid-1980s stems primarily from improvements in the efficiency of plumbing fixtures and appliances (Vickers, 2001). As time passes, devices will be produced that hopefully further increase in efficiency and affordability. Toilet design is likely to be improved to address some of the current technical drawbacks and to provide enhanced features (e.g., avoid blockage and allow for easy control of the amount of water used for each flush, as is found in existing European models).

Infrastructure Development Requirements

The infrastructure needed for this alternative is related to administrative staff and financial resources rather than to water distribution infrastructure.

Rebates are generally provided through the water billing system, so the system's programming structure must be capable of making bill adjustments for customers approved to receive rebates.

Incentives other than rebates could also be provided. For instance, conserving households (ones with a large reduction or that are consistently under their category's average) could be provided a "discount" on their water bill. Another incentive could be a streamlined administrative procedure for new construction that incorporates low-water design and technologies that exceed minimum standards. Other administrative incentives for new construction or building permits for renovations could include (1) a "trade" for something else in the plan approval process or (2) a streamlined review process for planned developments that emphasize water conserving designs and technologies.

Total Time to Implement

Rebate programs are in place in Albuquerque, Rio Rancho and possibly other jurisdictions in the Middle Rio Grande planning region. Additional or broader programs could be implemented when staff is made available to oversee, process, and inspect installations, and when the interested utility determines that it can provide rebates instead of collect revenue from customers.

The City of Albuquerque has an estimated 126,643 single family and 63,285 multifamily dwellings (MRCOG, 2002). Some of these homes are new construction or have already installed water conserving fixtures and landscapes. Rebates are targeted to conversion of older, high-water-use dwellings, yet only a fraction of residences have participated in the rebate program. As the 50 years of the regional water plan elapse, older fixtures, landscapes, and irrigation systems will be replaced with new, water-conserving ones. Rebates can speed that process. Setting a target date for complete saturation can guide how aggressive a rebate program should be.

Santa Fe had a toilet give-away program during the recent drought. Lessons can be learned from jurisdictions that have experience with giving away conservation devices.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Rebates are an incentive to speed up the installation of water-saving devices. Savings accrue as more of the items are installed over time. Water savings estimates from replacing non-conserving with conserving fixtures and appliances are summarized in Table 22-1. Refer also to the fact sheet for A-18, *Urban Conservation* for information on potential savings.

Table 22-1. Correlation of Rebate-Targeted Fixture to Acre-Feet Savings and Cost: City of Albuquerque Rebate Program 1996-2002

Item	Savings Per Unit Converted	Year Rebate Established	No. of Items Needed to Save 1 ac-ft/yr	Total No. of Rebates from Established Year to 2002	Total 2002 Savings Due to Items Converted 1996-2002 (ac-ft/yr)	Rebate Per Unit	Total Expenditure 1996-2002	Cost ($)/ac-ft of Savings Over 25-Year Life of Converted Item
Toilet: Convert from 5 to 1.6 gallons/flush	122 gallons/week	1996	51	43,261	842	$87.52	$3,786,203	$180
Xeriscape: Convert bluegrass to low water plants	19 gallons / per ft^2 /yr	1997	17,500 ft^2	1,586,819 ft^2 (1,127 properties)	93	$0.25 (per ft^2)	$317,079 [b]	$140
Clothes washer: Convert from 51 to 27 gallons/load [c]	115 gallons/week	2000	54	3,474	64	$100	$347,400	$215

Source: City of Albuquerque Water Conservation Office

[a] Unless otherwise noted.
[b] Personal communication with Jean Witherspoon, October 14, 2002 using billing and rebate program data. These numbers exceed the data reported in the City of Albuquerque's *2001 Water Conservation Annual Report* because of additional rebates issued since the annual report was written (for xeriscaping, price changed from $.20 to $0.25).
[c] Vickers, 2001, p. 119.
ac-ft/yr = acre-feet per year ft^2 = square feet

As seen in Table 22-1, water can be saved by replacing high-water-use toilets, landscapes, and clothes washers with low-water-use items that are currently available. To save 1 acre-foot of water per year, approximately 51 toilets, 54 clothes washers, or 17,500 square feet (ft^2) of landscape must be replaced. The City of Albuquerque has sponsored a water conservation rebate programs since 1995. Between 1995 and 2002, 42,082 toilets, 1,127 landscapes (1,586,819 ft^2) and 3,474 clothes washers have been replaced with low-water-use designs (Witherspoon, 2002; Cisneros, 2002). Data from this program (Table 22-1) indicate the savings and costs that can be expected from a rebate program.

In Albuquerque, utility customers have been offered a toilet rebate for about seven years. Approximately 4,000 to 8,700 toilets have been replaced each year, saving an estimated 2.9 gallons per flush or 122 gallons per week per fixture. (Witherspoon, 2002; Vickers, 2001)

The Albuquerque xeriscape rebate program has been operating for about six years. Initially, a rebate of $0.20/$ft^2$ was offered; this was later increased to $0.25/$ft^2$. Approximately 150 to 300 properties have converted (175,000 to 425,000 ft^2) each year. Xeriscape with drip system saves an estimated 30 inches/ft^2 (or 19 gallons/ft^2 per year) as compared to a bluegrass lawn with sprinklers (Witherspoon, 2002; Vickers, 2001). Note that xeriscapes can exhibit a delay in total water savings because newly installed xeric plants need more water to get established the first year or two. Savings are realized after the second year, if the homeowner is aware of how they can reduce watering (Cisneros, 2002).

The City of Albuquerque's clothes washer rebate program has been operating for approximately three years. About 700 to 1,200 washers have been replaced each year, saving an estimated 23 gallons per load or 115 gallons per week (Witherspoon, 2002; Vickers, 2001).

As clothes washers are more costly to replace, the target number of clothes washers to be replaced in a rebate program may be lower than for toilets or other lower cost items.

The amount of water saved will accrue over the life the installations, as shown in Table 22-1.

Effect on Water Supply (surface and ground water)

This alternative will not affect water supply.

Water Saved/Lost (consumption and depletions)

Savings projected from this alternative are presented in Table A-22. The savings for xeriscaping represent a reduction in consumptive use. However, since water from washing machines and toilets is returned to the wastewater treatment plant, the savings shown on Table A-22 represent potential savings in total water diversions rather than in consumptive use.

Impacts to Water Quality (and mitigations)

Replacing sprinklers with drip irrigation can reduce run-off and therefore reduce migration of lawn chemicals and soil into the river.

Watershed/Geologic Impacts

None specific to this alternative. Refer to the fact sheet for A-18, *Urban Conservation*.

3.1.2 Environmental Impacts

Impact to Ecosystems

None specific to this alternative. Refer to the fact sheet for A-18, *Urban Conservation*.

Implications to Endangered Species

None specific to this alternative. Refer to the fact sheet for A-18, *Urban Conservation*.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

As seen in Table 22-1, a cost per acre-foot can be calculated by the amount of water saved from the rebate program and comparing this to the cost of providing rebates. Using the rebate level currently offered by the City of Albuquerque and an accrued water savings (over the 25-year life of the converted item), rebate costs per acre-foot of saved water range from $10 for xeriscape rebates to $180 for toilet rebates to $215 for clothes washer rebates. Since the xeriscape option represents a savings in consumptive use and is the least expensive option, it provides the highest value.

Currently, replacing a high-water-use clothes washer with one that uses less water has a high initial cost to the consumer. Without a rebate, there may be little financial incentive for buying a more expensive, water-saving model. However, the significant water savings that can be realized make washers an effective rebate target (as seen in Table 22-1, it takes only 54 washers to save an acre-foot per year). Local jurisdictions should consider increasing the rebate amount for washers to make this a more economical choice for middle Rio Grande residents.

Table 22-1 summarizes costs found in the existing Albuquerque program. Costs can vary depending upon the amount of the incentive and the participation rate. Because rebates are provided as a "deduction from billed water," the actual cost of the program is related more to foregone revenue than capital outlay. Ability to forego revenue is contingent upon the water utility's cash flow and fiscal health.

Water rate "discount incentives" for highly conserving customers would similarly imply that the utility can afford to forego revenue.

Administrative incentives do not have to cost revenue or cause foregone revenue. Administrative incentives such as streamlined permit processing does not cost revenue, but does require trained staff with enough time set aside to make these cases a priority to clear to process toward approval.

The cost per acre-foot is calculated in Table 22-1 on the basis of the rebate provided and does not account for staff time to administer the program.

It can take a number of years to yield a return on investment for a water conserving installation, but the savings are long-term.

3.2.2 Potential Funding Source

The water utility and customers will share the cost for the installations. Generally rebates do not cover 100 percent of the cost of installation.

If the utility cannot forego revenue to keep up with demand, other funding sources such as grants, capital investment programs, or "borrowing" from other funding categories within the utility may be sought.

3.2.3 Ongoing Cost for Operation and Maintenance

Estimated operation and maintenance costs can be derived from the ongoing program in the City of Albuquerque (Table 22-1). By 2050, it is likely that low-water use fixtures will be used by all water consumers. Technology may improve water saving yields after that point. Rebate programs (and programs that offer free fixtures) boost the rate at which these fixtures are replaced. Saturation of the marketplace with low-water technologies and devices will eventually eliminate the need for rebate programs.

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Technical and Physical Feasibility Fact Sheet
Alternative 24: Reuse Greywater

Acknowledgements: This fact sheet was written by Beth Salvas of Daniel B. Stephens & Associates, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A24: Promote, through incentives, on-site residential and commercial greywater reuse and recycling.

2. Summary of the Alternative Analysis

Greywater reuse refers to either residential or commercial reuse of water that does not contain blackwater (from toilets) or kitchen wastes. Water from sinks (excluding kitchens) laundries, bathtubs, or showers is considered to be greywater. The analysis of on-site greywater reuse feasibility for the Middle Rio Grande water planning region included investigations pertaining to:

- Existing on-site commercial greywater reuse and recycling plans and activities
- Existing and proposed local and state regulations regarding on-site greywater reuse and recycling
- Health issues regarding greywater reuse
- The successes and drawbacks of experience from similar on-site greywater reuse projects in the western U.S.
- Potential decreases in fresh water demand and wastewater return flows that could result from on-site residential greywater reuse activities
- Possible economic and water rate incentives as a means to stimulate greywater reuse
- The costs associated with implementation, retrofitting, and maintenance for commercial and residential on-site greywater reuse systems

Advantages of reusing greywater are:

- Replaces potable water use and therefore lowers water bills and possibly sewer bills
- Increases life and/or improved performance of on-site septic systems
- When used for outdoor irrigation, the nutrients in greywater may support plant growth
- Reduces energy and chemical use (why chemical, not treated a wastewater treatment plant, household would limit cleaning agents as well)
- Possibly decreases the need to expand wastewater treatment facilities

Reusing greywater also has some disadvantages:

- Has the potential to spread disease if system is not properly operated
- May develop odors if stored more than 24 hours
- May adversely impact soil (salt buildup)
- Decreases the amount of wastewater going to treatment plant, which may affect the overall wastewater system
- Lowers availability of reclaimed water for return flow credits or other uses

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

On-site greywater reuse has been implemented in many states including California, Arizona, and Texas. Local commercial businesses have also implemented on-site water recycling. For example, Octopus Car Wash locations have an underground treatment facility built in to treat and recycle water (Gates, 2003).

Engineered Plumbing Solutions Inc. is an international environmental engineering firm that has a local Albuquerque office. The firm designs, manufactures, and sells the on-site wastewater recycling system, Aquamake, that has been approved by the New Mexico Environment Department (NMED). They offer systems for commercial operations and are developing a single household system (Skrak, 2003).

Infrastructure Development Requirements

Separate plumbing is required for greywater systems. The systems are easiest to install during construction, but retrofitting is feasible if plumbing is accessible. Already constructed locations on concrete slabs or crawlspaces are difficult to retrofit (Noah, 2001).

The standard components of a greywater system include (Little, 2003):

- *Conveyance piping* to collect water from source and deliver to greywater system
- *Surge tank* to hold flows (e.g., plastic trash barrel)
- *Filter* to remove particles such as lint and hair (e.g., sock, sand filter)
- *Storage tank* to hold water until ready to use
- *Three-way valve* to allow greywater to go to sewer or septic system
- *Pump* to move water to distribution point such as irrigation system

A permit is required by NMED, which currently considers greywater under liquid waste. The permit needed is the same type of permit required for a septic system (Duttle, 1994). In issuing the permit, NMED considers treatment, storage, and disposal of the water (underground leach field versus surface disposal for irrigation). Legislation addressing greywater reuse is being considered during the 2003 New Mexico legislative session. If enacted, this legislation would exclude the permit requirement for recycling systems when applying less than 250 gallons per day if the following conditions are met:

1. System overflow is directed to existing wastewater system.
2. Storage tank is enclosed and access is restricted.
3. System is outside of the floodway.
4. There is at least 5 feet vertically between greywater and the groundwater table.
5. Pipes for greywater system are marked as nonpotable water.
6. Greywater does not leave the property.
7. Standing water is minimized and prohibited for more than 24 hours.
8. Greywater is never applied by spraying.
9. Greywater use complies with local ordinances.

Potential water sources include washing machines, bathtubs, showers, and lavatory sinks.

Total Time to Implement

The time needed to implement a greywater system varies depending upon extent of system installed (e.g., washing machine only, shower, sinks and washing machine). The time needed to retrofit an existing system is typically less than a year. Due to the number of existing systems within the planning area, it could take ten years or more to retrofit all of the existing systems. The retrofit rate is dependent on whether or not there are incentives and/or financing to assist homeowners. Installing greywater systems for all new construction could be implemented quickly, once local ordinances are revised to reflect this requirement.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

This alternative has the potential to reduce demand for treated potable water by the amount of greywater that is recycled. The average person generates about 40 gallons of greywater per day (NSFC, 2002), and fresh water use could be reduced by 20 to 25 percent (Prososki-Marsland, 1995). However, even though the amount of diversions and water passing through a central treatment plant may be reduced, the consumptive use does not change as a result of this alternative.

The Intel New Mexico site committed to maintaining water use within its established historical range when a factory expansion was announced in 2000. Manufacturing process improvements and reuse of process waters have allowed the site to expand manufacturing capabilities and successfully operate within the site historical range of water use (Judd, 2003).

Effect on Water Supply (surface and groundwater)

This alternative does not have an effect on surface or groundwater supply.

Water Saved/Lost (consumption and depletions)

This alternative will not affect consumptive use. As discussed above, the alternative will reduce the amount of treated potable water that is needed to serve consumptive uses, but the total consumptive use will not change as a result of installing greywater systems. The greywater systems allow water that has been used internally (from laundry, sinks, etc.) to subsequently be used outside. However, consumptive uses do not change unless other adjustments are made. In fact, there is a potential for consumptive use to experience a slight increase if greywater is cheaper than other water supplies. This alternative can also affect the water supply by decreasing the amount of wastewater returned to the treatment plant by up to 60 percent (Gelt, 2002). If water rights stipulate a return flow requirement or if other users are depending on return flows, those issues must be addressed when implementing greywater reuse.

Impacts to Water Quality (and mitigations)

Use of greywater needs to be carefully monitored by the user. Greywater should never contain wastewater from toilets, washing machine loads that contain baby diapers, or kitchen waste. Systems should be turned off when someone in the household is diagnosed with an infectious disease (Office of Arid Lands Studies, 2002). Additionally, household chemicals should never be disposed of in greywater systems.

A residential greywater reuse study was conducted by the Water Conservation Alliance of Southern Arizona (Water CASA). For a summary of finding and water quality data, visit the Water CASA website at (http://www.watercasa.org/research/residential/resindex.htm). The study supports the conclusion that kitchen sink water should not be used in the greywater systems because it carries a greater risk of pathogen exposure (e.g. fecal coliform), and recommends that residents consider the makeup of their household before installing a greywater system (Water CASA, 2000).

Watershed/geologic impacts

This alternative would not directly impact on the watershed or geology.

3.1.2 Environmental Impacts

Impact to Ecosystems

When used for outdoor irrigation, the nutrients in greywater will support plant growth, but may cause damage to soil from the buildup of salts if greywater use is not rotated with harvested rainwater or fresh water (Prososki-Marsland, 1995). Plants can be damaged from greywater containing sodium, bleach, borax, or liquid fabric softeners (Duttle, 1994). Use of biodegradable soap low in sodium content is recommended as well as selection of plants that are salt tolerant and not edible (Prososki-Marsland, 1995).

Implications to Endangered Species

This alternative has no impact on endangered species.

3.2 Financial Feasibility

3.2.1 Initial cost to implement

The cost to implement a greywater system varies greatly depending on whether the work is done by the owner or by professionals. The cost to retrofit a greywater system is estimated to range from $135 to $2,000, where plumbing is relatively accessible. Costs would be prohibitive for existing structures where plumbing is inaccessible. The cost to build a greywater system during new construction is estimated to range from $65 to $650 (Little, 2003). For example, the cost to construct the greywater treatment and distribution system for Casa del Agua was about $1,500.

For the Aquamake system, installation costs are estimated to be between $50,000 and $500,000, depending upon the size of the unit. For example, installation costs for a 300-square-foot commercial building producing approximately 1,500 gallons of water for recycling each day would be approximately $105,000 (Skrak, 2003).

3.2.2 Potential Funding Source

Possible funding sources include incentives provided by public utilities.

3.2.3 Ongoing Cost for Operation and Maintenance

Annual maintenance costs are estimated to be less than $100 up to $600 for residential greywater recycling units, depending on whether the work is performed by the owner or by a maintenance contract. The cost would cover disinfectant use and regular cleaning and replacement of filters throughout the year. The greywater filtering system needs to be cleaned on a regular basis to prevent clogging.

For the Aquamake system, operation and maintenance cost are estimated to be between $500 and $4,000, depending upon the size of the unit. For example, operation and maintenance costs for a 300-square-foot gas station would be approximately $450 per year (Skrak, 2003).

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Technical and Physical Feasibility Fact Sheet

Alternative 26: Domestic Wastewater

Acknowledgements: This fact sheet was written by Sue E. Umshler, Esq., P.E. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-26: Expand use of centralized wastewater collection and treatment systems into all areas of urban and suburban development within the water planning region.

As further defined by the Water Assembly:

> Certain areas of the region rely on septic tank systems which do not ade uately purify the water before it returns to ground water. Technical limits such as distance and pipeline size make implementation costly. In addition to posing a water uality risk, widespread use of septic tanks often realize a near-zero return flow, or recharge, to the a uifer, resulting in a much higher proportion of consumptive use, as opposed to localized treatment systems, where the water can be contained and reused or returned to surface water.

2. Summary of Alternative Analysis

This alternative is technically and physically feasible and can result in a reduction of potential pollution sources for groundwater a uifers. It does re uire significant infrastructure to build and/or expand existing wastewater treatment plants and to construct pipelines to collect the wastewater from the facilities currently using septic tanks. This infrastructure is costly, and the time needed to implement this alternative depends on the septic tank locations, the treatment facility location, the funding methods, re uisite easements, and resource availability for design and construction.

Assuming that the septic tank is located in a shallow water table valley area near the river (as is the case with a large portion of existing septic tanks in the urban area of the Middle Rio Grande region), there is little effect on water demand or water supply uantities and therefore no water saved or lost from the existing consumption and depletion cycle. However, there could be a significant benefit in the protection of groundwater uality from degradation by inade uately treated wastewater. Once collected and treated, the effluent could be returned to surface water streams, be used for a uifer replenishment, and/or be treated to sufficient uality for direct reuse (see A-27). Constructed wetlands can provide aesthetic benefits to a community, but would re uire augmentation with conventional processes, such as disinfection, to meet current wastewater treatment re uirements.

If the treated wastewater is reused, it could result in decreasing demand by pumping or diversion reductions e uivalent to the recycled uantities, thus having a positive geologic benefit (reduced depletion of groundwater). Treatment costs may be higher to attain levels acceptable for a reuse or recharge project (see A-27, *Reuse Treated Effluent*).

There may be no net change to surface ecosystems since the water is already being diverted or pumped and then replaced to the vadose zone from the septic tanks and related drain fields. Removal of septic tanks should not impact ecosystems unless the septic systems have failed and are causing contamination of surface water courses and associated riparian areas and/or contamination of the groundwater that feeds the river systems. In such a case, removal should result in a positive benefit by reducing pollution and nutrient loads into those ecosystems, as well as protecting soil ecosystems. If the treated effluent is returned to the river, there would be more water available to the Rio Grande silvery minnow and the associated riparian areas used by the willow flycatcher, an endangered species. However, if the treated effluent is sent to a reuse application, it would not be available for these purposes.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

- No new technologies would be re uired.
- Current technologies exist to collect and treat wastewater to applicable standards.

Infrastructure Development Requirements

The following infrastructure would be needed for this alternative:

- Pipelines to collect wastewater from current septic tanks
- Potential pump stations to lift water if gravity were flow not available
- New or expanded wastewater treatment plants to treat wastewater to current federal and state standards
- Administrative processes to support the infrastructure project, such as permitting, easement ac uisition, sampling, monitoring, and reporting.
- Individual connections to central system

Total Time to Implement

- Total time needed depends upon:
  - Septic tank locations
  - Wastewater treatment plant location in relation to septic tanks (pipeline length and location; pump station location[s])
  - Existing and projected capacity in existing plants
  - Ac uisition time for funding (grants, loans, rate increases, etc.)
  - Easement ac uisition and public outreach to approve locations
  - Resource procurement such as design and construction personnel and materials
- Implementation could be accomplished in phases as it becomes economically feasible to connect developing areas to centralized treatment infrastructure.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

If wastewater were only being collected, there would be no change to demand.

Effect on Water Supply (surface and groundwater)

- There would be no net change from initial collection and treatment, as it is applied to water already being diverted from a surface source or pumped from a groundwater a uifer.

- An increase in supply could occur if treated effluent is used to replenish the groundwater a uifer placed in a surface source that serves as supply, or reused to decrease diversion and pumping for that demand and if a significant part of the septic tank effluent had previously been lost to evapotranspiration, (See A-27, *Reuse Treated Effluent*).

Water Saved/Lost (consumption and depletions)

No effect for collection alone, but perhaps some savings for reuse.

Impacts to Water Quality (and mitigations)

- Significant reductions in the number of multiple dispersed point sources of inade uately treated wastewater potentially moving into the vadose zone and thence to the groundwater a uifer. Volume estimates of reduction range from 1.6 to 3.0 million gallons per day (mgd) (5.0 to 9.2 acre-feet per day) in 2003 and 5.2 to 8.4 mgd (16 to 25.8 acre-feet per day) in 2050.

- Treatment must meet applicable state and federal re uirements to protect receiving bodies of water, soils, and/or a uifers from the concentration of a pollutant into a new single point source.

- If reuse is contemplated, higher standards of treatment may be re uired (see A-27).

Watershed/Geologic Impacts

- If reuse is instigated, this alternative could protect the geologic structure of the a uifer by reducing groundwater pumping.

- If returned to streamflows or used in a uifer replenishment, release points must be carefully chosen and monitored to prevent adverse geologic impacts such as erosion or the introduction of water with disparate water   uality at sensitive recharge areas.

3.1.2 Environmental Impacts

Impact to Ecosystems

- There may be no net change, just shifting of water use and effluent release locations.
- Should reduce potential pollution if ade uate treatment is achieved.
- Constructed wetlands provide inade uate treatment of raw sewage.

Implications to Endangered Species

- Could result in additional water supply to river system if treated effluent is returned to the river.
- Could result in more water available for riparian areas if a uifer replenishment and recharge programs are instituted near the river, affecting areas used by the willow flycatcher.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Capital costs are shown in Table 26-1 for both 2003 and 2050.

Table 26-1. Initial Cost to Implement, 2003 and 2050

Infrastructure Needed	2003 (millions of $)	2050 (millions of $)
Treatment plant (build or expand)	12.8 to 60.0	182.4 to 736.5
Pipeline(s) and pump stations	3.5 to 12.6	50.2 to 154.7
Administrative costs: permits, easements, etc.	2.9 to 12.0	41.0 to 147.3
Individual connection to system	48.0 to 96.0	684.0 to 1,179.0
Total capital costs	67.2 to 180.6	957.4 to 2,216.9

3.2.2 Potential Funding Source

- Rate increase or utility connection charges
- Bureau of Reclamation Title XVI program, Reclamation, Recycling and Water Conservation
- State/federal grants

- State/federal loans
- Private loans
- Revenue bonds
- Effluent sales income

3.2.3 Ongoing Cost for Operation and Maintenance

Annual operation and maintenance costs would range from $3.3 to $11.7 million in 2003 and from $46.5 to $144.1 million in 2050.

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Alternative 26

Exhibit A
Detailed Discussion

Exhibit 26A: Detailed Discussion of Alternative 26—Domestic Wastewater

Acknowledgements: This discussion, which follows the same basic format as the fact sheet it accompanies, provides additional details and information that support the conclusions presented in the fact sheet. It was written by Sue E. Umshler, Esq., P.E. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc.

1. Alternative Evaluation

1.1 Technical Feasibility

Enabling New Technologies and Status

The technology exists to collect, treat, and dispose of wastewater currently being deposited into septic tanks in the urban and suburban area. In fact, in portions of the planning urban and suburban area, it is both a requirement and policy to connect households and businesses to central wastewater treatment facilities where economically feasible. In November 1993, the Bernalillo County Commission adopted the Groundwater Protection Policy and Action Plan, which identified septic tanks as a "main source of groundwater contamination," particularly along the Rio Grande valley where the water table is high (Bernalillo County, 2002; Rose, 2001) Thus, the City of Albuquerque and the County of Bernalillo have made removal of septic tanks and connection to municipal sewer lines a high priority (Bernalillo County, 2002). The Bernalillo County Wastewater Ordinance requires all homes within 200 feet of a municipal sewer line to take this action (Bernalillo County, 2002). In addition, the City offers a loan program to provide funds for the down payment and monthly payment to cover the Utility Expansion Charge (UEC) or a grant for low income houses, which effectively waives the UEC (Bernalillo County, 2002).

At present neither Sandoval County nor Rio Rancho require sewer connections. However, Rio Rancho is in the process of reviewing their ordinances and considering such a requirement for residences and businesses within a reasonable distance to a sewer interceptor line (COA et al., 2002). Likewise, Valencia county and communities to the south do not have mandatory connection requirements, but voluntary connections have increased, with a commensurate decrease in onsite wastewater treatment permit requests since 1994 (COA et al., 2002). Over the planning period considered in this Report (to 2050) it is likely that all of the communities and counties in urban and most in the suburban settings will have mandatory sewer connection ordinances resulting in a decline in the number of new septic tank installations in those areas. However, for this report, an assumption of level installations is made to project a maximum number of potential systems that would be proposed for removal and connection to central wastewater treatment facilities.

Onsite/decentralized wastewater treatment systems (mostly septic tanks) serve approximately 25 percent of U.S. households. (U.S. EPA, 2000a). The Environmental Protection Agency (EPA) estimates that four billion gallons of wastewater per day are released from these systems, with about 25 percent of the systems failing annually, resulting in 700 million gallons of improperly treated wastewater being discharged daily nationwide. (U.S. EPA, 1997 and 2000a). Septic systems can provide adequate treatment to protect human health and the environment if they are properly sited, designed, operated and maintained. (U.S. EPA, 2000a). Unfortunately most existing systems do not provide the level of treatment needed to protect surface and groundwater quality at current standards and thus can pose a threat to public health and create environmental pollution (U.S. EPA, 2000a; Rose, 2001). Investigations in New Mexico have found that failing septic tank systems are the cause of the problem, with the most common reasons being "improper site evaluation and design, improper construction, and inadequate maintenance" (Rose, 2001). The New Mexico Environment Department (NMED) estimates that the 170,000 household septic tanks and cesspools are responsible for 61 percent of supply well contamination incidents and are responsible for "nitrate or anoxic pollution" in such areas as Albuquerque, Belen, Bernalillo, Bosque Farms, Corrales, and Los Lunas in aquifers as deep as 200 to 600 feet (Rose, 2001).

The EPA has concluded that "adequately managed decentralized wastewater treatment systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas" (U.S. EPA, 1997). That is the key to the issues of this alternative. It is expensive to construct and operate the centralized treatment facilities and costly to install the pipeline/pump station network necessary to collect the wastewater from the individual residences and/or businesses. Only as the population density increases does it become practical and economic to implement this alternative. It is also the density that contributes to the more significant pollution concerns for the underlying groundwater aquifers. Thus, the solution tends to converge with the problem in more densely populated areas such as Albuquerque, Rio Rancho, Bernalillo, and Sandoval counties.

Infrastructure Development Requirements

To implement this alternative, main interceptor pipelines would be required to collect wastewater from current septic tanks locations or clusters. If gravity flow could not be achieved, pump stations would be needed to lift water to collection points and/or the wastewater treatment plant. New or expanded wastewater treatment plants may be required to treat the wastewater to current federal and state standards if excess capacity is not available in a conveniently located plant. Administrative processes must be developed to support the infrastructure project; these would include permitting, easement acquisition, sampling, monitoring, and reporting if a new plant and/or new pipeline system were installed. Finally, individual homes and businesses would have to connect and additional lift pumps can be required if gravity flow into the collection system is infeasible.

Expansion of existing systems could utilize current organizations, but their personnel and material resources may need to be increased to handle additional wastewater flows. Another management alternative would be development of a central collection and treatment authority or cooperative joint management agreements between the various governmental entities encompassed by the urban and suburban areas.

Total Time to Implement

The total time (and related costs) to implement this alternative depends upon the septic tank locations; wastewater treatment plant location in relation to septic tanks (pipeline length and location; pump station location(s)); existing and projected capacity in existing plants; acquisition time for funding (grants, loans, rate increases, etc.); easement acquisition; and resource procurement such as design and construction personnel and materials. The time and costs would vary depending upon each site selected for the treatment plants and environmental studies, as well as the extensive public outreach and communication, which would be required based upon the proposed location for the project or projects.

This alternative may also experience a phased implementation as population density increases providing the economic and practical incentives to connect to or construct a new centralized facility in particular locations. Thus, over the planning period, septic tank numbers may decline as the urban and suburban area naturally expands and requires centralized collection and treatment. The costs would be distributed over the time frame of each cluster addition to such a centralized system, and the timing of removal would be phased in gradually as well.

For this report, an assumption that all septic tanks would be removed simultaneously, either in 2003 or 2050, was made to facilitate the cost computations and because a phased approach could not be reasonably assumed only for global planning purposes. This approach should result in describing lower and upper boundaries of resource needs for the alternative.

1.1.1 Physical and Hydrological Impacts

Effect on Water Demand

If this alternative just collects wastewater for treatment, there would be no change to demand. The same amount of water currently or planned for future diversions or pumping from the aquifer would occur. However, the wastewater that is not consumed would be shifted to a central treatment location. If the treated water is dedicated to a reuse program, there could be some effect on per capita demand (see A-27).

Effect on Water Supply (surface and groundwater)

Collection and treatment may result in no net change, i.e. just collecting and treating water that has already been diverted from a surface source or pumped from groundwater aquifer does not change the impact to surface or groundwater supply sources. Moving the wastewater discharge from current dispersed vadose recharge locations could impact local groundwater levels by changing where the water is returned to the cycle to a remote and singular NPDES outfall. However, as noted above, if the treated effluent is put into a reuse program, it could become a new source of supply for nonpotable consumptive uses (see A-27). The treated effluent could also result in increased supply, if it were directed to replenish groundwater aquifers or placed in a surface source that serves as supply.

Water Saved/Lost (consumption and depletions)

See above, there would be no effect for just collection and treatment, but perhaps some savings would be achieved by reuse of the treated effluent. There would be some system losses in the pipeline and treatment plant, but they would not exceed losses that are potentially occurring at present when the water is tied up in the vadose zone or removed from the tank during maintenance activities.

Impacts to Water Quality (and mitigations)

Collection of wastewater from septic tanks should result in significant reductions in multiple dispersed point sources of inadequately treated raw wastewater potentially moving into the vadose zone and thence to the groundwater aquifer. If failed onsite treatment systems produce pollutants that migrate to groundwater, the cleanup costs can be significant and such an expense would be avoided if the individual units were connected to a centralized treatment system. However, it is difficult to estimate this savings opportunity because the costs are so uniquely related to individual pollution plume characteristics and no attempt to do so was made in this report.

The estimate of septic tanks in operation in the urban corridor at present is between 32,000 and 40,000. (COA et al., 2002). This range is not presented as an absolute quantification since information sources could only document permits actually issued over a limited timeframe. The reported numbers do not account for unpermitted systems or septic tanks installed prior to the initiation of permitting activities in the mid 1970s. This range does aggregate information gathered from county and NMED databases with a 10 percent error allowance to provide for old or unpermitted systems. Therefore, the quantification of wastewater that could be collected from onsite treatment systems is between the following ranges:

Flow Estimate			
(mgd)	(ac-ft/day)	(gpcd)	(gptd)
6.4 to 8.0	19.6 to 24.5	75	200
9.6 to 12.0	29.5 to 37.8	110	300

mgd = Million gallons per day
ac-ft/day = Acre-feet per day
gpcd = Gallons per person per day
gptd = Gallons per tank per day

No volume reductions would be assumed based upon implementation of a conservation program that reduced indoor use flows for capital construction, which would have to be premised on maximum estimates of daily flows and failure of conservation initiatives, i.e. the plant and collection system must be sized for the maximum anticipated volumes.

Using the EPA national estimate that 25 percent of these septic systems are in failure, then removal of these onsite treatment units could result in elimination of between 1.6 to 3.0 mgd

(5.0 to 9.2 ac-ft/day) of potential pollutants from transport into the groundwater from inadequately treated wastewater.

Using a level projection of new septic tank installations to the year 2050 of about 1,500 new systems per year results in the following ranges. These values are probably too high based upon the more realistic gradual decline of such installations in the urban/suburban area. However, they present a maximum volume scenario using permit applications rates at the present time.

Flow Estimate			
(mgd)	(ac-ft/day)	(gpcd)	(gptd)
20.8 to 22.4	63.8 to 68.7	75	200
31.2 to 33.6	95.7 to 103.1	110	300

mgd = Million gallons per day
ac-ft/day = Acre-feet per day
gpcd = Gallons per person per day
gptd = Gallons per tank per day

Again, no volume reductions would be assumed based upon implementation of a conservation program that reduced indoor use flows for capital construction, which would have to be premised on maximum estimates of daily flows and failure of conservation initiatives, i.e. the plant and collection system must be sized for the maximum anticipated volumes.

Using the current EPA national estimate that 25 percent of these septic systems would fail, removal of these onsite treatment units in 2050 could result in elimination of between 5.2 to 8.4 mgd (16.0 to 25.8 ac-ft/day) of potential pollutants from transport into the groundwater from inadequately treated wastewater.

To protect receiving bodies of water, soils, and/or aquifers, treatment must meet applicable state and federal requirements, to avoid concentration of pollutants into a new single point source. If reuse is contemplated, higher standards of treatment may be required (see A-27).

Watershed/Geologic Impacts

If reuse is instigated, this alternative could protect the geologic structure of the aquifer by reducing or delaying groundwater pumping. Release points of water when returned to stream flows or in aquifer replenishment must be carefully chosen and monitored to not create adverse geologic impacts at other specific locations. Such negative affects could result from different water flow or new recharge locations, whereby erosion occurs or different water quality is placed in sensitive sites where vadose transport could carry contamination into the aquifer.

1.1.2 Environmental Impacts

Impact to Ecosystems

There may be no net change, just a shifting of water use and effluent release locations. This could decrease the water available in some ecosystems and increase it in other areas. Collection and treatment should reduce potential pollution releases if appropriate treatment is achieved and proper disposal or reuse implemented. Reuse can result in other impacts (see A-27).

Constructed wetlands are not a viable option for treatment of raw sewage because they do not currently meet secondary or tertiary requirements for discharge of effluent or for ponding in aesthetic areas where human exposure is possible. They are an alternative if additional treatment processes are employed in conjunction with the wetland proposal, but the particular circumstances must be carefully evaluated based on the site, the potential exposure to humans, and other uses of the water in the wetland. This conclusion is derived from the following quotations and citations.

"Constructed wetlands are complex systems in terms of biology, hydraulics, and water chemistry," which necessitates a specific case-by-case evaluation of design specification and performance measures (U.S. EPA, 2000b; Thomson et al., 1996). Constructed wetlands are not able to remove significant amounts of nitrogen and phosphorus and must be used in conjunction with other aerobic treatment process to remove nitrogen to meet current and upcoming nutrient standards. (U.S. EPA, 2000b; Thomson et al., 1996). A study of constructed wetlands in the state found that the "average effluent total nitrogen concentration of 38.4 … in nearly four times the 10 mg N/L as NO3 established for groundwater protection [in New Mexico]" (Thomson et al., 1996) "Constructed wetlands may require post-treatment processes, depending on the ultimate goals of the treatment system. More demanding effluent requirements may require additional processes in the treatment train or may dictate the use of other processes altogether." (U.S. EPA, 2000b; Thomson et al., 1996). Constructed wetlands are poor at removal of bacteria and are potential reservoirs of pathogens that could be harmful to humans and wildlife while attracting both humans and wildlife to use them. (U.S. EPA, 2000b; Thomson et al., 1996). "The very high Fecal Coliform concentrations in all of the wetland effluents sampled in this study suggest that this effluent should continue to be considered a possible health hazard and that reasonable precautions should be taken to limit contact with it" (Thomson et al., 1996). Maintenance costs can be quite high and require many hours of specialized manpower and most New Mexico facilities are "not being properly operated due to inadequate understanding of the treatment process by the operator, or due to difficulties inherent in the facility." (Thomson et al., 1996). However, constructed wetlands have an inherent aesthetic appeal to the general public so the tension is the demand by the public and the lack of knowledge concerning the treatment mechanisms so that the public and the environmental community can appreciate the limitations of the technology. (U.S. EPA, 2000b). "In [some] situations, constructed wetlands will be too costly or unable to produce the required effluent water quality." (U.S. EPA, 2000b)

There is some viability of using constructed wetlands to polish secondary effluent from the central treatment facility, but that would be outside the scope of evaluation of this alternative, which is simply collection and treatment (to standards) of raw wastewater. Because of the extremely large number of variables, this option is not considered in the evaluation for this alternative as stated.

Implications to Endangered Species

This alternative could result in additional water supply to river system if treated effluent is returned to the Rio Grande or its tributaries. It could also result in water being available for riparian areas if aquifer replenishment and recharge programs were instituted near the river, effecting areas used by the willow flycatcher. If the water is not so released, there would be no impacts unless pollution from currently installed failed systems is impairing the surface flows or riparian areas presently used by the endangered species listed in the region.

1.2 Financial Feasibility

In recent years several New Mexico rural communities have evaluated the costs of developing decentralized systems versus the "Big Pipe" option of centralized collection and treatment. In 1986, Peña Blanca estimated that a central system (facultative ponds with sand filters) would cost 3.1 Million dollars compared to new septic tanks installation of about $1.2 Million. Columbus, found in 1995 a Big Pipe (areated ponds and wetlands) cost of $4.21 Million versus $1.19 Million for new septic tanks. And in 2000, Willard determined that facultative ponds would cost about $1.6 Million compared to $0.97 Million for advanced treatment septic systems (Rose, 2001)

In urban and suburban areas with high population densities (more than three to four dwellings per acre), large scale, centralized collection and treatment of wastewater is most cost-effective. But in areas with one dwelling per one-half to one acre, located at moderate distances from a centralized treatment facility, the discussion centers on cost and the benefits that the high price tag creates depending on local conditions. (U.S. EPA, 1997). In 1995, the EPA provided the following estimates for centralized systems in rural communities (450 people living in 135 homes) and fringe communities (10 miles from city, population 1550 people in 443 homes). (U.S. EPA, 1997)

- Rural:
  - Capital cost (1995 dollars): $2.322 Million to $3.570 Million
  - Operation & Maintenance Costs: $30,000 to $40,000 per year

  - Using Engineering News Record Indices (ENR, 2002) and a 3 percent escalation for O&M, these figures for 2003 could be estimated at:
  - Capital: $2.77 to $4.27 million; O&M: $37,000 to $49,000 per year

- Fringe: One Mile From Sewer Line
  - Capital cost (1995 dollars): $3.323 to $3.787 Million
  - Operation & Maintenance Costs: about $83,800 per year

  - Using Engineering News Record Indices (ENR, 2002) and a 3 percent escalation for O&M, these figures for 2003 could be estimated at:
  - Capital: $3.97 to $4.525 Million; O&M: $103,100 per year

- Fringe: Five Miles From Sewer Line
  - Capital cost (1995 dollars): $5.378 to $5.842 Million
  - Operation & Maintenance Costs: about $95,900 per year

- Using Engineering News Record Indices (ENR, 2002) and a 3 percent escalation for O&M, these figures for 2003 could be estimated at:
- Capital: $6.43 to $6.98 Million; O&M: $118,000 per year

Planning, design, and construction require professional expertise and resources. For purposes of cost estimation, it is assumed all septic tanks would be removed simultaneously, thus requiring treatment plant construction and/or expansion, pipeline installation, some lift stations, administration costs, and individual connections with related lift pumps if necessary. All of these values are highly dependent upon locations and distances and for ease of comparison, median assumptions have been used and values listed in dollars per gallon. Extreme caution must be used before projecting these costs to any real project, which will present unique challenges and requirements that could make the specific costs higher or lower. The variables are too numerous to make rational assumptions at this planning stage. More realistic costs would be determined during the feasibility and conceptual design stages of actual proposed projects.

For instance, pipeline costs would be provided based upon length of pipe and variability of elevations and terrain, not in dollars per gallon. If a treatment plant exists and has surplus capacity, the plant costs would be unnecessary. If gravity flow is obtainable, no lift station would be required. If new easements must be obtained, administrative costs could be higher depending upon the cost and location of the land. If the rate base is large enough the connection fees can be lowered on a per customer basis or adsorbed by grants, such as County Dona Ana has been able to achieve with its county-wide program to connect septic tanks to several, phased centralized treatment systems. Therefore, these cost estimates should only be used for relative planning comparisons and not to project actual costs to connect any one or more of the existing septic tanks in the region.

The 2050 figures are based upon an escalation rate of 3 percent for the cost values and a flat increase of 1500 septic tank installations over the next 48 years. This value is probably too high, but provides a maximum potential number of systems and related volume upon which to estimate volumes and costs in 2050. These values also assume that no systems are removed before that date and this would be the cost to begin the alternative at the later date. This is also unrealistic, but should present a cost that would exceed real project costs, particularly if the septic tanks are removed gradually over that time period and new installations likewise are steadily reduced as central treatment facilities become available and are close enough to economically justify connection. This result is feasible, especially if onsite treatment standards become more stringent driving up the installation and maintenance costs of individual septic tanks.

1.2.1 Initial Cost to Implement

To expand current treatment facilities or build new smaller stand-alone satellites and/or wastewater treatment plants estimated 2003 dollars could range as follows (no adjustment is made for conservation as design and construction of treatment facilities, pipeline collection, administrative costs, and connection fees would be based upon maximum potential volumes):

- Treatment Plant build or expansion (COA et al., 2002; New Mexico Heritage Preservation Alliance, 2002)
  - Low flow (200 gallons per tank), range of 32,000 to 40,000 tanks – $12.8 million to $40.0 million
  - High flow (300 gallons per tank), range of 32,000 to 40,000 tanks –$19.2 million to $60.0 million
- Interceptor Collection Pipeline(s) (COA et al., 2002; New Mexico Heritage Preservation Alliance, 2002)
  - Low flow (200 gallons per tank), range of 32,000 to 40,000 tanks –$3.5 million to $8.4 million
  - High flow (300 gallons per tank), range of 32,000 to 40,000 tanks – $5.3 million to $12.6 million
- Lift Costs and Administrative, such as permits, easements, etc. (COA et al., 2002; New Mexico Heritage Preservation Alliance, 2002)
  - Low flow (200 gallons per tank), range of 32,000 to 40,000 tanks – $2.9 million to $8.0 million

  - High flow (300 gallons per tank), range of 32,000 to 40,000 tanks – $4.3 million to $12.0 million

- Individual Connections to Sewer System ($1500 to $2400 each) (COA et al., 2002; New Mexico Heritage Preservation Alliance, 2002)

  - Range of 32,000 to 40,000 tanks – $48.00 million to $96.00 million

The total initial capital cost could range from a low of $67.2 million to a high of $180.6 million dollars to implement this alternative in 2003.

If implementation of the alternative is delayed to the end of the planning period, initial costs, 2050 dollars are estimated using a 3 percent escalation and a flat increase of 1500 new onsite treatment installation per year for 48 years, resulting in the following ranges:

- Treatment Plant build or expansion

  - Low flow (200 gallons per tank), range of 104,000 to 112,000 tanks – $182.4 million to $491.0 million

  - High flow (300 gallons per tank), range of 104,000 to 112,000 tanks – $273.6 million to $736.5 million

- Interceptor Collection Pipeline(s)

  - Low flow (200 gallons per tank), range of 104,000 to 112,000 tanks – $50.2 million to $103.1 million

  - High flow (300 gallons per tank), range of 104,000 to 112,000 tanks – $75.2 million to $154.7 million

- Lift Costs and Administrative, such as permits, easements, etc.

- Low flow (200 gallons per tank), range of 104,000 to 112,000 tanks – $41.0 million to $98.2 million
- High flow (300 gallons per tank), range of 104,000 to 112,000 tanks – $61.6 million to $147.3 million

- Individual Connections to Sewer System ($6,575.85 to $10,521.36 each)
  - Range of 104,000 to 112,000 tanks – $683.9 million to $1,178.4 million

The total initial capital cost could range from a low of $957.4 million to a high of $2,216.9 million dollars to implement this alternative if action were delayed to 2050.

1.2.2 Potential Funding Source

- Rate increase or Utility Connection Charges to individual residence or business
- Bureau of Reclamation Title XVI program, Reclamation, Recycling and Water Conservation. This funding is available for projects that include reclamation and reuse of municipal wastewater, other wastewater, or naturally impaired waters. Thus, the program could be a potential source of funds if the collection and treatment system were linked to a reuse program. The maximum federal cost share is 50 percent for planning,

onsite septic systems. In states where they are significant source of nonpoint pollution, 319 funds may be used to construct, upgrade or repair onsite systems (U.S. EPA, 1997)

- USDA Rural Utilities Service has water and waste disposal loans and grants in rural areas and towns with 10,000 or fewer residents, up to 75 percent of eligible project costs and RUS guarantees loans made by banks and other institutions (New Mexico Heritage Preservation Alliance, 2002)

- HUD provides community development block grant programs to construct public facilities and improve water and sewer facilities (New Mexico Heritage Preservation Alliance, 2002)

- For Tribes, HUD has resources for Native Americans, EPA has American Indian Environmental Office tribal grants, and the U.S. Department of Health & Human Services also has grant programs for such projects. (New Mexico Heritage Preservation Alliance, 2002)

- The Water and Wastewater Grant Fund (W/WWGF) was created for the purpose of awarding grants to qualified entities for water and wastewater projects. In FY02 77 projects were authorized grants statewide and with 27.6 million in grants and emergency requests being obligated. The fund balance is $13.3 million, with some funds obligated, but not spent. The NM Finance Authority has received 65 applications by October 2002, totally $99.1 million for consideration of funding in FY02-03 (New Mexico Heritage Preservation Alliance, 2002)

- State/Federal loans

  - Clean Water State Revolving Fund provides $1 billion annually to the states which manage individual revolving loan funds for wastewater and other water quality projects (U.S. EPA, 1997). The program provides loans at low or zero interest with repayment periods up to 20 years. Terms vary by state, but typically the money goes to capital costs and not to O&M expenses. There is a lot of competition for these funds (New Mexico Heritage Preservation Alliance, 2002)

- The Wastewater Facility Construction Revolving Loan program is administered by the NMED. It is capitalized by federal grants, state matching and other funds accrued from construction loans. The program is restricted to low-interest loans and eligible entities include municipalities, counties, sanitation districts, and Native American tribes or pueblos with resources to repay loans. The current unobligated balance in the fund is $52.2 million with pending applications for $40.8 million (New Mexico Heritage Preservation Alliance, 2002)

- The Public Project Revolving Loan Fund (PPRLF) is administered by the NM Finance authority and provides low-cost financing for long-term capital projects such as sewerage and waste disposal systems. The program is capitalized with 75 percent of annual government gross receipts tax revenue combined with federal state and local funds. Each project financed for the PPRLF must be authorized by the legislature by way of a statute. The loan capacity at current market rates from the PPRLF is about $500 million (New Mexico Heritage Preservation Alliance, 2002)

- Private loans

- Revenue bonds

- Effluent sales income

1.2.3 Ongoing Cost for Operation and Maintenance

Generally operation and maintenance costs are not included in the grant programs and in many of the loan programs, particularly those from the federal government. Thus, the community or project authority must normally have sufficient rate base or other funds to pay the O&M costs by itself. Moreover, these costs increase as the system complexity increases. For centralized wastewater treatment facilities and pipeline system maintenance, qualified management, operation, and maintenance staff must be provided to keep the system functional and protective of human health and the environment. Sharing of resources via a central authority or joint agreement could maximize use of resources, thereby reducing competition for scarce resources and personnel.

Using cost estimates from current treatment facilities, the following range of values for the first operation year can be predicted in 2003 dollars to be: (COA et al., 2002)

- Low flow (200 gallons per tank), range of 32,000 to 40,000 tanks – $3.8 million to $6.4 million per year
- High flow (300 gallons per tank), range of 32,000 to 40,000 tanks – $5.8 million to $9.6 million per year

Using an industry estimate computation method whereby O&M is estimated at 6.5 percent of total capital costs, the ranges in 2003 dollars for the first year would be as follows:

- Low flow (200 gallons per tank), range of 32,000 to 40,000 tanks – $4.4 million to $9.9 million per year
- High flow (300 gallons per tank), range of 32,000 to 40,000 tanks – $5.0 million to $11.7 million per year

If a conservation program is effective in reducing indoor use and thence wastewater discharges, the O&M costs could be reduced because of the reduced volumes that would require treatment, assuming treatment standards do not become more stringent and offset such savings. Based upon an assumed reduction of indoor use by 15 percent the following reduced initial year O&M cost estimates can be made:

- Low flow (200 gallons per tank), range of 32,000 to 40,000 tanks – $3.3 million to $5.4 million per year
- High flow (300 gallons per tank), range of 32,000 to 40,000 tanks – $4.90 million to $8.2 million per year

Using an industry estimate computation method whereby O&M is estimated at 6.5 percent of total capital costs, the ranges in first year costs in 2003 dollars with a 15 percent conservation rate are as follows:

- Low flow (200 gallons per tank), range of 32,000 to 40,000 tanks – $3.7 million to $8.4 million per year

- High flow (300 gallons per tank), range of 32,000 to 40,000 tanks – $4.2 million to $10.0 million per year

The estimated initial year O&M costs could range from a low of $3.3 million to a high of $11.7 million dollars per year if this alternative was implemented in 2003.

Estimated O&M values for 2050, using a 3 percent escalation results in the following ranges for the two methods:

- Low flow (200 gallons per tank), range of 104,000 to 112,000 tanks – $54.7 million to $78.6 million per year

- High flow (300 gallons per tank), range of 104,000 to 112,000 tanks – $82.1 million to $117.8 million per year

Using an industry estimate computation method whereby O&M is estimated at 6.5 percent of total capital costs, the ranges in 2050 dollars of the first year costs are as follows:

- Low flow (200 gallons per tank), range of 104,000 to 112,000 tanks – $62.2 million to $121.6 million per year

- High flow (300 gallons per tank), range of 104,000 to 112,000 tanks – $71.1 million to $144.1 million per year

With implementation of a conservation program and based upon an assumed reduction of indoor use by 15 percent the following reduced 2050 O&M initial year cost estimates can be made:

- Low flow (200 gallons per tank), range of 104,000 to 112,000 tanks – $46.5 million to $66.8 million per year

- High flow (300 gallons per tank), range of 104,000 to 112,000 tanks – $69.8 million to $100.2 million per year

Using an industry estimate computation method whereby O&M is estimated at 6.5 percent of total capital costs, the ranges in 2050 first year dollars with a 15 percent conservation rate are as follows:

- Low flow (200 gallons per tank), range of 104,000 to 112,000 tanks – $52.9 million to $103.4 million per year

- High flow (300 gallons per tank), range of 104,000 to 112,000 tanks – $60.5 million to $122.5 million per year

The estimated O&M costs could range from a low of $46.5 million to a high of $144.1 million dollars for the first year if implementation of this alternative were delayed to 2050.

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Technical and Physical Feasibility Fact Sheet

Alternative 27: Reuse Treated Effluent

Acknowledgements: This fact sheet was written by Sue E. Umshler, Esq., P.E. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-27: Reuse treated wastewater for nonpotable uses.

As further stated by the Water Assembly:

> The cost to bring wastewater to a state where it can be used for watering lawns, etc., is much lower than cleaning the water to a drinkable level. Find a way to distribute the treated wastewater for any or all non-drinking needs. The treated wastewater can be reused once or several times before it is returned to the river or lost to evaporation. Several implementation approaches are possible. One approach is to retrofit homes and businesses with a second set of water pipes. Another approach is to apply this to new construction only.

2. Summary of the Alternative Analysis

This alternative is technically and physically feasible and can result in a reduction of water diversion or pumping demand on a per capita basis if the recycled water is effectively deployed to offset other consumptive uses (e.g., turf irrigation, cooling water, or other nonpotable uses). However, the reductions will not completely offset growing water demand from increased population or new uses. Treated effluent is currently being used for nonpotable purposes such as the addition water to the river and riparian system, irrigation activities downstream from National Pollutant Discharge Elimination System (NPDES) outfalls, and to meet compact requirements on the Rio Grande. Shifting water from one place to another and one use or another is the essence of this alternative, and such shifts must be considered carefully as they affect the entire region.

Significant infrastructure is required for treatment that reliably and consistently brings the wastewater to the high quality levels necessary for uses that involve human contact. Also, depending on the distance from the treatment plant to the reuse location(s), significant costs may be incurred for the dual piping system required to distribute the treated wastewater. The time required to implement this alternative is depends on the required treatment level and associated treatment facilities, pipeline locations and lengths, permit acquisition, and public acceptance. Retrofitting established facilities or servicing scattered, remote locations would be more costly than the establishment of such systems in new areas of construction or implementing on-site use for larger industrial and commercial applications. Public education concerning potential health risks is also a key component of such a program and would affect any implementation schedule.

This alternative can reduce per capita demand by reusing water that has already been diverted from surface or groundwater sources, thereby reducing the need to divert or pump additional water for consumptive demands supplied by reuse. However, water is not really saved or lost from the consumption/depletion cycle because overall demand is not really reduced; it is simply met with a recycled supply, resulting in a delay of water extraction. Reuse can result in more efficient use of water supplied to urban and suburban developments in the region. It can also result in evaporation and leakage losses from treatment and other processes that may not occur if the effluent is released to a surface watercourse. If the reuse system cannot be deployed because of failure to meet water quality requirements or loss of demand for nonpotable water at the reuse location, treated water must be released through a NPDES permitted location. If this occurs on either an irregular or permanent basis, the efficiency savings or reduced demands on other water supply sources would not be realized.

The water demand curve is of some significance to the feasibility of this alternative. For example, the demand for turf irrigation is high in the spring, summer, and early fall months, but drops to very low levels in the winter. If reuse water designated for turf irrigation cannot be applied to other more constant demands (such as industrial uses) during the low season, storage facilities must be constructed to hold the water until demand increases. In such cases, it may be possible to use underground storage or aquifer replenishment in the winter months to level the demand for the reuse water. However, if the demand cannot be leveled by suitable year-round demand centers or the construction and maintenance of large storage areas, the water must be released at a NPDES discharge outfall. Such releases reduce the benefits of the alternative.

The volume of effluent available for a reuse program can be reduced through domestic conservation programs or the implementation of on-site recycling programs at industrial facilities. However, in the Middle Rio Grande (MRG) planning area, the greatest constraint to effluent reuse may be the need to meet return flow requirements related to groundwater pumping permits and the water rights of downstream users. Past pumping debts must be repaid as the aquifer cone of depression deepens. In addition, the new Albuquerque diversion permit proposal depends on wastewater flow to return "borrowed" surface water. These could become serious limitations and must be fully evaluated in the implementation of a nonpotable reuse program.

Initially, reuse may reduce the pumping demand on the aquifer and thus reduce the likelihood of aquifer consolidation and subsequent subsidence; however, increased demand over time will likely result in increased pumping, so that this alternative only delays potential future adverse impacts. Also, reuse of treated wastewater would decrease the amount of effluent discharged into surface water courses, thus decreasing the amount of water in riparian areas. The reduction in effluent discharged to the Rio Grande by the City of Albuquerque, Rio Rancho, and other municipal treatment plants would directly reduce the flow in the river. This would require offsets from native waters to assure that minimum flow requirements for the Rio Grande silvery minnow are met. If return flow is mandated by the user's water rights permits, any reductions in effluent return could require acquisition of additional water rights, probably from agricultural interests, to assure compliance with New Mexico Office of the State Engineer permit conditions.

Finally, both the City of Albuquerque and City of Rio Rancho have some limited nonpotable water reuse programs in place and are in the process of evaluating and developing expanded programs. The City of Albuquerque and some industrial users currently irrigate some turf areas with treated effluent, and the Albuquerque wastewater plant reuses about 1 million gallons per day (mgd) of treated effluent for plant utility and wash water purposes. Rio Rancho has used reclaimed effluent to irrigate the city golf course and a local cemetery uses treated effluent for its grounds. Albuquerque's "Nonpotable Surface Water Reclamation Project" proposes to use treated effluent along with nonpotable surface water for industrial purposes and the irrigation of large turf areas. Demand, proximity of users to the treatment facilities, and ability to meet health and safety requirements (and obtain public acceptance) are all important factors in the decision to pursue a nonpotable reuse program.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

- No new technologies are required for this alternative.
- Current technologies exist to collect and treat wastewater to the level needed to meet quality standards for nonpotable uses and to distribute the water to the reuse locations.

Infrastructure Development Requirements

- New or expanded treatment plants would be needed to treat wastewater to current federal and state reuse standards.
- Potential pump stations would be needed to lift water if gravity flow is not available.
- Winter storage facilities such as tanks, surface impoundments, or underground storage may be needed.
- Pipelines would be needed to distribute wastewater from the plant to potential reuse locations, including residences if economically feasible.
- Administrative processes to support the infrastructure project, such as permitting, easement acquisition, sampling, monitoring, reporting, and public outreach and education would be necessary.

Total Time to Implement

Total time depends upon:

- Potential reuse location

- Distance from wastewater treatment plant to reuse locations (pipeline length and location)
- Funding acquisition (grants, loans, rate increases, etc.)
- Easement acquisition
- Resource procurement such as design and construction personnel and materials
- Public outreach and education campaign needed to gain acceptance of the concepts and specific projects
- Time required to amend of local ordinances to permit and regulate installation and control of reuse facilities

Based on these factors, the total time to implement a program could be between five and ten years. If a National Environmental Policy Act (NEPA) analysis is required to secure federal funds and the necessary public outreach is extensive, the initial implementation would be lengthy.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

- There would be no effect on overall water demand.

- Reuse to meet consumptive purposes would result in more efficient use of water withdrawn, thus delaying the need for new diversions or increased pumping.

Effect on Water Supply (surface and groundwater)

- Could result in short-term reduction in water pumped or diverted and potential long-term reduction in per capita demands on water supply if reuse offsets current consumptive demands.

- Provides an alternative source of water to meet nonpotable consumptive demands.

- Reuse could result in complete consumption of the recycled water, or if applied to some nonconsumptive purposes, could have about a 50 percent decay (i.e., about 50 percent of the reuse water is returned to the system, thus requiring some input of new water sources). These estimates are highly system-dependent and exact values are inappropriate for this level of study. However, the concept of decay is relevant for determining water volumes for planning purposes.

- An estimate of reuse water available to meet nonpotable demands is as follows:

  - 2003: 1,224 million gallons per year (mg/y) (3,745 acre-feet per year [ac-ft/yr]) to 3,240 mg/y (9,914 ac-ft/yr)
  - 2050: 2,300 mg/y (8,500 ac-ft/yr) to 9,100 mg/y (27,900 ac-ft/yr)

Water Saved/Lost (consumption and depletions)

- Water is neither saved nor lost, simply allocated to a different use in the water cycle.

- Less water may be pumped from the aquifer, but water would be lost to riparian and river systems when effluent is diverted back to urban and suburban areas for consumptive uses.

- If water is treated and used for aquifer replenishment, some water may be saved through lower evaporation; however, water will still be lost to the surface systems.

Impacts to Water Quality (and mitigations)

- Water would be treated to reuse standards. However, any recycling results in concentration of salts and metals, which are then loaded in the soils or recycled to undergo treatment again. Such concentration must be offset by dilution with fresh water to maintain dissolved salts at acceptable levels.

- Dissolved solids, nitrogen species, and other pollutants result in adverse impacts if the soil loading exceeds acceptable levels for turf or foliar irrigation. Salt or nitrogen from reuse water may also migrate through the vadose zone and degrade underlying groundwater. To mitigate for this, regulatory loading limits must be met through the use of vigilant monitoring systems, dilution of reuse water with fresh supplies, and/or the use of higher (and more costly) treatment levels at the plant.

- Treatment sludges and brines must be properly handled to avoid depositing impurities in landfills, thus creating a different point source of the pollution.

- Significant water quality concerns must be addressed to protect the public health and safety of workers, citizens, and water users. This increases treatment requirements, public education and outreach needs, and costs.

Watershed/Geologic Impacts

- There would be no change to the watershed.

- Aquifer conditions could be positively impacted if groundwater withdrawals rates are reduced by reusing pumped water for nonpotable uses. However, this would be a per capita reduction and as population increases, the benefits may be offset by new demand. Thus, the benefit is a delay, not an absolute protection.

3.1.2 Environmental Impacts

Impact to Ecosystems

- There would be a reduction in the volume of treated effluent that is currently being released from municipal treatment plants to the river or other surface water courses.

- This reduction could affect the minimum flow levels in the river or the water levels in the riparian areas immediately adjacent to the current outfalls.

- The reuse water would concentrate salts and metals, which could change the ecosystems where it is reused.

Implications to Endangered Species

- Decreased river flow below the current wastewater treatment outfalls could impact the silvery minnow if the water required is not offset by native or other surface flows.

- If the riparian areas adjacent to the surface water courses are affected, there could be an impact on willow flycatcher habitat.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Estimated initial costs to implement this alternative are provided in Table 27-1 for 2003 and 2050.

Table 27-1. Initial Cost to Implement, 2003 and 2050

Needed Infrastructure	2003 (millions of $)	2050 (millions of $)
Treatment plant (build or expand)	20.25 to 65.36	511.4 to 1,000.0
Interceptor collection pipeline(s)	0.68 to 1.87	5.7 to 16.7
Administrative costs: permits, easements, etc.	0.68 to 1.87	5.7 to 16.7
Storage costs for three days of production	32.4 to 61.6	272.7 to 550.0
Total capital costs	54.0 to 130.7	795.5 to 1,583.4

3.2.2 Potential funding source

- Rate increase
- Bureau of Reclamation Title XVI, Reclamation, Recycling and Water Conservation
- State/federal grants
- State/federal loans
- Private loans
- Revenue bonds
- Effluent and reuse water sales

3.2.3 Ongoing Cost for Operation and Maintenance

- 2003: First year costs would range from $5.74 to 14.01 million
- 2050: First year costs would range from $48.30 to $125.00 million

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Alternative 27

Exhibit A
Detailed Discussion

Exhibit 27A: Detailed Discussion of Alternative 27—Reuse Treated Effluent

Acknowledgements: This discussion, which follows the same basic format as the fact sheet it accompanies, provides additional details and information that support the conclusions presented in the fact sheet. It was written by Sue E. Umshler, Esq., P.E. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc.

1. Alternative Evaluation

1.1 Technical Feasibility

Enabling New Technologies and Status

No new technologies are required for this alternative as the wastewater treatment and piping distribution systems exist today. Current technologies can collect and treat wastewater to quality standards required to reuse water for nonpotable demands and to distribute such recycled water to the reuse locations. However, such infrastructure is expensive and requires a positive benefit/cost ratio for constructing and operating the facilities in return for reduced water pumping requirements, delayed procurement of new water supplies and new water rights, and/or revenues from the reuse locations.

Water reuse has been practiced in the United States for over forty years (Asano, 2001). The Irvine Ranch Water District in California has reused treated effluent for irrigation, industrial, and such domestic uses as toilet flushing in high-rise buildings since 1961 (Asano, 2001). The Montebello Forebay project consisting of spreading basins to accomplish groundwater recharge from the Los Angeles Area began in 1962 (Asano, 2001). In 1976, Orange County California implemented the Water Factory 21 project which uses treated effluent to recharge groundwater aquifers by direct injection (Asano, 2001). St. Petersburg, Florida has reused its treated wastewater to irrigate parks, golf courses, schoolyards, residential lawns, and cooling tower make-up water since 1977 (Asano, 2001). In 1985, El Paso implemented its direct injection groundwater recharge project and power plant cooling water from treated effluent (Asano, 2001). Studies began in 1987 for use of reclaimed wastewater for agricultural irrigation of food crops that are typically eaten raw, including artichoke, celery, broccoli, lettuce, and cauliflower (Asano, 2001).

The largest current water reuse application is agricultural irrigation. Landscape irrigation, including commercial, office, industrial, and single residence landscaped areas, employing dual pipe systems, is the second largest consumer of reclaimed water (Asano, 2001). Industrial activities represent the third major use of treated effluent, primarily for cooling and process needs, which vary greatly in water quality requirements (Asano, 2001). Groundwater recharge is the fourth largest user of reclaimed water and recreational and environmental uses constitute the fifth major use of reused water (Asano, 2001). The lowest uses are presently non-potable urban uses such as fire protection, air conditioning, toilet flushing, construction water, and cleaning system supplies. Potable reuse is the rarest form of water recycling in the United States today, although it has been practiced in Namibia since 1968 (Asano, 2001).

Infrastructure Development Requirements

To implement this alternative new or expanded treatment plants may be required to treat the wastewater to current federal and state reuse standards, which are becoming more stringent. California has adopted the most stringent requirements (Department of Health Services, 2001). New Mexico is considering regulations that would track the California requirements, commonly called “Title 22” standards. (Department of Health Services, 2001, NMED, 2000) Treatment standards involve actual technology and equipment operational requirements, specific numeric values for potential pollutant constituents (particularly pathogenic organisms), narrative standards regarding water quality, monitoring and reporting requirements, and limitations on the reuse opportunities for certain produced treated effluent. (U.S. EPA, 1992) The highest levels of treatment must be met for unrestricted use where it is very likely that humans will be in contact with the water, the water spray, or the product that results from the water reuse (U.S. EPA, 1992). Examples of such reuse are toilet flushing, irrigation of public parks and recreational areas, irrigation of food crops, and aesthetic uses like decorative ponds or fountains (U.S. EPA, 1992). Water uses that would require less rigorous treatment include industrial cooling and process water, cement production, construction dust control, and wetland augmentation (U.S. EPA, 1992). In some cases it is more economical to simplify the system by treating the water to the highest levels required for any of the uses.

Specific requirements that may be imposed by the New Mexico Environment Department (NMED) to assure protection of human health and the environment could add additional cost to the infrastructure. For example, Florida requires that reclamation facilities be manned while water is being transferred to users to assure quality standards are met and to implement immediate shut-down if the system experiences failures (Florida Reuse Regulations, Undated). This requires 24 hour, 7-day staffing to provide on-demand deliveries to an urban reuse system. The treatment plant must be operated by a Class C operator and must include back-flow prevention devices and automatic cut-off if quality declines. Such systems may be more costly than routine wastewater treatment facilities striving only to achieve NPDES limits before discharge.

Additional infrastructure requirements include pump stations to lift water if gravity flow is not available and pipelines to distribute wastewater from the plant to potential reuse locations, including residences if economically feasible. Such pipelines must be totally separate and are usually color-coded (often called purple pipe systems) to distinguish from normal plumbing systems. This practice protects potable water quality systems and reduces the possibility of dangerous cross-connections that could impair human health and safety. To assure such segregation of the reuse system, state regulations will often prohibit use in locations where inexperienced persons may unwittingly connect the pipe systems incorrectly. (Department of Health Services, 2001; Florida Reuse Regulations, Undated). Reuse is restricted to facilities where residents and guests do not have access to the plumbing systems for repairs. Individual homes are therefore excluded from permissible reuse applications. The water is diverted to motels, hotels, apartment, and condominium complexes for toilet flushing or landscape use. This addresses the health considerations and assures that the quantity of the demand is high enough to justify the reclaimed water treatment and distribution cost. Retrofitting existing facilities can be quite expensive because of the need for the dual pipe system. It may be more cost effective to implement dual pipe systems in new developments and subdivisions for landscape irrigation or toilet flushing, but this does not overcome the concerns about cross-connections. Thus, in most states, reuse water is being applied where it can be centrally controlled and monitored, such as golf courses, industrial parks, large city recreational facilities, etc. Albuquerque, Rio Rancho, and Santa Fe have all rejected consideration of existing, small and isolated urban parks because the cost of the piping network was too high for such distributed uses. These cities focused their proposal analysis of potential reuse customers on the larger recreational facilities, golf courses, wetland uses, and new common area developments. (Camp Dresser & McKee, 1998; COA et al., 2002)

Because of the changes in water demand from summer to winter, storage facilities may also be required. The storage unit may be a surface impoundment or tank. In either case it may have to be quite large to hold the winter reuse water production until the demand begins in the spring. If such storage facilities cannot be constructed because of land requirements and costs, the water must be released through NPDES outfalls. If this occurs, the reuse opportunities are limited to the excess flows available in the spring, summer and early fall seasons.

Finally, there would be significant administrative costs to support the infrastructure project, such as permitting, easement acquisition, sampling, monitoring, reporting, and public outreach and education.

Total Time to Implement

The total time to implement this alternative depends upon the potential reuse location(s), the wastewater treatment plant location in relation to reuse locations (pipeline length and location), acquisition time for funding (grants, loans, rate increases, etc.), easement acquisition, resource procurement such as design and construction personnel and materials, the length of the requisite public outreach and education campaign to gain acceptance of the concepts and specific projects, permit(s) acquisition, and the time required to amend local ordinances to permit and regulate installation and control of reuse facilities. Reuse projects require extensive coordination with the regulatory agencies including NMED and local health departments. If an environmental impact statement is required because of use of federal funds or location on federal or Native American properties, such a study could take from three to five years to complete with adequate public participation.

The actual project implementation could take several years depending upon the administrative and technical requirements for the project specifications. A reuse project must be implemented in complete phases which match capacity and demand to assure collection of the wastewater and provide adequate supplies to meet the demands. Emergency alternatives should be provided to meet the water demand and/or to dispose of wastewater if the system fails. A reasonable total time to implement a new comprehensive reuse program, given the most complex scenario, which would include a National Environmental Policy Act (NEPA) analysis for use of federal funds, would be five to ten years.

Successful implementation in five to ten years depends upon many factors. The time could be extended if a detailed NEPA analysis is required to secure federal funds or the necessary public outreach and education is extensive. Initial implementation of any reuse program takes time because of the complexity of the issues involved in developing a reliable and safe new supply of water derived from wastewater flows.

1.1.1 Physical and Hydrological Impacts

Effect on Water Demand

There would be no effect on overall water demand with this alternative. It could result in more efficient utilization of water withdrawn by recycling to meet consumptive purposes, thus supplying another source of water to meet demand. This could result in delaying the need for procurement and development of new supply sources such as pumping or diversions to meet growing demand. If the reuse system had to be cutoff because of water quality failure, pipeline failure, or other disruptions, the water demand would have to be met from another source, probably the fresh water supply. The wastewater would then be discharged to an NPDES outfall. If the disruption occurred over an extended period of time, water demand from basic supplies would resume at its normal levels. Often, fresh water is needed for blending to meet reuse water quality requirements.

If water conservation programs are effective in reducing indoor water demand, then the quantity of water available for reuse would be decreased and the strength of the sewage that must be treated at the wastewater reclamation plant would increase. On-site recycling systems for industrial users can reduce the water supply demand, but they also reduce the flow and increase the wastewater strength flowing to the wastewater treatment facilities. This occurred when Intel implemented its recycling program, dropping the flow to the Albuquerque plant by about 3 mgd (**COA et al.**, 2002). If significant flow reductions occur, the amount of water available for reuse may be too limited to justify the treatment and distribution costs. This was the experience of Santa Fe when its call for reduction in water use was effective and reduced the flow to the wastewater treatment plant enough to impair the treatment processes. Reduced wastewater flows also cause anaerobic conditions in pipes and lift stations, which can be a public nuisance. Thus, the available quantity of treated wastewater available for reuse must also consider the long-term conservation goals and other programs of a community.

Finally, the water returned to the river and surface water courses may be necessary to meet return flow credit requirements or historical water use offset debts of the users' water rights permits. If this is the case, the quantity of water available for a reuse system is significantly reduced. This factor must be considered in the planning and development of a reuse system.

Effect on Water Supply (surface and groundwater)

If the reuse offsets current consumptive demands, this alternative could result in short-term reduction in water pumped or diverted and potential long-term reduction in per capita demands on the potable water supply for the entity deploying the reuse system. It would provide an alternative source of water to meet nonpotable consumptive demands. Reuse can result in complete consumption of the recycled water or, if applied to nonconsumptive as well as consumptive uses, can produce some return flow (i.e. about 50 percent is returned to the system, thus requiring some input of new water sources). These estimates are highly system-dependent, so exact values are inappropriate for this level of study, but the concept of return flow is relevant to determining water volumes available for planning purposes. For this paper, 100 percent consumption for the first recycling event is assumed.

If water that is currently returned to surface water systems is being used as a water supply for other uses, such as agriculture, down-stream water supplies, or environmental uses in riparian areas and river flows, it would be removed for those purposes and could result in a water supply deficit for downstream users. Thus, while this alternative could extend the water supply for one community, it might result in a decrease of supply for other water needs in the region.

Water reclamation and reuse can provide a viable opportunity for a particular community to augment traditional water supplies, but requires integration of water supply and wastewater treatment functions (Asano, 2001).

To estimate the amount of reuse water that would be available to supply water demand (approximated at 15 percent and 30 percent of plant production), a current effluent use and maximum capacity is utilized for 2003, adjusted for an assumed 15 percent indoor conservation rate. In 2050, using projected population figures from MRCOG (15), effluent production is estimated and again demand is set at a range of 15 to 30 percent. Figures are presented with and without a 15 percent conservation on indoor use (see Table 27A-1).

Table 27A-1. Reuse Conservation Estimates

	200 Day Demand					
	10% Losses		15% Losses		20% Losses	
Reuse Type	15% demand	30% demand	15% demand	30% demand	15% demand	30% demand
2003						
Without conservation (mg/y)	1,620	3,240	1,530	3,060	1,440	2,880
Without conservation (ac-ft/yr)	(4,957)	(9,914)	(4,682)	(9,364)	(4,406)	(8,813)
With conservation (mg/y)	1,377	2,754	1,301	2,601	1,224	2,448
With conservation (ac-ft/yr)	(4,214)	(8,427)	(3,980)	(7,959)	(3,745)	(7,491)
2050 [a]						
Without conservation (mg/y)	3.1 to 4.6	6.2 to 9.1	2.9 to 4.3	5.9 to 8.6	2.8 to 4.1	5.5 to 8.1
Without conservation (ac-ft/yr)	(9.5 to 14)	(19 to 27.9)	(9 to 13.2)	(18 to 26.4)	(8.5 to 12.4)	(16.9 to 24.8)
With conservation (mg/y)	2.6 to 3.9	5.3 to 7.8	2.5 to 3.7	5 to 7.3	2.3 to 3.5	4.7 to 6.9
With conservation (ac-ft/yr)	(8.1 to 11.9)	(16.2 to 23.7)	(7.6 to 11.2)	(15.3 to 22.4)	(7.2 to 10.5)	(14.4 to 21.1)

mg/y = Million gallon per year   ac-ft/yr = Acre-feet per year

[a] 1,000 million gallon and 1,000 acre-feet; range reflects a low flow of 75 gallons per day and a high flow of 110 gallons per day.

Water Saved/Lost (consumption and depletions)

Water is not saved or lost in this alternative, it is just put to a different use in the water cycle, i.e. it provides a new source to meet water demand, but does cut off return flows to the river. Water may be saved from groundwater pumping but would be lost to the riparian and river systems when effluent is diverted back to the urban and suburban area for consumptive uses. This does not alter the total amount of available water in the system. The treatment and pipelines required would result in some additional evaporative and leakage losses that may not occur from present systems that simply discharge at an NPDES outfall. If water is treated for aquifer replenishment, then a greater potential exists for water being saved from evaporation, but it would still be lost to downstream surface systems.

Impacts to Water Quality (and mitigations)

“The acceptability of reclaimed water for any particular use is dependent on the physical, chemical, and microbiological quality of the water” (Crook, 1998). Assurance of treatment reliability is an important quality control measure for a reuse system (Crook, 1998). The distribution system must be designed, constructed, and operated to assure the reclaimed water is not degraded prior to use. The reuse system must not become a source of pollution to existing surface streams or potable groundwater aquifers (Crook, 1998). Open storage of the water can degrade the treated water quality by growth of algae and microorganisms, or introduction of particulates. It can also cause objectionable odor or color in reclaimed water, and result in significant evaporative losses. (Crook, 1998).

The water would be treated to reuse standards, however, any recycling results in concentration of salts and metals, which are then loaded in the soils or recycled to undergo treatment again (U.S. EPA, 1992). Such concentration must be offset by fresh water inputs for the use called "leaching requirement."

There are two types of reuse classifications depending on water quality required: Unrestricted Urban Reuse (UUR), which has a high likelihood of human contact with the reclaimed water, necessitating strict pathogen control, or Restricted Urban Reuse (RUR), where human contact is prohibited or unlikely (U.S. EPA, 1992). The potential nonpotable reuse possibilities in the region, with applicable classification include (U.S. EPA, 1992).

- Landscape irrigation
  - Golf courses (UUR where golfers are present, RUU if watered when humans not present)
  - Parks, schoolyards, play areas, and other turf recreation facilities (UUR)
  - Commercial and industrial open areas (UUR)
  - Single-family homes (UUR)
  - Cemeteries (RUR if watered when humans are not present)
  - Roadway medians (RUR)
- Aesthetic uses
  - Decorative ponds (UUR)
  - Decorative fountains (UUR)
- Industrial uses (all OSHA worker protection requirements apply)
  - Cooling water (RUR)
  - Process water (RUR, but can have higher water quality standards)
  - Construction dust control, aggregate washing, and mix water (RUR)

  - Road cleaning, sidewalk and outdoor work area cleaning (RUR)

- Other municipal uses

  - Toilet flushing (UUR)
  - Car and equipment washing (UUR)
  - Air conditioning (UUR)
  - Fire protection (UUR)
  - Commercial laundry (UUR)

- Agriculture

  - Non-food crop production (RUR, but quality depends on crops)
  - Food crop production (UUR and depends on crop)

- Groundwater recharge (UUR if can affect potable aquifers)

- Environmental enhancement

  - Wetland creation or maintenance (meet NPDES requirements)
  - Surface water augmentation (meet NPDES requirements)

In the region, surface water augmentation and wetland uses are already implemented by returning the treated wastewater effluent to the river system. The water thus returned is also being used for agricultural purposes down-stream as the water is mixed with native river flows.

Groundwater recharge requires the highest level of treatment—probably better than current drinking water standards—and will not be discussed in this alternative.

The opportunities for altering effluent uses in the region by more direct reuse are:

- Landscape irrigation
- Aesthetic ponds and fountains
- Industrial uses

The water quality requirements for the effluent and its potential impacts to groundwater or surface water quality depend upon the reuse application. Municipal uses, aesthetic facilities, and most landscape irrigation require the highest levels of treatment because of potential human contact. Industrial uses also require high levels of treatment and/or extensive worker education and protection systems. Some industrial processes require extremely clean water that would exceed treatment levels for irrigation systems.

The economic evaluation of the reuse project makes replumbing existing systems for fire protection, toilet flushing, car washing and air conditioning too expensive unless there is a dense concentration of demand, such as an industrial park. Distribution costs to single residences are much too expensive, again, unless the water can be applied in dense population centers such as apartment complexes. The final project conceptual designs would determine if such chemical reuse centers are available. After the nonpotable water demands are located, the most economic treatment and distribution system plans to supply these demands can be evaluated.

Turf irrigation with treated wastewater can result in adverse impacts if the soil loading for certain constituents is exceeded, resulting in potential pollutant migration through the vadose zone to the groundwater (National Academy of Science, 1996). Certain source constituents in municipal wastewater such as nutrients (potassium, nitrates, iron, calcium), salts, cadmium, copper, cesium, nickel, lead, selenium, molybdenum, arsenic, and zinc could be phytotoxic if added to the soil in excess of critical levels, if the crop uptake levels are exceeded and the elements are not immobilized in the surface soil, they may escape the root zone and leach to groundwater (National Academy of Science, 1996). The best mitigation is to design the system for site specific adsorption capabilities, to meet regulatory loading limits with vigilant monitoring systems, to dilute the recycled water with fresh supplies, and/or to meet higher treatment levels at the treatment plant, which are more costly (National Academy of Science, 1996).

In Florida, excess water that cannot be used in citrus groves is diverted to rapid infiltration basins for disposal. Overall, salts in reclaimed wastewater must be managed to preserve productivity of the soil for whatever is being grown. Thus, golf courses, recreational facilities, and other turf applications cannot rely totally on reuse water as the “leaching requirement” must be met with fresh water dilution of this resource. As water is recycled numerous times, the salt concentration continues to accumulate and finally reaches a level that prevents growth in all but the most tolerant plants (National Academy of Science, 1996). Even in ideal conditions, plants remove less than 10 percent of these constituents. This is also true in constructed wetlands, and the problem is exacerbated in arid or semi-arid soil systems, which contain higher initial salt concentrations (National Academy of Science, 1996). Repeated applications of reused effluent without fresh water dilution can result in the accumulation of metals to levels toxic to plants and soil organisms. (National Academy of Science, 1996). Eventually, the levels could become toxic to humans, domestic animals, and wildlife if the water is applied to crops consumed by them or if the toxic constituents migrate to drinking water supply wells (National Academy of Science, 1996). Thus, the U.S. Environmental Protection Agency (EPA) has established soil concentration limits in Part 503 of its sludge rule. The rules set out specific application rates, monitoring requirements, and leaching requirement recommendations.

Other constituents of concern are trace organics, including new potential contaminants such as endocrine disrupters (hormones), and pathogens such as bacteria, viruses, and parasites (National Academy of Science, 1996). Wastewater irrigation can potentially transport pathogens to groundwater under certain conditions and certainly to surface water if the pathogens are not removed in the treatment process (National Academy of Science, 1996). Disinfection and rigorous monitoring are necessary to minimize this risk. (National Academy of Science, 1996). This is a limitation of constructed wetlands, which do not provide adequate disinfection and filtration, and thus could not be used as stand alone treatment units for reuse applications. Constructed wetlands would not meet the proposed New Mexico minimum reuse standards for Unrestricted Urban Reuse (U.S. EPA, 1992). They could be used for aesthetic ponds, but there is some concern about exposure to pathogens by individuals who may contact that water (U.S. EPA, 2000; Thompson et al., 1996)

Public health concerns and public acceptance of the reuse system, are critical elements in studying and designing a proposed project. The results of this public outreach program will ultimately determine how much and where reclaimed wastewater can be applied (Asano et al., 1992).

For industrial reuse and some municipal reuse options such as toilet flushing, fire protection, and air conditioning, quality concerns include potential scaling, erosion, biological growth and fouling, and public health concerns, especially for workers (Asano et al., 1992). Recreational and aesthetic impoundments present issues related to health concerns, eutrophication and algal blooms as well as the need to dechlorinate the treated effluent to protect fish and plants if chlorine was used as the disinfection agent. (Crook, 1998; Asano et al., 1992)

Sludges and brines from the treatment plant must be properly handled to avoid simply moving the impurities to landfills, thus creating a different pollution source.

Available engineering knowledge and technology can address all of these issues and provide reclaimed water of the desired quality for use in landscape irrigation, groundwater recharge, and other nonpotable uses. Tertiary treatment can reduce pathogen concentrations to levels suitable for direct contact with the reuse water. Care must be taken in the system design to assure protection of water quality throughout the treatment and distribution cycle. In California, landscape irrigation and groundwater recharge have been the most rapidly growing categories of reclaimed water use and that state has the most stringent reuse water quality requirements (Crook, 1998).

Watershed/Geologic Impacts

There would be no change to the watershed. The geologic formation of the aquifer could be positively impacted if groundwater withdrawals were reduced or extended over time by recycling pumped water back to non-potable uses. However, this would be a per capita reduction and as long-term population increases, the benefits may be offset by new demand. Thus, the benefit is a delay, not an absolute protection of the watershed or the aquifer structure.

1.1.2 Environmental Impacts

Impact to Ecosystems

The treated effluent that is currently being released to the river from municipal treatment plants would not go into the river or other surface water courses where it is currently being discharged. This reduction in surface flows from these sources could affect the minimum flow levels in the river or the water levels in the riparian areas immediately adjacent to the current outfalls. The reuse water would contain concentrations of salts and metals which could change the ecosystems where it would be reused. See above discussion for potential impact to plants and soil organisms if the water is repeatedly used without dilution with fresh water supplies.

Implications to Endangered Species

If the river flow is decreased by reductions in treated wastewater discharges, there could be an impact to the silvery minnow if reduced flow is not offset by native or other surface flows.

If the riparian areas are changed adjacent to the surface water courses there could be an impact on Willow Flycatcher habitat. The addition or deletion of current NPDES outfalls could affect the riparian areas in the region upon which this species depends. Additional erosion or changes in the location of the outfalls should be evaluated to determine potential positive or negative benefits to this species.

1.2 Financial Feasibility

1.2.1 Initial cost to implement

In development of Reuse concepts, several factors need to be considered. Public input is an absolute necessity to evaluate options, determine locations for treatment facilities, potential reuse applications, and pipeline locations. The amount of effluent for reuse must be determined by consideration of return flow requirements, success of conservation programs, costs to treat and distribute, and impacts of reuse system development to the river and the regional environment. Nonpotable demands must be located and the costs to distribute the treated effluent to demand clusters must be determined, along with timing of new sources to match available effluent supply. The successful development of this dependable water resource depends upon close examination and synthesis of all elements of infrastructure and facilities planning, treatment plant siting, treatment process reliability, economic and financial analyses, and water utility management (Asano, 2001, COA et al., 2002). In this paper there is no attempt to do the critical analysis and water balance calculations necessary for an actual project.

The cost estimates below do not reflect a "real project scenario" and should not be used for such a purpose. The attempt here is to quantify volumes and costs based upon a range of potential values and an assumption that water users can be identified and economically served. Indoor conservation effects cannot be evaluated, but the initial computations for the three system losses of 10 percent, 15 percent, and 20 percent are repeated using an assumed reduction of 15 percent to provide a range of potential reduction to the reuse water supply if conservation occurred.

"A common misconception in planning for water reclamation and reuse is that reclaimed water represents a low-cost new water supply" (Asano, 2001). This could be true, but only where water reclamation facilities are conveniently located near large agricultural or industrial users and when no additional treatment is required beyond the typical secondary levels achieved at most central facilities (Asano, 2001). When the water has to be treated to higher quality levels, new plants or expansions to existing treatment facilities are required. Sometimes, this can improve the economics of a specific proposal because new satellite facilities can be located near potential nonpotable water users (COA et al., 2002). The conveyance, distribution, and potential storage facilities represent the principal cost of most reuse projects with recent California experiences indicating that $8 million dollars in capital costs are required to reclaim and reuse 1 million gallons per year(Asano, 2001). Many reuse projects result in water costs that are higher than delivered potable water from conventional systems (Asano, 2001). Such reclaimed water is probably too expensive for traditional agriculture, but urban irrigation systems can afford to pay the price if the cost of finding other water supplies is even higher (Asano, 2001). As an area becomes more urbanized, reclaimed water prices can compete with new water resources to provide nonpotable uses such as toilet flushing and irrigation of common areas, because the distribution network is more affordable in densely developed areas (Asano, 2001).

A critical factor affecting costs is the degree of utilization of the available capacity of existing wastewater treatment facilities (Asano, 2001). To maximize this utilization, storage units can be constructed to compensate for seasonal slack water reuse demands, mixing reuse water with fresh supplies to reduce seasonal peaks that exceed production capacity, and using alternative supplies to meet peak demands (Asano, 2001). The current demands in the Middle Rio Grande region are limited because of the low industrial demand and distance from effluent production plants to large agricultural demands. For example, the City of Albuquerque is planning for a maximum of about 15 percent of the effluent production being economically applied to nonpotable irrigation and industrial demands, while the Rio Rancho planning outlook is closer to 30 percent. The Rio Rancho figures reflect a newer and faster developing community providing opportunities to implement reuse at project initiation as well as lower effluent production quantities.

For the following calculations, a 15 percent and 30 percent estimate of the range of reuse demand was used to determine the effluent volume requiring higher treatment costs. These costs are estimated to provide additional treatment required and do not reflect basic wastewater treatment costs to meet NPDES permit requirements. In the analysis, the reuse volume never exceeded the present wastewater treatment capacity of about 80 mgd in the region. However, it is expected that some new treatment facilities would be needed and desirable to more economically meet reuse demands. Thus, for the 2050 estimates, a blended cost of expansion and new treatment facilities was used.

Only three days of storage was allowed, which would not be adequate to collect winter effluent to save for application in the spring. Because of the high cost of storage, it is assumed that excess winter production would be discharged. This could change if industrial uses with winter reuse demand were identified or if toilet flushing in new areas or buildings could be developed. Another potential use for the winter overage or surplus effluent production from the remainder of the year would be an aquifer injection program, but that is not considered in this alternative.

Planning, design, and construction of a reuse project require professional expertise and resources along with careful integration of a public education and sensitivity program. For purposes of cost estimation, it is assumed that the reuse program treats, distributes and stores all of the reuse water simultaneously, thus requiring treatment plant construction and/or expansion, pipeline installation, some lift stations, administration costs, and storage facilities. All of these values are highly dependent upon source and demand locations. For ease of comparison, median assumptions have been used and values listed in dollars per gallon. Extreme caution must be used before projecting these costs to any real project, which will present unique requirements that could make these costs higher or lower. The variables are too numerous to make specific project assumptions at this planning stage. More realistic costs would be determined during the feasibility and conceptual design stages of actual proposed projects.

For instance, pipeline costs would be based upon length of pipe and variability of elevations and terrain, not in dollars per gallon. If a satellite treatment plant is constructed near the reuse application, pipeline, lift and storage costs would be reduced. If gravity flow is obtainable, no lift station would be required. If new easements must be obtained, administrative costs could be higher depending upon the cost and location of the land. Therefore, these cost estimates should only be used for relative planning comparisons and not to project actual costs of any specific reuse proposal.

The 2050 figures are based upon an escalation rate of 3 percent for the cost values and a population projection of 1,536,100 persons actually connected to centralized treatment facilities. The 2050 values also assume that no reuse systems are implemented before that date. This assumption may be unrealistic, but should present a cost that would exceed real project costs, particularly if reuse programs are implemented at specific sites throughout the region over the projected timeframe as they become economically feasible.

To expand current treatment facilities with additional treatment processes the estimated 2003 dollars could range as follows (no adjustment is made for conservation as design and construction of treatment facilities, pipeline collection, administrative costs, and storage would be based upon maximum potential volumes) and (new plant construction is not considered here as the current facilities have excess capacity to meet projected reuse demands with expansion costs assumed to be 50 percent of new construction costs):

- Treatment Plant expansion (**COA et al., 2002;** New Mexico Heritage Preservation Alliance, 2002; ENR, 2002)
  - Current effluent production, 9-18 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $20.25 million to $47.25 million
  - Current treatment plant capacity, 12.5-24.9 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $28.01 million to $65.36 million
- Interceptor Collection Pipeline(s) (**COA et al., 2002;** New Mexico Heritage Preservation Alliance, 2002; ENR, 2002)
  - Current effluent production, 9-18 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $0.68 million to $1.35 million
  - Current treatment plant capacity, 12.5-24.9 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $0.93 million to $1.87 million

- Lift Costs and Administrative, such as permits, easements, etc. (10,11,12)
  - Current effluent production, 9-18 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $0.68 million to $1.35 million
  - Current treatment plant capacity, 12.5-24.9 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $0.93 million to $1.87 million
- Storage Costs for 3 days of production (10,11,12)
  - Current effluent production, 9-18 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $32.4 million to $44.6 million
  - Current treatment plant capacity, 12.5-24.9 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $44.8 million to $61.6 million

The total initial capital cost could range from a low of $54.0 million to a high of $130.7 million dollars to implement this alternative in 2003.

If implementation of the alternative is delayed to the end of the planning period, initial costs, 2050 dollars are estimated using a 3 percent escalation and a population of 1,536,100 persons connected to central facilities results in the following ranges:

- Treatment plant expansion
  - Low flow effluent production (75 gallons per day [gpd]), 17.3-34.6 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation and assume blend of new construction and expansion for unit costs: $511.4 million to $681.8 million

  - High flow effluent production (110 gpd), 25.3-50.7 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $750.0 million to $1,000.0 million

- Interceptor collection pipeline(s)

  - Low flow effluent production (75 gpd), 17.3-34.6 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $5.7 million to $11.4 million

  - High flow effluent production (110 gpd), 25.3-50.7 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $8.3 million to $16.7 million

- Lift costs and administrative, such as permits, easements, etc.

  - Low flow effluent production (75 gpd), 17.3-34.6 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $5.7 million to $11.4 million

  - High flow effluent production (110 gpd), 25.3-50.7 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $8.3 million to $16.7 million

- Storage costs for three days of production

  - Current effluent production, 9-18 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $272.7 million to $375.0 million

  - High flow effluent production (110 gpd), 25.3-50.7 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $400.0 million to $550.0 million

The total initial capital cost could range from a low of $795.5 million to a high of $1,583.4 million dollars to implement this alternative if action were delayed to 2050.

1.2.2 Potential funding source

- Rate increase

- Bureau of Reclamation Title XVI program, Reclamation, Recycling and Water Conservation. This funding is available for projects that include reclamation and reuse of municipal wastewater, other wastewater, or naturally impaired waters. Thus, the program could be a potential source of funds if the collection and treatment system were linked to a reuse program. The maximum federal cost share is 50 percent for planning, 25 percent for design, and 25 percent for construction, with an overall cap of $20 million for construction of a single project, regardless of total project cost. Often the federal share is non-reimbursable, resulting in a de facto grant, however, projects are funded by specific congressional appropriations, which require advance planning and requests that can be delayed depending upon the federal budget process and its shifting priorities. Matching local funds are essential to obtain and maintain these grants and state programs are designed to leverage such federal funding programs through vehicles such as the Water Project Fund administered by the Water Trust Board.

- State/federal grants

  - USDA Rural Utilities Service (RUS) has water and waste disposal loans and grants in rural areas and towns with 10,000 or fewer residents, up to 75 percent of eligible project costs and RUS guarantees loans made by banks and other institutions (New Mexico Heritage Preservation Alliance, 2002).

  - The U.S. Department of Housing and Urban Development (HUD) provides community development block grant programs to construct public facilities and improve water and sewer facilities (New Mexico Heritage Preservation Alliance, 2002).

  - For Tribes, HUD has resources for Native Americans, EPA has American Indian Environmental Office tribal grants, and the U.S. Department of Health & Human

Services also has grant programs for such projects (New Mexico Heritage Preservation Alliance, 2002).

- The Water and Wastewater Grant Fund (W/WWGF) was created for the purpose of awarding grants to qualified entities for water and wastewater projects. In FY02 77 projects were authorized grants statewide and with 27.6 million in grants and emergency requests being obligated. The fund balance is $13.3 million, with some funds obligated, but not spent. The NM Finance Authority has received 65 applications by October 2002, totally $99.1 million for consideration of funding in FY02-03 (New Mexico Heritage Preservation Alliance, 2002).

- State/federal loans

  - Clean Water State Revolving Fund provides $1 billion annually to the states which manage individual revolving loan funds for wastewater and other water quality projects (Camp Dresser & McKee, 1998). The program provides loans at low or zero interest with repayment periods up to 20 years. Terms vary by state, but typically the money goes to capital costs and not to O&M expenses. There is a lot of competition for these funds (New Mexico Heritage Preservation Alliance, 2002).

  - The Wastewater Facility Construction Revolving Loan program is administered by the NMED. It is capitalized by federal grants, state matching and other funds accrued from construction loans. The program is restricted to low-interest loans and eligible entities include municipalities, counties, sanitation districts, and Native American tribes or pueblos with resources to repay loans. The current unobligated balance in the fund is $52.2 million with pending applications for $40.8 million (New Mexico Heritage Preservation Alliance, 2002).

  - The Public Project Revolving Loan Fund (PPRLF) is administered by the NM Finance authority and provides low-cost financing for long-term capital projects such as sewerage and waste disposal systems. The program is capitalized with 75 percent of annual government gross receipts tax revenue combined with federal state and local funds. Each project financed for the PPRLF must be authorized by the legislature by way of a statute. The loan capacity at current market rates from the PPRLF is about $500 million (New Mexico Heritage Preservation Alliance, 2002).

- Private loans
- Revenue bonds
- Effluent sales income would be a primary source of income, particularly for operation and maintenance costs of a reuse project.

1.2.3 Ongoing cost for operation and maintenance

Operating and maintenance costs include power for the pumps, repair and replacement of mechanical parts, including pipeline systems, chemical acquisition, waste management, sampling and monitoring, and reporting (Camp Dresser & McKee, 1998). Sampling can be quite expensive, as high as $30,000 per year just for the daily fecal coliform tests (Florida Department of Environmental Protection, Undated). Considering all of the monitoring costs in total, the sampling budget alone is quite significant and a 25 percent increase above standard O&M costs are used for the following estimates.

Generally operation and maintenance costs are not included in the grant programs and in many of the loan programs, particularly those from the federal government. Thus, the community or project authority must normally have sufficient rate base or other funds to pay the O&M costs by itself. Moreover, these costs increase as the system complexity increases. For centralized wastewater treatment facilities and pipeline system maintenance, qualified management, operation, and maintenance staff must be provided to keep the system functional and protective of human health and the environment, especially to assure the reliability and consistent quality demanded in a reuse program. Sharing of resources via a central authority or joint agreement could maximize these resources, thereby reducing competition for the scarce resources and personnel and related costs.

Using cost estimates from current treatment facilities, the following range of values for the first operation year can be predicted in 2003 dollars to be: (COA et al., 2002; New Mexico Heritage Preservation Alliance, 2002; ENR, 2002)

- Current effluent production, 9 to 18 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $6.75 million to $10.13 million

- Current treatment plant capacity, 12.5 to 24.9 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $9.34 million to $14.01 million

If a conservation program is effective in reducing indoor use and thence wastewater discharges, the O&M costs could be reduced because of the reduced volumes that would require treatment. Based upon an assumed reduction of indoor use by 15 percent the following reduced initial year O&M cost estimates can be made:

- Current effluent production, 9-18 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $5.74 million to $8.61 million

- Current treatment plant capacity, 12.5-24.9 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $7.94 million to $11.91 million per year

The estimated initial year O&M costs could range from a low of $5.74 million to a high of $14.01 million dollars per year if this alternative was implemented in 2003.

Estimated O&M values for 2050, using a 3 percent escalation results in the following ranges:

- Low flow effluent production (75 gpd), 17.3-34.6 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $56.82 million to $85.23 million

- High flow effluent production (110 gpd), 25.3-50.7 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $83.33 million to $125.00 million

With implementation of a conservation program and based upon an assumed reduction of indoor use by 15 percent the following reduced 2050 O&M initial year cost estimates can be made:

- Low flow effluent production (75 gpd), 17.3-34.6 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $48.30 million to $72.44 million

- High flow effluent production (110 gpd), 25.3-50.7 mgd (15 to 30 percent demand proportions), average flow estimates for cost computation: $70.83 million to $106.25 million

The estimated O&M costs could range from a low of $48.30 million to a high of $125.00 million dollars for the first year if implementation of this alternative were delayed to 2050.

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Technical and Physical Feasibility Fact Sheet
Alternative 28: Infill/Density

Acknowledgements: This fact sheet was written by Phyllis Taylor of Sites Southwest as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-28: Increase building densities (as compared to typical suburban density) and infill development through adoption of local government land use policies and regulations.

2. Summary of the Alternative Analysis

As described by the Water Assembly, this alternative is primarily a land use alternative with incentives and regulations related to the density and location of new development. This approach is most applicable in urban areas, including Albuquerque, Rio Rancho, and other parts of Bernalillo County. Implementation of the proposed policies and regulations would affect water demand, primarily because of lower per capita outdoor water use resulting from reductions in the amount of land devoted to irrigated landscapes.

The following alternative actions, recommended by the Water Assembly, have been incorporated into this alternative:

- Develop land at higher densities and in patterns that use less water than typical suburban development
- Increase building densities (multifamily housing)
- Increase infill development
- Redevelop brownfields
- Encourage infill by reducing new service charges

Residential and commercial (office and retail) developments are the most promising for high density development and infill. Industrial and institutional projects, which tend to be larger and require more space for parking, would be more difficult to locate on smaller infill sites. High density housing could include single-family detached homes on smaller-than-average lots, attached housing, and multifamily developments. Urban commercial centers and mixed-use centers that contain retail, office, and possibly housing on a single site typically would have less outdoor landscaping than standard suburban shopping centers.

Zoning and financial incentives are common methods used by local governments to encourage increased development densities and infill. Examples of these approaches are described below:

- *Local land use regulations.* Communities in New Mexico regulate development through zoning and subdivision ordinances and building codes. Zoning ordinances specify the land use, lot sizes, building setbacks, building height, parking requirements, and other development criteria within specified areas of the community. Subdivision ordinances specify infrastructure requirements and define rules for lot layouts within a subdivision. Building codes establish safety requirements for building construction. High density and infill developments are often difficult to develop because nearby neighbors may oppose them, the approval process may take longer than usual, and existing regulations may not be appropriate for the unique circumstances of an infill site. High density development can only occur if it is allowed by the community's land use regulations. Infill and higher density development is more likely if there are no regulatory impediments—that is, if this type of development is as easy as any other new development.

- *Streamlined development process*. One method of encouraging "desirable" development is to streamline the development process so that less time is needed to gain project approval. By reducing the amount of time needed for a developer to obtain zoning, subdivision, and other approvals, the community can help make the project more financially feasible. This can be accomplished by expediting technical review of the project and reducing the time from plan submittal to public hearings.

- *Density bonuses*. Density bonuses allow developers to increase the number of housing units or the square feet of commercial space on a site above what is normally allowed by the community's zoning ordinance. Density bonuses are granted for projects that meet specified community goals, and the method for granting bonuses is described in the community's land use regulations. For example, the State of California adopted a state density bonus law to make affordable housing development economically feasible (Section 65915, Chapter 842, Statutes of 1989). This statute requires all cities and counties to adopt ordinances that grant bonuses to developers who agree to construct a portion of the units in their subdivisions for low-income households or senior citizens. A similar approach could be used to encourage development that meets other community goals, such as infill, redevelopment, or water conservation. The community's comprehensive plan would list the community's goals, and the relevant ordinances would describe the actions that would trigger density bonuses and how these bonuses would be granted.

- *Variable impact fees*. The New Mexico Development Fees Act states that once a community establishes impact fees, all development is subject to these fees. A community cannot grant a "waver" that exempts a development from fees, but the community can pay a portion of the fees out of other community funds to lower the cost of projects that meet community goals.

- *Metropolitan redevelopment incentives*. Municipalities in New Mexico have the power to assist development in areas that have been declared slum and/or blighted according to the requirements of the New Mexico Metropolitan Redevelopment Act. The local government can choose to reduce local taxes for a certain period of time or can participate directly in a project as described below. These community incentives help make the projects economically feasible and help mitigate the risks associated with projects deteriorated parts of the community. The costs of these incentives include lost tax revenue or direct participation costs. The benefit to the community, in the long run, is additional tax revenue associated with property improvements.

- *Direct participation in development*. Municipalities can participate directly in a metropolitan redevelopment project, thus reducing project costs and/or development risks. The City of Albuquerque has purchased land and made property available, through a public bidding process, to developers who agree to meet the City's goals for the project. In some cases, the City has also constructed needed infrastructure, such as roadway and drainage improvements, and amenities, such as landscaping. Local government incurs the costs of these improvements.

The City also has used standard zoning categories, special zoning through neighborhood scale plans, and its metropolitan redevelopment authority to encourage higher density and infill development. The City and County Planned Growth Strategy (PGS) identifies additional techniques, including new mixed-use zoning categories, variable fees, utility services areas, and policies regarding higher densities in specific areas as ways to encourage more infill and higher density mixed-use development in new communities.

In 2002, the City Council began implementing parts of the PGS through the adoption of ordinance number O-02-39, which specifies what the City will do to begin implementing the PGS, and resolution number R-02-111, which provides policy guidance for further legislation. The City has appointed a citizen task force to advise the administration and council on implementation. It has also agreed to establish impact fees, amend the Albuquerque/Bernalillo County Comprehensive Plan, adopt an infrastructure plan for future capital improvements, and encourage sequencing of capital expenditures so that new infrastructure is provided to new planned communities in a timely fashion. The community continues to debate exactly how the goals of the PGS will be met, and new ordinances will be required to accomplish the recommendations in the PGS.

Development economics can result in higher development densities without regulatory changes. For example, as land prices have increased in Albuquerque, the result has been smaller lots, which effectively increase the density of new single-family subdivisions. Rural communities in the region have experienced suburban development, which is higher density that existing rural development. New subdivisions near I-25 in Los Lunas are examples of this. New communities such as Mesa del Sol, south of Albuquerque International Airport include some higher density centers in their plans. The “village centers” proposed for new communities include a mix of commercial and higher density housing in fairly compact areas that are surrounded by more traditional single family subdivisions. The new communities have not yet been built, but their master plans incorporate new ideas about land use and include water conservation as part of the overall development plan.

An increase in residential density would reduce demand for outdoor irrigation by effectively reducing the area to be irrigated. Higher density development is only one way to accomplish this goal; low water use landscaping can accomplish the same result. Water conservation techniques for outdoor irrigation and landscaping are discussed in other alternatives.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Technically, municipalities in the region can adopt zoning regulations and planning policies that encourage higher densities and infill development. However, the success of this alternative is probably more related to administrative and political feasibility issues than to technical issues.

A county or municipality usually specifies its goals for the future in a comprehensive plan. These documents are created by the local government with community participation through public meetings and hearings. The community's land use regulations can then be modified to be consistent with comprehensive plan goals. For example, if infill development is a goal, the comprehensive plan will describe how infill development should be accomplished. The local government will amend its zoning ordinance, if necessary, to allow the types of land uses desired and to map areas where infill is desired. The local subdivision ordinance may be modified to define desirable lot layout characteristics and street standards. Other incentives could be applied, such as a streamlined review process for infill projects.

If metropolitan redevelopment incentives are appropriate for a particular area, the jurisdiction must formally (by ordinance) declare the area blighted, adopt a metropolitan redevelopment plan that describes the projects that the jurisdiction will undertake, and implement the projects described.

Each of these approaches requires time and financial resources from the local government. Some technical training or hiring of qualified staff or consultants may also be required if the community does not have the administrative capacity to do this work themselves.

Infrastructure Development Requirements

In new areas, infrastructure can be designed from the start to accommodate higher densities. However, the cost of infrastructure upgrades is a potential issue for infill development and brownfields redevelopment areas that lack adequate capacity. Streets, water and sewer systems, and storm water drainage facilities may need to be upgraded in portions of some communities to implement this alternative.

Total Time to Implement

The time needed to implement this alternative includes the time to change land use policy and the time for new development to respond to the policy change. The City of Albuquerque has spent several years debating the policies in the PGS and is just beginning the process of changing its local laws. Other communities may be able to act more quickly if the community supports the proposed changes.

A change in land use policy will impact new development, but will not have an impact on existing developed areas. Therefore, there is a lag time between policy implementation and a noticeable effect on water demand. The Mid-Region Council of Governments (MRCOG) projects the average annual growth rate over the next 50 years to be 1.5 percent per year in its Focus 2050 plan (MRGCOG, 1999).

Growth projections to 2050 indicate that the number of housing units and jobs in the region will double in the next 50 years (MRGCOG, 1999). While change in water demand as a result of land use change is an incremental process, decisions made today could have a significant impact on water demand in 20 to 50 years.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Approximately 56 percent of urban land use in the region is for residential use; however, multifamily residences occupy only about 2 percent of urban land. Based on current trends, the MRCOG projected that single family residential land use would increase to 79 percent of the region's total urban land use, while multifamily land use would decline to 1.7 percent of total (MRGCOG, 1999). From 2000 to 2050, the number of housing units in the region is expected to more than double. In the long term, land use policies that encourage more compact development, with smaller irrigated yards, could make a significant difference in residential outdoor water demand.

An analysis of City of Albuquerque residential water use record shows that per capita household use in Albuquerque is about 100 gallons per capita per day (gpcd), of which an estimated 40 gpcd is for outdoor use and 60 gpcd is for indoor use. City of Albuquerque building permit records for 2001 and 2002 indicate that the average lot size for single family homes in Albuquerque is 6,500 square feet. The average house area under the roof (including garages and covered porches and patios) is about 2,500 square feet, and a typical driveway is 400 square feet (minimum of 20 feet deep and 20 feet wide for a two-car driveway). On average, a home would have a maximum of 3,600 square feet of landscaped area. If lot size were reduced to an average of 5,000 square feet, with no change in the size of house, the maximum landscaped area would be reduced to 2,100 square feet, or about 58 percent of the current amount of landscaped area. This could reduce outdoor water usage for new homes to less than 23 gpcd, making Albuquerque's per capita water usage more in line with that of Santa Fe, Tucson, and El Paso.

The irrigated landscaped area of a commercial property in a typical suburban development is based on zoning requirements for landscaping. In Albuquerque, 15 percent of the lot, excluding the building footprint, must be landscaped. According to City of Albuquerque building permit records, a typical retail or office building occupies 20 to 25 percent of the lot area, leaving 5,000 to 5,250 square feet of required landscaped area per acre of development. A more compact development would increase the ratio of developed floor area to lot size, and could reduce the required landscaped area by as much as 25 percent for an equivalent building size. However, the major determinant of lot size is surface parking. Multi-story buildings and shared or structured parking would be needed to significantly reduce commercial lot sizes. This approach is most appropriate in dense urban centers, which are most likely to occur in the region's urban areas of Albuquerque and, potentially, Rio Rancho.

Rural communities do not tend to require landscaping in new development; therefore, reductions in water demand due to more dense commercial development would be realized in urban areas.

It should be noted that similar results could be achieved through xeriscaping, increased paved patio areas, and other water conservation approaches. Increased densities are only one way to reduce residential and commercial water usage.

Effect on Water Supply (surface and groundwater)

This alternative does not have an impact on water supply.

Water Saved/Lost (consumption and depletions)

The greatest water savings under this alternative would be the reduction in residential outdoor water usage. The average density of new single-family homes would increase from 5.7 units per acre to 7.4 units per acre if the average lot size were reduced from 6,500 square feet to 5,000 square feet. In Albuquerque, approximately 3,600 new homes are built per year. The savings in water usage for 3,600 homes, based on a reduction of outdoor water usage from 40 gpcd to 23 gpcd and assuming 2.7 people per single family home, is about 170 acre-feet per year. These savings would compound as new homes are built.

Approximately 5,000 new homes are built each year in the greater Albuquerque area, which includes Bernalillo, southern Sandoval, and Valencia Counties (City of Albuquerque, 2002; Bernalillo County, 2002; City of Rio Rancho, 2002; MRGCOG, 2002). Approximately 90 percent of these are suburban homes in Albuquerque, Rio Rancho, and Los Lunas. These are the communities most likely to achieve water savings through increased densities.

MRCOG projects approximately 225,000 to 275,000 new single family homes will be built in the region by 2050 (MRGCOG, 1999). If water savings as calculated above were realized for 90 percent of these new units, the long-term savings would be about 11,000 acre-feet per year by 2050.

Impacts to Water Quality (and mitigations)

None.

Watershed/Geologic Impacts

None.

3.1.2 Environmental Impacts

Impact to Ecosystems

To the extent that smaller residential lots reduce land area impacted by development, this alternative could reduce the demand for undeveloped land and the rate of land development, while providing for the region's population growth. However, implementation of this alternative would not necessarily protect ecosystems unless it is linked to other policies such as a policy to protect sensitive lands, as described in Alternative 30, Land Use. In fact, high-density development is not feasible in certain areas, such as those with steep slopes or fragile soils, and could have negative consequences on habitat, views, and other environmental resources if not located appropriately.

Implications to Endangered Species

As with ecosystem protection, this alternative would not protect endangered species unless linked to other policies explicitly geared to protection of endangered species. This alternative affects the flow of the Rio Grande to the extent that it could reduce demand for surface water for outdoor irrigation.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

For a local government, the initial cost to implement this alternative will be the cost of amending local policies and ordinances such as the community's comprehensive plan and zoning and subdivision ordinances. Costs would include expenses for a city or county planner or the cost of contracting with MRCOG or a consultant. The cost of a comprehensive plan can range from $25,000 for a fairly simple plan in a small community to over $100,000 for a more complex document. Revisions to local ordinances can have a similar cost, depending on the extent of revisions, the amount of public participation, and the length of time the community spends on evaluating the changes.

If infrastructure must be upgraded to accommodate increased densities in existing developed areas and infrastructure upgrades are provided by the local government as an incentive, the cost of these upgrades will be borne by taxpayers. If the developer must pay for upgrades, the cost will be passed onto the consumer.

3.2.2 Potential Funding Source

The Local Government Division of the State of New Mexico Finance and Administration Department provides grants of $25,000 to small communities for planning through the Community Development Block Grant Program. Local governments in New Mexico have used these funds to develop or update comprehensive plans and to pay for new or amended land use regulations. Other sources of funds include the local government's administrative budget.

Potential funding sources for infrastructure upgrades in developed areas include utility rates, general obligation bonds, and state and federal grants.

Potential funding sources for new infrastructure needed to accommodate new growth include utility rates, development fees, general obligation bonds, and state and federal grants.

If per capita water usage declines, utility revenues would decline proportionally unless rates are increased.

3.2.3 Ongoing Cost for Operation and Maintenance

Operation and maintenance costs would be a normal part of ongoing local government operations. Experts debate whether infrastructure costs for compact development are less than infrastructure costs at traditional densities. The PGS includes a literature review in support of compact development; PGS opponents have submitted counter arguments. The ongoing costs for water utility operations and maintenance would likely remain the same as current costs since much of the cost for these systems is based on production, plant capacity, and plant operation and maintenance rather than construction of the distribution system.

3.3 Other Considerations:

Political acceptability. To date, efforts by the City of Albuquerque to implement a land use policy that supports increased densities and MRCOG's *Focus 2050 Regional Plan* have had mixed support. The City of Albuquerque is seeking to increase infill development, redevelopment, higher densities along major transportation corridors, and mixed-use centers. Rural and suburban communities have not followed this strategy.

Higher density developments, infill, and redevelopment are often met with neighborhood resistance. A jurisdiction that implements this policy will need to work carefully with neighborhood groups and developers if infill development and higher densities are to be successful.

Local governments in the region may need to amend their existing land use plans, and possibly their land use regulations, to allow for increased densities.

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Technical and Physical Feasibility Fact Sheet

Alternative 30: Land Use

Acknowledgements: This fact sheet was written by Phyllis Taylor of Sites Southwest as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-30: Adopt policies to integrate land use and transportation planning and water resource management in all government jurisdictions in the Middle Rio Grande planning region.

2. Summary of the Alternative Analysis

As described in the Water Assembly database, this alternative includes incentives and regulations related to water resource management as well as the land use policies described in Alternative 28, *Infill/Density.* Water resource management is part of a comprehensive, integrated approach to development and growth management. Water resource management strategies are also being evaluated in other alternatives being considered by the Water Assembly, such as those addressing water conservation, wastewater reuse, greywater use, or other similar strategies. Additionally, Alternative 52, *Growth Management,* focuses on combined strategies for growth management. Because there is overlap among the alternatives, this alternative has focused on land use and subdivision development.

Original suggested actions that are incorporated into this alternative are as follows:

- Integrate or create linkages between water management and land use plans.
- Review/approve land use plans for water resource impact at all levels of government.
- Develop land use policies that support water plan goals.
- Use transfer of development rights to protect sensitive areas.

Land use policy can also provide incentives for implementation of the water conserving or water management techniques identified and being evaluated in other alternatives.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Linking Development Projects to Water Supply

Under the New Mexico Subdivision Act, counties can require proof of a long-term water supply that is adequate to serve new subdivisions as part of the subdivision approval process. Limitations to this are that there is no consistency in how counties apply the statute in their ordinances, and the act does not apply to municipalities. For example, ordinances can require proof of water for 50 years or 70 years, and the time frames may not be sustainable over a longer term. The definition of "adequate" can vary, and counties have not necessarily technically defined what water availability means. Consistent technical definitions of water availability and adequacy for the counties in the region, as well as a means of evaluating the cumulative effect of multiple subdivisions over time, could be the responsibility of a Regional Water Authority (A-67, *Water Authority/Banking*). New subdivisions within municipalities are typically served by a municipal system, and a municipality could include consideration of system capacity in its land use regulations. The City of Albuquerque, for example, requires a written statement of water and sewer availability for any proposed development project for building permits, site plan or subdivision approval. Again, a jurisdiction that ties approvals to system capacity should have a sound technical basis for evaluating development and implementing such regulations.

Presently, the fact that municipalities do not consistently require proof of available water may move development from rural areas to municipalities. Municipalities in this region do not consistently evaluate the availability of water. Regional consistency between municipalities and counties and a method of evaluating cumulative impacts is needed to effectively tie water supply availability to land use planning. This would be a complex process due to the diverse jurisdictions in the region.

The State of California has used the technique of directly linking land use approvals to available water supply. Since 1995, land use agencies in California have been required to consider water supply when approving a development project. Historically, public water suppliers issued "will serve" letters to meet this requirement. In 2001, two bills (SB 211 and SB 610) were passed that require more specific evaluation and documentation of available water, with much of the burden of documentation on the utilities.

SB 211 applies to residential development of more than 500 dwelling units unless it is within an urbanized area or exclusively for very low and low-income households. The bill applies to a smaller subdivision if the water system serving it has less than 5,000 service connections. Local governments must include as a condition for subdivision approval the written verification from a public water supplier that a sufficient water supply is available to serve the subdivision.

SB 610 requires that public water suppliers prepare a water supply assessment for residential and commercial projects meeting certain size thresholds. The water utility must identify the anticipated water supply and its rights to that supply. Urban water suppliers are required to prepare, adopt, and update an urban water management plan that forecasts water demands and supplies within their service area. If groundwater is a source, the urban water management plan must consider the basin from which water is to be extracted. The plan must also include a description of all projects and programs that will be undertaken to meet projected water demand.

On the positive side, these bills could directly link project level requests for water service to long range plans and encourage suppliers to plan further ahead to develop adequate water supplies.

On the negative side, these requirements create new administrative responsibilities for water systems and potentially increase the cost of new housing. The California building and real estate industries project that new home prices will escalate as a result of the administrative and legal costs associated with compliance with these bills. The bills also place a burden on water utilities to respond to requests and provide detailed documentation of water availability in a timely manner.

Protection of Sensitive Areas

Local governments have several means of protecting sensitive areas from inappropriate development. Areas critical to water quality or aquifer recharge can be identified in a community's comprehensive plan, and the county or municipality can establish zoning for these areas that would restrict certain uses or establish appropriate densities. Local governments in New Mexico have purchased sensitive lands outright as open space, established wellhead protection ordinances to restrict threats to groundwater, established setbacks for new development, and regulated storm water discharge as ways to protect sensitive areas.

One technique included in the Water Assembly's description of this alternative is the transfer of development rights (TDR) is a method for protecting land by transferring the right to develop from one area to another area. The difference between the current and potential use of a parcel, as permitted by existing zoning, is the development right that can be transferred. An area that the community wants to preserve is identified as the "sending site". The owner can record a legal restriction on future development of the sending site, and sell the development rights to the owner of another property, which becomes the "receiving site." By purchasing development rights, the receiving site owners are allowed to build at a higher density than the zoning ordinance would allow if the project did not include the transferred development rights. A similar concept is cluster development within a single property, with land set aside as permanent open space.

TDR has not been used in the Middle Rio Grande planning region, primarily because most development is low density. Unless developers perceive a demand for higher density development than is currently allowed by zoning and this development is supported by nearby residents, few sites in the region are candidates for additional development rights. Cluster development has been used infrequently in the region. The La Luz townhouse project in Albuquerque is an example of a single site with development clustered on a portion of the site. In this case, development is away from the Rio Grande while the property closest to the river is set aside as permanent open space for the residents of the development.

Infrastructure Development Requirements

Infrastructure development requirements would tie development approvals to existing or planned system capacity. Local governments could better link capital improvements to the timing of new development by identifying growth areas in advance and providing new publicly funded infrastructure to serve these areas in a timely manner. Conversely, local governments have established concurrency ordinances which require that new development is restricted to areas where infrastructure capacity exists or will be available within a specified period of time. This alternative may not alter the type or cost of improvements, but would affect the timing of construction.

If water suppliers do not have the capacity to serve new development, they may either increase capacity through system expansion or refuse to provide services. If a water supplier does not provide service, and local governments have no provision for private utilities, then development will go elsewhere. Planning in a rational way for system expansion, and an equitable sharing of cost between developers and existing ratepayers, may be the preferable method of directing growth in the region. Typically, a public water supplier provides a master plan for its system without any change to existing laws. However, cost sharing would be defined through the supplier's rate structure and modifications to local subdivision and/or other ordinances. To meet future capacity needs, the water supplier must also determine that funding will be available as needed through revenues, developer fees, and other sources as needed. Outside funding sources might include state and federal loans and grants.

Total Time to Implement

This alternative will be implemented over the long-term as new development occurs. However, local governments could begin the process immediately by designing and passing new ordinances and policies.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

- A change in land use policy will not have an immediate impact on water demand. The effect will be realized as new development occurs that uses less water than existing development.

- A regulatory link between land use policy and water use can provide an incentive for reduced water demand through higher densities, xeriscaping, storm water management, and other conservation techniques. The effects of these techniques are discussed in the fact sheets for other alternatives (A-18, *Urban Conservation,* A-22, *Conservation Incentives,* and A-28, *Infill/Density*).

Effect on Water Supply (surface and groundwater)

None.

Water Saved/Lost (consumption and depletions)

This alternative describes ways that local governments can reduce water demand through incentives in its land use policies. Water savings will result from water conservation and other techniques described in fact sheets for other alternatives, primarily A-18, *Urban Conservation,* and A-22, *Conservation Incentives*.

The potential for water savings is only marginally related to land use patterns, as the land use does not necessarily relate to water use unless there is a specific link. Outdoor water use is the major component of residential water use. Most savings from residential development will come from reducing landscaped areas or installing water conserving landscapes. Indoor water use is the more significant component of commercial, industrial and institutional uses. Water savings in non-residential uses may come from conserving water in industrial processes, heating and cooling systems, domestic plumbing fixtures, and water conserving landscapes

Impacts to Water Quality (and mitigations)

Protection of sensitive lands through land use measures could maintain and potentially improve water quality by protecting surface and groundwater at these locations. Integrating wellhead protection into land use policies could also protect water quality.

Watershed/Geologic Impacts

None.

3.1.2 Environmental Impacts

Impact to Ecosystems

Land use policies that protect sensitive areas would have a positive impact on ecosystem by protecting water quality and, potentially, critical habitats.

Implications to Endangered Species

Land use policies could set aside and protect sensitive areas, including habitat for endangered species.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Costs for developing, implementing and enforcing new regulations and programs depend upon the size and extent of the programs, the number of jurisdictions and agencies involved, and the staffing for the various programs. Because this alternative could be implemented in any number of ways, specific costs cannot be determined. However, the types of costs expected to be incurred from this alternative include:

- Administrative cost to local governments and water utilities.
- Increased housing costs that result from costs incurred by developers to verify water availability and development fees for water rights acquisition.
- Administrative costs for special studies and staff training.

See A-67, *Water Authority/Banking,* for costs associated with creation of a regional water management authority.

3.2.2 Potential Funding Source

Local governments will likely fund the cost of developing new regulations, special technical studies, staffing, and staff training. Some of the costs could be shifted to new development through impact fees, in which case costs would be borne by homebuyers and commercial building owners and reflected in higher home prices and rents.

Potential funding sources for any costs that are not a landowner responsibility under the normal development process include utility rates, general obligation bonds, and state and federal grants.

3.2.3 Ongoing Cost for Operation and Maintenance

The primary ongoing program administrative costs to local governments and water utilities would be additional staff to administer regulations and provide the technical expertise needed for assessments of water system capacity.

3.3 Other Considerations:

- Complexity of regulations and implementation process.
- Need for jurisdictions to amend existing regulations, preferably in a consistent way for the region.
- Need for ongoing staff training.
- Potential impact on local real estate markets, including increased cost of development and likelihood that developers will seek opportunities in jurisdictions with simpler regulations.
- Need to develop the technical knowledge required to draft and enforce regulations.
- Technical studies will be required to support scientifically based regulations. For example, if a jurisdiction adopts a policy to protect critical habitat, the jurisdiction must identify the locations of critical habitat and the criteria that will be used to evaluate development.
- Development constraints and opportunities should be identified in local land use plans.
- Need to understand who will bear the responsibility and costs of regulations. Costs borne by the developer of a new subdivision will be passed to the people who buy land and build homes in the subdivision. Costs borne by the local jurisdiction will be spread over the jurisdiction's residents and businesses or utility ratepayers. Local governments must act fairly and anticipate the consequences of either development costs or tax increases.

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Technical and Physical Feasibility Fact Sheet
Alternative 38: Surface Modeling

Acknowledgements: This fact sheet was written by Robert Leutheuser of Leutheuser Consulting as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-38: Increase monitoring and modeling of surface water system to improve water management at the watershed level, and retain excess water flow from entering Elephant Butte Reservoir during wet cycles.

2. Summary of the Alternative Analysis

The improvement of hydrologic and predictive modeling, and the supporting monitoring network can lead to more precise management of water stored in a system of reservoirs, which *could* result in water savings. The opportunities for improved water management are not limited to a single reservoir (i.e., Elephant Butte Reservoir), nor limited hydrologic cycles. Furthermore, it would be erroneous to couple improved monitoring and modeling to a reduction of releases of excess flows, or spills, from Elephant Butte Dam.

Please see Exhibit 38A for additional details regarding the analysis for this alternative.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Modeling: New developments and technologies are constantly improving climatologic and hydrologic modeling, providing water managers with better forecasting and routing tools. Some of these advances are being generated in the Upper Rio Grande Basin, while others are simply being tested or applied. The Upper Rio Grande Water Operations Model (URGWOM), a reservoir/river routing model using RiverWare, is scheduled to be operational in 2003, and has served as an effective avenue to bring many of the related modeling improvements into the basin. (See Exhibit 38A for additional discussion of these and other models.)

- *Climatologic forecasting*: Advances are being realized in short- to long-term forecasts and spatially from a global scale down to a local/subregional scale.

- *Inflow modeling*: Snowmelt runoff forecasts are of particular importance to the Upper Rio Grande Basin. Improvements in modeling include the Moderate Resolution Imaging Spectroradiometer (MODIS), which uses satellite imagery to map snow, and more recently, to estimate snow-water equivalency. The Snowmelt Runoff Model developed by the U.S. Department of Agriculture is being developed to integrated numerous advances, while the U.S. Geological Survey's (USGS') Modular Modeling System (MMS) enables both runoff and precipitation forecasts to be made for smaller hydrologic units and incorporates the physical attributes of the watersheds.

- *Outflow modeling*: The Evapotranspiration (ET) Toolbox is being developed by the Bureau of Reclamation in partnership with many others, to estimate and forecast consumptive uses of vegetation, including crops, in conjunction with state-of-the-art mesoscale weather data.

These activities (and many others), pursued by a multitude of public and academic interests, are amazingly well-coordinated and have a synergistic effect on one another.

Monitoring: The essential technology for effective snowpack, streamflow and weather monitoring is in place. Satellite telemetry technology, a relatively recent development, is being applied throughout the Upper Rio Grande Basin system, allowing real-time access to the data. Additional features, such as snow depth sensors, are available and are being integrated into the systems. Doppler technology has been developed for manual stream gaging, and is more efficient and accurate than the standard Price-type® meter. Research to apply this technology to fixed-site stream gage stations is ongoing.

Infrastructure Development Requirements

None for modeling. For monitoring, the installation or upgrading of fixed-site data collection stations is required to improve the monitoring complex in the Upper Rio Grande Basin. Of the 24 snow monitoring stations in the Upper Rio Grande Basin, 13 have yet to be converted to SNOTEL (Snowpack Telemetry). Currently, 51 of the basin's 99 official USGS stream gaging stations are not equipped with telemetry equipment.

Total Time to Implement

Modeling: Incremental improvements in modeling activities are being incorporated continuously. An interagency team began development work on URGWOM in 1997; the accounting model has been in use for several years and the forecast model is completed and now in use. Portions of the water management model are being used, although enhancement and testing of this model continues. The planning model is scheduled to be operational in 2003 and its primary application will be for the Upper Rio Grande Water Operations Review.

Monitoring: The addition or upgrading of monitoring sites is dependent upon funding. Once funding is secured, the upgrades or new site installations generally can be done within a year.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

None.

Effect on Water Supply (surface and groundwater)

None.

Water Saved/Lost (consumption and depletions)

Improvements in monitoring and climatological and hydrologic modeling will not, in and of themselves, result in any additional water savings. Improved tools will allow water managers to make better decisions, especially in the realm of predicting future conditions. However, assuming that water right holders will continue to abide by the principle of as storing as much water as possible for future *use within existing hydrolologic and legal constraints*, improved tools will allow them to be more knowledgeable, thereby reducing the amount of water that passes downstream that they would otherwise have the right to use.

Elephant Butte Reservoir has spilled seven times since the existing complex of upstream reservoirs has been in place, discharging a total of 782,700 acre feet of usable water in excess of demands downstream from Elephant Butte (RGCC, various). Although spills are the cumulative results of years of climatic/hydrologic conditions, presumably more numerous and sophisticated monitoring stations and more sophisticated models could have reduced the volumes spilled by an unknown amount.

Impacts to Water Quality (and mitigations)

None.

Watershed/Geologic Impacts

None.

3.1.2 Environmental Impacts

Impact to Ecosystems

There would be no direct environmental impacts associated with increasing modeling efforts in the Upper Rio Grande Basin. Water management decisions that rely on the expanded or improved models could, however, have environmental impacts. Increasing and improving monitoring, such as the installation of new on-the-ground measurement stations would have insignificant localized effects on ecosystems.

Implications to Endangered Species

Improved monitoring and modeling could be used to improve the timing and releases for aquatic and riparian ecosystems, which could be beneficial for endangered species such as the silvery minnow and willow flycatcher. Conversely, water management decisions could be made which would be detrimental to endangered species.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Modeling: Because of the seamless improvements in the fields of climatologic and hydrologic modeling and the innumerable independent, but related, activities, it is not possible to quantify initial costs to implement improved modeling within the Upper Rio Grande Basin. Over the past five years, the development of URGWOM alone has cost the participating federal agencies approximately $1 million per year.

Monitoring: The conversion of a snow monitoring station to SNOTEL costs between $15,000 and $20,000. The installation of a new USGS stream gaging station costs between $10,000 and $35,000, depending on the site and the need to construct a cable way. Automation of the remaining 13 non-SNOTEL snow monitoring sites and approximately the same number of the remaining 51 stream gages would be desirable.

3.2.2 Potential Funding Source

Modeling: All significant improvements to, and expansion of, hydrologic modeling in the Upper Rio Grande Basin are being made by governmental agencies at various levels, funded by public monies. Involved agencies and entities ultimately rely on taxpayer funding, with the exception of some public-private partnerships that are being developed by agencies such as the Department of Energy.

It is principally federal public agencies that have taken the organizational and financial lead in modeling activities, often with significant support from state and local public agencies. Advancements in modeling would be hastened by increasing the funding earmarked for the sponsoring and contributing agencies. The public can help secure additional funds through the appropriate legislative process, in coordination with the benefiting agencies.

Monitoring: Both the Natural Resources Conservation Service (NRCS), which is the federal agency responsible for the snow monitoring program, and the USGS currently require funding from outside their agencies to upgrade or install monitoring stations. In the past, such funding has come from federal agencies (e.g., U.S. Army Corps of Engineers and Bureau of Reclamation), state agencies (e.g., New Mexico Interstate Stream Commission [ISC]), municipalities, water districts, etc. Improvements in the Middle Rio Grande Conservancy District monitoring network have been made possible largely through funding from the ISC and Bureau of Reclamation. Public and quasi-public agencies at all levels are potential funding sources for expanded monitoring. Expanded NRCS and USGS monitoring budgets would also benefit the programs.

3.2.3 Ongoing Cost for Operation and Maintenance

Modeling: Because of the seamless improvements in the fields of climatologic and hydrologic modeling, it is not possible to quantify costs for operation and maintenance. However, as a point of reference, once URGWOM is fully operational it may cost about $250,000 per year to operate and maintain, including upgrades to the model.

Monitoring: The NRCS absorbs the cost for continued operation and maintenance of SNOTEL sites. The sponsor's annual cost for operation and maintenance of a USGS stream gage is about $12,000.

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Alternative 38

Exhibit A
Detailed Discussion

Technical and Physical Feasibility Fact Sheet
Alternative 38: Surface Modeling

Acknowledgements: This discussion, which follows the same basic format as the fact sheet it accompanies, provides additional details and information that support the conclusions presented in the fact sheet. It was written by Robert Leutheuser of Leutheuser Consulting as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc.

1. Definition of Alternative

Increase monitoring and modeling of surface water system to improve water management at the watershed level, and retain excess water flow from entering Elephant Butte Reservoir during wet cycles.

> "Under the Rio Grande Compact, NM accrues credits for excess water flow and debits for deficits. A spillover (sic) of the Elephant Butte dam wipes out all accumulated debits. Proposal is to improve monitoring of the snow pack so that NM is able to predict how much water to let flow down to Elephant Butte and thereby manage the wet year water excess to NM's best interest."

2. Approach

- Review water management and predictive models that have been, are being developed, or scheduled to be developed, for use in the Upper Rio Grande basin (from the headwaters of the Rio Grande in southern Colorado to Elephant Butte Reservoir) that are pertinent to Middle Valley (Rio Grande Valley between Cochiti Dam and Elephant Butte Reservoir) water management. These could include hydrologic and climatological models. Cost estimates and time lines will be included where possible.

- Interview key water managers to determine what additional monitoring and modeling efforts would result in measurably improved water management. Cost estimates and time lines will be included where possible.

- Summarize historical records to identify and quantify Elephant Butte Reservoir spill events, and describe upstream reservoir conditions contemporary to the spills.

3. Alternative Analysis

Background. The improvement of hydrologic and predictive modeling and the supporting monitoring network can lead to more precise management of water stored in a system of reservoirs, which *could but not necessarily* result in water savings. The opportunities for improved water management are not limited to a single reservoir (i.e., Elephant Butte Reservoir), nor limited hydrologic cycles. Furthermore, it would be erroneous to couple improved monitoring and modeling to a reduction of releases of excess flows, or spills, from Elephant Butte Dam.

Models of hydrologic systems depend on computing capabilities, input data, knowledge of relationships between data, and understanding of the physical conveyance system as well as the institutionalized water operation "rules." For river and reservoir management, the basic components of the hydrologic system are the water inflows (runoff, precipitation, groundwater discharge, transbasin imports), and the outflows (evaporation, evapotranspiration, groundwater recharge, diversions). These constitute the inputs to a reservoir-river routing model that attempts to predict the spatial and temporal effects of the inflows and outflows.

There is a broad interrelated network of organizations actively working on improvements to hydrologic modeling and monitoring that is, and will continue to, directly benefit water management in the Upper Rio Grande Basin. The complexity of the activities sometimes appears to rival the complexity of the physical system being modeled.

Within each major area of consideration, modeling is first addressed followed by a discussion of monitoring.

3.1 Technical Feasibility

Enabling New Technologies and Status

It is beyond the scope of this effort to comprehensively document all of the related modeling activities. It is the author's intent to address the major areas of research, development, and application; and describe some of the more salient efforts.

Collaboration. As a prelude to the discussion, it is important to note that there is a high degree of coordination and integration of efforts and products. This is accomplished through professional and institutional linkages: All federal agencies that are involved in water management have formed modeling and research groups; academic institutions have created centers dedicated to the task. A *sampling* of coordination groups of particular importance to the Middle Rio Grande water planning area is presented in Table 38A-1. Please note that other important coordination groups undoubtedly are active; their omission is not intentional.

Table 38A-1. Sampling of Hydrologic Modeling Coordination Groups

Group/Organization	Home Organization	Website
WaRSMPWatershed & River System Management Program	US Bureau of Reclamation	usbr.gov/rsg/warsmp
National Research Program	U.S. Geological Survey	water.usgs.gov/nrp
SAHRA Sustainability of semi-Arid Hydrology and Riparian Areas	University of Arizona	sahra.arizona.edu
Advanced Hydrologic Prediction Service	National Oceanic & Atmospheric Administration	nws.noaa.gov/oh.ahps
National Water & Climate Center	Natural Resources Conservation Service	wcc.nrcs.usda.gov
CADSWESCenter of Advanced Decision Support for Water and Environmental Systems	University of Colorado	cadswes.colorado.edu
Center for Nonlinear Studies	Department of EnergyLos Alamos National Lab	cnls.lanl.gov
Agricultural Research Services	U.S. Department of Agriculture	nos.ars.usda.gov

The Upper Rio Grande Water Operations Model is of particular importance to the Middle Rio Grande water planning area for the coordination and exploitation of advances made in the field of hydrologic and climatological modeling.

Modeling

Reservoir/River Routing Models. There is a wealth of hydrologic models available to assist water managers in various aspects of water management. In 1996, federal water management agencies determined, with the support from other agencies, the need to improve the modeling tools available for Upper Rio Grande Basin water management, to be called the *URGWOM (Upper Rio Grande Water Operations Model)*.[1] After a thorough review of alternatives, *RiverWare* was chosen as the appropriate model. RiverWare was cooperatively developed by the Bureau of Reclamation, Tennessee Valley Authority, and the University of Colorado's Center of Advanced Decision Support for Water and Environmental Systems (CADSWES). RiverWare is a generalized river basin modeling environment that can address the multitude of management objectives and institutional rules through an object-oriented approach (USBR, 2000).

As outlined in project literature (URGWOM, 2002), the purpose of URGWOM is to facilitate the more efficient and effective management of water in the upper basin. It will be used from the headwaters of the Rio Grande down to Elephant Butte Dam for integrated water operations, and extended to Fort Quitman, Texas for flood operations. It has four modules:

- Water Operations Model, to be used for determining reservoir releases;
- Accounting Model, to account for San Juan-Chama Project water;
- Planning Model, to be used for predictive functions, including supporting the Upper Rio Grande Water Operations Review; and,
- Forecast Model, to develop daily hydrographs throughout the basin.

URGWOM is designed to take advantage of, and is taking advantage of, all improvements in related measurement and modeling activities.

URGWOM's accounting model has been in use for a several years and the forecast model has been completed and is in use. Portions of the water management model are being used in conjunction with existing tools; work continues on its enhancement and testing, and it is scheduled to be fully operational in 2003. The planning model is also scheduled to be operational in 2003, its primary application to be for the Upper Rio Grande Water Operations Review (Yuska, 2002).

There are other contemporary hydrologic modeling activities ongoing in the basin as well, such as Los Alamos National Laboratory's Los Alamos Distributed Hydrologic System (LADHS), an integrated model under development for the Rio Grande Basin (R.Murray, 2001).

Climatological forecasting. Steady advancements are being made in weather forecasting, a critical component of water management. The National Weather Service, National Oceanic and Atmospheric Administration, National Center for Atmospheric Research and National Aeronautics and Space Agency, in cooperation with many others, are improving forecasts on all temporal and spatial scales. Research and development continue to look at the North Atlantic and Pacific oscillations on a global scale (Matthews, 2002), down to the local/subregional scale of how local land surface attributes affect local weather (the Land Data Assimilation System - LDAS) (NASA, 2002). Runoff modelers and water managers are incorporating the improvements as they develop.

Inflow modeling. Improving the predictions of river systems inflow is key element in improving hydrologic models, and an area of focused attention (Leavesly, 2002; Matthews, 2002; Yuska, 2002). Enhanced predictions rely on climatological forecasts as well as runoff forecasts.

In the Upper Rio Grande Basin, *snowmelt* accounts for the majority of the renewable water supply, averaging about 2.5 million acre-feet per year (Wilson, 1999), and for all practical and intent purposes, provides all the storable water for agricultural and other uses (USACE, 1989).

The NRCS and the National Weather Service cooperatively generate *snowmelt runoff forecasts*, based upon the snow measurement sites with information being correlated to historical conditions. Monthly "New Mexico Basin Outlook Reports" are issued January to June for the upper Rio Grande at 19 river stations. As the winter progresses, the forecasts become more accurate. Most water managers use the April 1 forecast as a basis for water management plans. From 1991 through the year 2000, the NRCS forecast of native runoff flows at the Otowi gage was within 10 percent of observed flows 40 percent of the time. They ranged from 47 percent (53,000 acre-feet) over observed flows in year 2000, to 26 percent (80,000 acre-feet) under observed flows in 1994. For Rio Chama inflow to El Vado Reservoir, forecasts for the same period were within 10 percent 5 out of 10 times for the same time period. The high forecast was 78 percent over observed (year 2000); the low, 45 percent under observed (year 1999).[2]

Remote sensing is increasing employed to monitor snow conditions. The National Aeronautics & Space Agency (NASA) initiated *MODIS* (Moderate Resolution Imaging Spectroradiometer) in 1999. MODIS uses satellite imagery to map snow cover at 500-meter or 1-kilometer grids (NASA 2002a), and in cooperation with other agencies such as the National Weather Service, has incorporated the capability to estimate snow-water equivalency in related activities (Matthews, 2002). Likewise the National Oceanic and Atmospheric Administration (NOAA) has initiated the Advanced Hydrologic Prediction Service to provide new forecasting products using a combination of remote sensing, data automation, and models to produce improved probability forecasts (NOAA, 2002)

The U.S. Department of Agriculture's Agricultural Research Services is developing the *Snowmelt Runoff Model*, which integrates many of the contemporary advances in runoff predictions into a user-friendly environment for water managers (USDA, 2002c).

The *Modular Modeling System* (MMS), developed by the USGS' National Research Program Precipitation-Runoff Modeling Project enables users to selectively couple the most appropriate relationships from applicable models to create a uniquely responsive model for specific applications (Leavesly, Date unknown). MMS is a physical attribute-based toolbox that incorporates such variables as elevation, slope, aspect, vegetation cover, and soil moisture for hydrologic response units to refine quantitative, spatial, and temporal runoff forecasts for snowmelt and precipitation events (Leavesly, 2002.; Matthews, 2002). MMS is currently being used in the Yakima, Truckee, and Gunnison river basins with encouraging results. For the Upper Rio Grande Basin, MMS-generated forecasts are being compared to URGWOM forecasts for 1998 and 1999, and the two systems are scheduled to be run concurrently for 2003 runoff (Yuska, 2002).

Outflow modeling. Outflows from a hydrologic system are also important to understand and quantify. Beyond the measured direct diversions from a river or reservoir, there are consumptive use, atmospheric and ground water outflows. Surface-groundwater relationships continue to be studied in the Middle Rio Grande Valley by a multitude of agencies. An area of applied technological advances is the measurement of consumptive use of riparian vegetation, crops, and evaporative losses from the river channel and wetted sands, coupled with mesoscale climatological data.

The Bureau of Reclamation, in partnership with many others, has been developing the *ET (evapotranspiration) Toolbox* over the past 4 years. The goal of the ET Toolbox is to develop a methodology for refining and automatically inputting riparian and crop evapotranspiration, open water evaporation, and rainfall estimates into URGWOM (Brower, et al., 2000). The Toolbox integrates NEXRAD (NEXt Generation RADar) rainfall estimates, weather station data, crop and riparian evapotranspiration requirements, GIS information, and land usage (Brower et al., 2000). Currently, it is based on a 4km X 4km grid cell system, with initial work focusing from Cochiti Dam to San Marcial. Middle Rio Grande Valley water managers now use the ET Toolbox information on a daily basis to assist them in making short-term water delivery decisions. When the ET Toolbox data is coupled with land use inventories and trend analyses, NASA's Land Data Assimilation System, etc., the ET Toolbox will also improve long-term water demand forecasting (Matthews, 2002). ET Toolbox data is being incorporated into URGWOM.

Measurement snow pack. To generate Upper Rio Grande Basin snowmelt runoff the forecasts, Natural Resources Conservation Service maintains a network of 24 high elevation snow monitoring sites, 12 each in Colorado and New Mexico. Nine of the sites in New Mexico are *SNOTEL* (SNOwpack TELemetry) sites, meaning they are fully automated and can transmit real-time data; four in Colorado are SNOTEL sites (USDA, 2002a). Basic SNOTEL sites have a pressure sensing pillow (for snow-water equivalency), storage precipitation gage, and an air temperature gage (USDA, 2002b). Snow depth sensors are being installed at SNOTEL sites (Murray, 2002) The conversion of the "manual course" sites to SNOTEL improves the accuracy of the forecasts, especially on the receding side of the snow pack (Murray, 2002). Existing sites are being converted to SNOTEL as sponsoring agencies fund the installation costs. For example, the New Mexico Interstate Stream Commission is currently funding the conversion of one site within the state per year (Murray, 2002).

River, inflow, and diversion measurements. Runoff can be measured after it enters a defined water course. The location of the stream gages is determined by established importance in estimating river system discharges and/or specific needs to monitor flows for accounting or research purposes. Although many measurements are collected by a variety of interests, it is the U.S. Geological Survey (USGS) that installs and maintains the system of *official stream gaging stations*. The gages generally measure and record the river stage (height of water at a set location), from which corresponding volumes are computed based on periodic field measurements.

Advances have been realized in the real-time communication of stream gage information. However, stream discharges remain computed values which are based upon periodic manual field measurements needed to continually recalibrate the stage-discharge relation curves. There is now the technology that uses *acoustic Doppler technologies* to measure discharges, resulting in more accurate and less time intensive field measurements (USGS, 1997). Commercial Doppler equipment is now on the market (SonTek/YSI, 2002) and the USGS/Albuquerque District anticipates that it will begin using technology for field measurements in the near future (Roark, 2002). Additionally, the USGS funds a program researching new technologies that may replace the current design of the stream gaging station, which has essentially remained unchanged for 100 years (Hirsch et al., 2001).

In the Upper Rio Grande Basin, including southern Colorado the USGS has 99 official stream gages, 51 of which transmit real-time data via satellite telemetry. Fourteen of the stations that do not have telemetry are in the Albuquerque metropolitan area's storm drain system, and most of the other in high elevation small tributaries. In Colorado, the State of Colorado operates most of the gages; in New Mexico, the USGS operates the vast majority; a few being operated by either the Bureau of Reclamation or the USACE.[3] As with the NRCS' SNOTEL sites, the USGS adds sites at the request and expense from other sponsoring interests.

Within the Middle Rio Grande water planning area, the rapidly improved and expanded water measurement system instituted by the Middle Rio Grande Conservancy District (MRGCD), with funding assistance from the New Mexico Interstate Stream Commission and U.S. Bureau of Reclamation, is of great importance. Since 1997 the MRGCD has installed 41 improved gages and flumes that accurately quantify diversions and return flows on key canals, laterals, drains, and wasteways . Eleven more are scheduled for construction in 2003. In addition, the MRGCD has installed nine weather stations throughout its service area. With few exceptions, the entire network is automated, transmitting real-time data to water managers (Gensler, 2002).

Municipal and industrial discharges into water courses are measured in compliance with water quality and/or water rights permit requirements. Groundwater withdrawals are likewise measured and recorded.

Infrastructure Development Requirements

Beyond the intensive analytic work required, improvements in modeling largely depend on improved data. This data can be obtained from satellite imagery, weather balloons, airplanes, ocean temperature stations, etc. In the more immediate sense, improved data for hydrologic modeling is obtained from water measurement, SNOTEL, and local weather stations. An increase in the number and sophistication of all of these is required for more real-time data and corresponding gains in the precision of the hydrologic models.

Total Time to Implement

Incremental improvements to both modeling and monitoring are continually being made and incorporated into water management tools. Therefore, no timetable can be established.

3.1.1 Physical and Hydrologic Impacts

There would be no physical or hydrologic impacts, for example, influences on water supply or demand, that would result from improved hydrologic monitoring and/or modeling. Any influences would be the result of water management decisions being made with improved tools.

The Middle Rio Grande Water Assembly has linked improved modeling within the watershed to "retain excess water from entering Elephant Butte Reservoir during wet cycles." For the purposes of this discussion, the documentation of spills from Elephant Butte Reservoir can serve as a *surrogate indicator* of water that the Middle Rio Grande planning area would like to retain for use within the region. As summarized in Table 38A-2, there have been seven years that Elephant Butte Reservoir has spilled since it began filling (this includes a 1996 "paper spill") in 1916, including four consecutive years in the 1980s (RGCC, various). The "actual spill of usable water," [4] as officially reported by Rio Grande Compact Commission, has ranged from 4,800 acre-feet (1996) to 510,000 acre-feet (1987).[5] Since the existing complex of upstream reservoirs has been in place, there have been seven spill events, discharging a total of 782,700 acre-feet of water in excess of downstream demands.

Table 38A-2: Elephant Butte Spills as Officially Reported by the Rio Grande Compact Commission

Year	1942	1985	1986	1987	1988	1995	1996
Quantity Spilled [a] (acre-feet)	470,100	7,800	47,600	510,400	187,600	24,500	4,800

[a] Values are for "actual spill of usable water." See footnote 4.

At the end of the years preceding the spills, Elephant Butte Reservoir ranged from being essentially full to 80 percent full. El Vado, the largest upstream reservoir permitted to store native Rio Grande water, ranged from about 45 to 70 percent of capacity in the Decembers prior to the spill years (available capacity to store about 100,000 acre-feet and 55,000 acre-feet, respectively.)

3.1.2 Environmental Impacts

There would be no direct environmental impacts associated with increasing modeling efforts in the Upper Rio Grande Basin. Water management decisions that rely on the expanded or improved models could, however, have insignificant-to-significant environmental impacts. Increasing and improving monitoring, such as the installation of new on-the-ground measurement stations would have insignificant localized effects on the environment.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Cost estimates for improving and expanding modeling efforts are unknown because of the seamless investments made in modeling efforts, as well as the plethora of cooperators and related activities that are combined for successful advances in modeling. Based upon the author's personal estimates, the multi-agency costs associated with the specific development of URGWOM may have been in the neighborhood of $1,000,000 per year since the team was assembled in 1997.

For measurement activities, the cost to convert NRCS manual course snow measurement sites to SNOTEL is estimated to be between $15,000 and $20,000 per site (Murray, 2002). It can cost between $10,000 and $35,000, depending on the need to construct a cable way, to install a USGS stream gaging station (Roark, 2002).

3.2.2 Potential Funding Source

All significant improvements to, and expansion of, hydrologic modeling in the Upper Rio Grande Basin are being made by agencies funded by public monies. All agencies and entities ultimately rely on taxpayers funding, with the exception of some public-private partnerships being developed by some agencies such as the Department of Energy.

3.2.3 Ongoing Cost for Operation and Maintenance

All models and monitoring sites require upkeep; the former to assimilate new data and make modifications for new computing capabilities and software; the later for physical operation and maintenance. The annual cost for the operation and maintenance of a USGS stream gage is estimated at $12,000/year (Roark, 2002). The NRCS absorbs the operation and maintenance costs for SNOTEL sites (Murray, 2002). The Middle Rio Grande Conservancy District employs one person full-time to operate and maintain its system of gages and weather stations with as-needed support from other staff. Once URGWOM is fully operational, it may cost about $250,000 a year to maintain and operate it.

4. Conclusions

4.1 Modeling

There are aggressive ongoing efforts to improve hydrologic and climatologic models. The key to the Upper Rio Grande Basin realizing the benefits from these activities is the Upper Rio Grande Water Operations Model, which is integrating the improvements as they occur. URGWOM and the national activities are well coordinated. It is principally federal public agencies that have taken the organizational and financial lead in the modeling activities, often with significant support from state and local public agencies. Advancements in modeling would be hastened by increasing earmarked funding for the sponsoring and contributing agencies. The public can assist securing additional funds through the appropriate legislative process, in coordination with the benefiting agencies.

4.2 Monitoring

As a whole, the monitoring system in place in the Upper Rio Grande Basin has improved over the past 5 years or so, and is adequate. There is, however, room for additional for improvements. The Natural Resources Conservation Service and the U.S. Geological Survey, responsible for the monitoring the snow pack and streams respectively, require partners to finance the upgrades of existing stations, or installation of new stations. The public can petition for financial support from federal, state, and local public agencies. The situation is similar for weather stations installed to support the ET Toolbox.

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[1] Signatories to the Memorandum of Understanding include: U.S. Army Corps of Engineers (USACE), Bureau of Reclamation, US Geologic Survey (USGS), Bureau of Indian Affairs, U.S. Fish & Wildlife Service, International Boundary and Water Commission, Cities of Albuquerque and Santa Fe, Los Alamos and Sandia National Laboratories, and Rio Grande Restoration. A broad range of professionals from many organizations and agencies are actively involved via the Technical Review Committee. URGWOM is permanently staffed by the USACE, Reclamation, and the USGS.

[2] Percent deviations derived from official NRCS data, provided by NRCS (Pagano, 2002).

[3] Data derived from information in USGS Water Resource Data reports (USGS 1998, 2002).

[4] Rio Grande Compact definition of **usable water**: "... all water, exclusive of credit water, which is in project storage and which is available for release in accordance with irrigation demands, including delivery to Mexico. Rio Grande Compact definition of **actual spill**: " ... all water which is actually spilled from Elephant Butte Reservoir, or is released there from for flood control, in excess of the current demand on project storage and which does not become usable water by storage in another reservoir; provided, that actual spill of usable water cannot occur until all credit water shall have been spilled."

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[5] In their 1989 report, the USACE stated that for the 3 spill years of 1986 through 1988, 1,185,000 acre-feet of water spilled from Elephant Butte. The source of their data is unknown.

Technical and Physical Feasibility Fact Sheet
Alternative 39: Desalination

Acknowledgements: This fact sheet was written by Mark Miller of Daniel B. Stephens & Associates, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

Utilize technological advances for treating deep saline and brackish water for potable or non-potable use in the region.

2. Summary of the Alternative Analysis

Desalination can potentially provide a new source of water to the Middle Rio Grande (MRG) planning region (region) by using highly mineralized water that would otherwise have little practical use. 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. The terminology used for classification of water quality based on the total dissolved solids is presented in Todd (1980) (Table 39-1).

Table 39-1. Classification of Saline Groundwater

Classification	Total Dissolved Solids (mg/L)
Fresh water	0 - 1,000
Brackish water	1,000 - 10,000
Saline water	10,000 - 100,000
Brine	>100,000

mg/L = milligrams per liter

Supplies of brackish and saline groundwater in the MRG region have the potential to yield potable fresh water through desalination. A proven technology that has been used for many years, desalination is increasingly common in areas with scarce water supplies. However, because of its relatively high cost, it is generally used only if fresh water supplies are limited.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Desalination is being used increasingly in the U.S. and worldwide, indicating that it is a technically feasible alternative. Approximately 13,600 desalination units in 120 different countries currently produce 26 million cubic meters of fresh water each day (Reuters ENN, 2001). The U.S. has approximately 16 percent of world desalination capacity (Buros, 1999).

Desalination processes require large amounts of thermal or electric energy; however, advances in desalination technology continue to make these processes more efficient. 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. Other alternative renewable energy sources available for desalination are wind-turbines, geothermal, biogas, and landfill gas-to-energy systems. Another approach is the use of dual-purpose plants, where the desalination plant is connected to a conventional electric power generating station and uses the waste heat from that station as an energy source (Buros, 1999; Goosen et al., 2000).

Infrastructure Development Requirements

Two main types of desalination processes are currently in use: (1) membrane methods and (2) thermal methods. Membrane technologies are constantly improving and a larger share of the new desalination plants being constructed, particularly in the U.S., use these technologies. The various types of membrane processes include:

- Reverse osmosis (RO), the most common membrane method, which passes pure water through a semipermeable membrane under pressure, leaving the dissolved salts (minerals) behind in a more concentrated brine solution.

- Nanofiltration membranes, a related technology that also uses membranes to remove salts, although removal is not as complete as with RO.

- Electrodialysis (ED), which uses charged electrodes to cause dissolved ions to pass through semipermeable membranes, leaving behind water of lower salinity.

The most well-known thermal process is distillation, in which saline water is heated to increase its vapor pressure, and subsequent condensation of the resulting water vapor yields fresh water. Thermal processes include (Buros, 1999):

- Multi-stage flash (MSF) distillation, in which water is boiled to produce steam, then passed through a series of low pressure vessels, causing the water to immediately boil.

- Multi-effect distillation (MED), which uses a series of vessels with a variety of designs of misters or water films to enhance the evaporation process.

- Vapor compression (VC) distillation, which uses an electric or diesel powered compressor to condense steam produced by spraying water on a heated surface.

Most existing desalination plants use RO and MSF processes (Ettouney, et al., 2002). Thermal processes are applied most often to water with high salinity; more than half of the world's sea water desalination plants use thermal processes (Buros, 1999). Membrane processes (RO or ED) are generally the preferred technologies for desalination where brackish water containing less than 10,000 parts per million dissolved salts is available. Treatment of brackish water by RO is the most commonly used desalination technology in the U.S. (Buros, 1999). In New Mexico, the preferred treatment would vary depending on the degree of source water salinity, with RO or ED most favorable for brackish water and thermal methods more favorable for highly saline water.

An emerging technology for smaller scale desalination systems is solar humidification. This process uses solar energy to evaporate fresh water, which is condensed on a cool surface and collected. Solar desalination systems are simple and easy to operate and maintain. They are also environmentally friendly because they do not require 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.

Additional infrastructure required for a desalination project includes:

- Production wells in saline or brackish aquifers
- Pipelines from a supply well or well network to the treatment plant and to connect into existing water distribution network(s)
- Brine disposal systems

The specific characteristics of these infrastructure components will depend on the size and location of the desalination project.

Total Time to Implement

The time needed to implement a desalination project is highly variable depending on the nature and scale of the project.

- Small-scale projects involving the installation of commercially available RO equipment or solar humidification could be implemented in 1 to 2 years.
- Large-scale projects involving plant construction, bringing new power supplies on-line and drilling new wells could require 5 to 10 years.

Additional time may be needed to implement large-scale projects that require the investigation of saline aquifers, energy supply development, public involvement, regulatory permitting, or other issues.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

In general, desalination will not affect water demand, except for possible minor reductions related to the relatively high cost for treatment (see fact sheet for A-21, *Urban Water Pricing*).

Effect on Water Supply (surface and ground water)

Sources of brackish and saline groundwater are available within the MRG planning region; however, the ability to develop these sources depends largely on whether pumping the brackish or saline groundwater will affect existing freshwater sources within the central Rio Grande Basin. This analysis focuses on identifying brackish and saline groundwater resources that are sufficiently isolated from the central basin to prevent adverse impacts on fresh water resources.

Pumping brackish or saline groundwater in the MRG region would constitute mining of a finite resource, although there may be sufficient quantities of saline and brackish water to make these depletions acceptable. The New Mexico Office of the State Engineer (OSE) will have authority over pumping of saline and brackish groundwater to prevent any possible impairment of existing water rights.

Potential source waters must be sufficiently disconnected from the MRG surface water and aquifer system to ensure that groundwater pumping will not further deplete the central basin. This means that sources should be located outside the defined boundaries of the Middle Rio Grande Administrative Area (MRGAA). This area was designated by the OSE for compliance with the Rio Grande Compact (NM OSE, 2000) and includes the areal extent of the alluvial aquifer known to be in hydrologic connection with the Rio Grande.

Most of the suitable brackish and saline aquifers that are sufficiently distant from the MRGAA are located in the western part of the MRG region, including portions of Sandoval, Bernalillo, and Valencia Counties. The following contain brackish and saline groundwater:

- Middle Rio Grande Basin; Santa Fe Group aquifer (Bexfield, 2001)
  - Rio Puerco drainage basin
  - Laguna Bench
  - Sierra Ladrones Formation Piedmont
- Glorieta Sandstone (Geoscience Consultants, 1986)
- San Andres Limestone (Geoscience Consultants, 1986)

Water Saved/Lost (consumption and depletions)

Desalination has the potential to make use of water that is currently unappropriated. An application to appropriate brackish or saline water for beneficial use may be filed with the OSE, if it can be shown that other water rights will not be impaired by the new appropriation. Water rights are not required by the OSE for saline groundwater (total dissolved solids [TDS] concentration exceeding 10,000 milligrams per liter [mg/L]) in deep aquifers more than 2,500 feet below ground surface (NMSA 1978, §72-12-25). However, brackish groundwater (TDS of 1,000 to 10,000 mg/L) is subject to the same New Mexico water law that governs the use of fresh water.

Impacts to Water Quality (and mitigations)

The major environmental concern for desalination is the disposal of brine, which is a byproduct of all desalination processes. Brine disposal must be conducted in a manner that protects water quality. Alternatives for disposal of brine include (Winter et al., 2000):

- Deep subsurface injection wells, which require permitting as either Class I wells (non-hazardous industrial wastewater) or Class V wells (other non-hazardous wastewater) under the New Mexico Environment Department's (NMED) Underground Injection Control (UIC) Program.

- Disposal to sanitary sewers, which is permissible if the flow is small enough to not cause a significant salinity change in the total flow to the wastewater treatment plant.

- Lined evaporation ponds, which are a simple approach where sufficient land is available. Depending on the site's hydrogeologic conditions, a groundwater discharge plan will most likely be required from NMED to protect underlying groundwater.

- Crystallization and landfill disposal, which has become increasingly popular due to the high technical and regulatory costs of surface or subsurface brine disposal.

A unique brine management approach used for some desalination projects in Texas is to mix the brine with irrigation water (Burkstaller, 2003). The blend of brine and irrigation water must be of suitable quality and managed to avoid negative effects on crop production or soil salinity.

An additional brine disposal option that may be feasible is discharging brine to one of the permitted and lined solid waste landfills in the region. This approach would use an emerging technology known as a "bioreactor landfill," in which water is added to degrade the solid waste, increasing methane production for a landfill gas-to-energy project. Development of a cogeneration desalination/gas-to-energy project would combine two emerging technologies and would use landfill gas to meet the energy requirements of desalination and groundwater pumping. This approach may prove feasible for the City of Albuquerque Cerro Colorado Landfill, which is currently developing a landfill gas collection system and also has brackish water resources available in the area.

Watershed/Geologic Impacts

A well planned desalination project should not cause any watershed or geologic impacts.

3.1.2 Environmental Impacts

Impact to Ecosystems

Local ecosystems will not be affected, aside from the immediate effects resulting from facility construction. Indirectly, the energy requirements for desalination could have an effect on ecosystems due to the associated power generation impacts, including the use of fossil fuel and air emissions.

Implications to Endangered Species

Desalination will not affect endangered species.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Several considerations influence the cost of desalination per volume of fresh water produced. These include: (1) feed water salinity, (2) energy costs, and (3) economies of scale. Costs rise significantly with increasing salinity of the feed water; the cost of desalting seawater (TDS of 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).

RO plants are generally the preferred choice for desalting brackish water in most small to medium-size communities in the United States. In comparison to other desalination methods, RO plants offer simpler operation, lower energy consumption, and resultant lower fresh water unit costs (Glueckstern, 1999). RO of brackish water using solar energy is potentially the cheapest way to provide new fresh water resources in remote areas (McCarthy and Leigh, 1979; Voivontas et al., 1999).

Costs for desalination processes typically fall in the range of $1.90 to $4.43 per 1,000 gallons of water produced ($620 to $1,440 per ac-ft) (Ettouney, et. al., 2002). Costs reported for sea water desalination plants in Florida and California are in the range of $2.00 to $2.40 per 1,000 gallons (Krishna, 2002). These costs do not typically include pipeline costs of the magnitude that may be required for the MRG planning region, where saline and brackish water sources are located at considerable distance from the areas of water demand. At present, costs for traditional water supplies generally remain lower than the cost of desalination. However, the gap between the two might narrow with (1) reductions in the cost of desalination (e.g., through reduced energy costs or increased energy efficiency) and/or (2) increases in the cost of traditional water sources.

3.2.2 Potential Funding Source

Potential funding sources for desalination projects include:

- New Mexico Legislative appropriation
- New Mexico Finance Authority loan
- NMED Construction Programs Bureau loan
- U.S. Department of Agriculture Rural Utilities Service
- Local financing (revenue bonds)
- Public private partnerships

The U.S. EPA is providing $7 to $21 million to help fund the Hueco Bolson desalination project to serve El Paso, Texas. Funding for this project is also being provided by the U.S. Department of Defense, in return for additional capacity to serve Fort Bliss, an adjacent military installation (Burkstaller, 2003).

3.2.3 Ongoing Cost for Operation and Maintenance

Operation and maintenance (O&M) costs are directly affected by the quality of the feed water (Morin, 1999). In practice, energy costs often represent 50 to 75 percent of operating costs

(Mesa et al., 1996), and energy costs are directly linked to feed water quality. Membrane processes are often more attractive than distillation because they typically have the lowest energy requirements (Sackinger, 1982; Glueckstern, 1999), and rising energy prices tend to increasingly favor RO or ED.

Ongoing costs for brine disposal are a significant component of desalination O&M costs. Disposal of brine in lined evaporation ponds can be relatively inexpensive in arid regions where land is readily available. Brine evaporation ponds in Texas add costs of $0.05 to $0.25 per 1,000 gallons of fresh water (U.S. Congress, 1988). Brine disposal using deep injection wells is often more expensive, and the feasibility of injection wells depends on whether existing geologic conditions can confine the brine. Salt crystallization and solid waste disposal can result in additional costs of $1.15 to $1.85 per 1,000 gallons of fresh water produced (U.S. Congress, 1988).

Cost Evaluation Scenarios

To provide a preliminary cost feasibility analysis for desalination projects in the region, two representative cost evaluation scenarios were developed. These cost scenarios are based on hypothetical small- to large-scale projects that may be used to augment water supplies for communities in the region. The cost evaluation scenarios, which are not intended for use as a complete feasibility analysis, are described below. Table 39-2 summarizes preliminary project cost estimates.

Small-scale project. The cost evaluation scenario for a small-scale desalination project is based on an RO system, which is intended to supplement the water supply available to a small community. The desalination system would add an additional capacity of 100,000 gallons per day (gpd) (112 acre-feet per year [ac-ft/yr]), enough to serve approximately 300 additional households. The small-scale scenario includes costs for the following project components:

- Brackish water supply well: 1,000 feet deep drilled into an aquifer containing water with a TDS concentration of 5,000 mg/L

Table 39-2. Preliminary Cost Projection
Cost Evaluation Scenarios for Desalination Projects
Mid-Region Council of Governments

Item No.	Item Description	Unit	Unit Cost	Quantity	Cost
	Small Scale Project (100,000 gpd)				
1.0	Supply well	lump sum	$ 200,000.00	1	$ 200,000
2.0	RO treatment plant	lump sum	$ 350,000.00	1	$ 350,000
3.0	Evaporation ponds	acre	$ 50,000.00	5	$ 250,000
4.0	Land purchase	acre	$ 5,000.00	40	$ 200,000
5.0	Design and permitting	lump sum	$ 80,000.00	1	$ 80,000
6.0	Operation and maintenance	annual	$ 270,000.00	40	$ 10,800,000
				Subtotal	*$ 11,880,000*
				Contingency @ 20%	*2,376,000*
				Grand Total	**$ 14,256,000**
		Annual water produced (acre-feet)			**112**
		Water cost per 1000 gallons			**$9.76**
	Large Scale Project (20,000,000 gpd)				
1.0	Supply wells	each	$ 1,500,000.00	30	$ 45,000,000
2.0	RO treatment plant	lump sum	$ 89,000,000.00	1	$ 89,000,000
3.0	Evaporation ponds	acre	$ 50,000.00	320	$ 16,000,000
4.0	Pipeline	mile	$ 1,150,000.00	30	$ 34,500,000
5.0	Land purchase	acre	$ 5,000.00	640	$ 3,200,000
6.0	Design and permitting	lump sum	$ 18,450,000.00	1	$ 18,450,000
7.0	Operation and maintenance	annual	$ 19,000,000.00	40	$ 760,000,000
				Subtotal	*$ 966,150,000*
				Contingency @ 20%	*193,230,000*
				Grand Total	**$ 1,159,380,000**
		Annual water produced (acre-feet)			**22,400**
		Water cost per 1000 gallons			**$3.98**

Notes: Costs are preliminary estimates for planning purposes only. Because the estimates are preliminary, the Water Assembly requested that costs for each alternative be compared based on 2003 dollars with no present worth adjustment.

- Commercially available RO treatment plant, along with ancillary facilities (building, roadways, electric connections, system controls, chlorination facilities, storage tank, connection to existing supply system, etc.)

- Evaporation ponds covering 5 acres, lined with high-density polyethylene (HDPE) for brine disposal

- Purchase of a 40-acre tract of land

- Engineering design and permitting

- Operation and maintenance costs for electric power (for plant operation and pumping of groundwater and treated water), labor, parts, chemicals, equipment, and other expenses.

Large-scale project. The cost evaluation scenario for a large-scale desalination project considers a major infrastructure project, assumed to provide 20 million gpd of treated water to the region's urban corridor. This water supply rate is equivalent to 22,400 ac-ft/yr or approximately 20 percent of the City of Albuquerque's total annual water use of 120,000 ac-ft/yr. The treated water would go to urban rather than agriculture uses because of the relatively high cost of the water supply. The large-scale scenario considers costs for the following project components:

- Wellfield consisting of 30 supply wells drilled into a saline aquifer to a depth of 3,000 feet, producing water with a TDS concentration of 25,000 mg/L at a rate of 500 gallons per minute.

- RO treatment plant constructed using a series of commercially available RO units, with all ancillary facilities (building, roadways, system controls, chlorination facilities, storage tanks, power supply to the plant and wells, etc.)

- Evaporation ponds covering 320 acres, lined with HDPE for brine disposal, with evaporation rates enhanced by a misting sprayer system.

- Conveyance pipeline, 30 miles long with two pump stations constructed from the western part of the region to the central region urban corridor
- Purchase of a 640-acre tract of land and lease agreements for the wellfield and pipelines
- Engineering design and permitting
- Operation and maintenance costs for electric power (for plant operation and pumping of groundwater and treated water), labor, parts, chemicals, equipment, and other expenses.

Cost Summary

The cost evaluation scenarios are summarized in Table 39-2. This preliminary cost evaluation for desalination projects provides an initial estimate of representative costs. Initial estimates range from $9.76 per 1,000 gallons ($3,180 per ac-ft) for a small-scale project to $3.98 per 1,000 gallons ($1,300 per ac-ft) for a large-scale project. These costs are relatively high as compared to reported costs for sea water desalination because the latter does not include the added costs for well installations, groundwater pumping, evaporation ponds, and pipelines. Desalination costs are much higher than current water prices; augmenting existing water supplies with desalinated water would be costly.

The cost estimates are intended only for the purpose of a preliminary evaluation of the desalination option as compared to other water supply alternatives considered. Therefore, the cost estimates for each alternative are for 2003 costs, and adjustments for present worth have not been considered. Much additional study is needed to develop desalination plans more fully before a complete feasibility analysis can be made for specific projects.

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Alternative 39

Exhibit A
Detailed Discussion

Exhibit 39A: Detailed Discussion of Alternative 39—Desalination

Acknowledgements: This discussion, which follows the same basic format as the fact sheet it accompanies, provides additional details and information that support the conclusions presented in the fact sheet. It was written by Mark Miller of Daniel B. Stephens & Associates, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc.

1. Definition of Alternative

Utilize technological advances for treating deep saline and brackish water for potable or non-potable use in the region.

2. Summary of the Alternative Analysis

Desalination of brackish or saline water can potentially provide a new source of water to the Middle Rio Grande (MRG) planning region (region) by using highly mineralized water that would otherwise have little practical use. Supplies of brackish and saline groundwater within the MRG region have the potential used to yield potable fresh water through desalination.

The terminology used for classification of water quality based on the total dissolved solids is presented in Todd (1980).

Table 1. Classification of Saline Groundwater

Classification	Total Dissolved Solids (mg/L)
Fresh water	0 - 1,000
Brackish water	1,000 - 10,000
Saline water	10,000 - 100,000
Brine	>100,000

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 limited. Desalination is further complicated by issues of environmentally acceptable disposal of reject brines, especially in inland areas. Desalination is proven technology that has been used for many years, and is increasingly common, in areas with scarce water supplies.

The analysis of the desalination feasibility for the region included the following:

- Determination of potential water sources of brackish and saline water that currently are not used for water supply.

- Consideration of how to protect the water quality of fresh water sources from potential degradation due to pumping saline groundwater or brine disposal.

- An examination of successes and lessons learned from existing desalination projects and plans for similar projects in the western U.S.

- An analysis of how desalination technologies could be applied to variously size communities in the MRG planning region. This included preliminary scenarios for:

  - Small-scale reverse osmosis (RO) units to serve individual users and small, particularly rural, communities
  - Large-scale municipal systems

- Energy requirements for desalination plants, including variable energy costs associated with increasing source water salinity.

- A preliminary cost assessment using cost data from comparable projects. Costs were derived from:

  - Published costs for comparable desalination projects
  - City of Albuquerque standard construction cost data

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Desalination Processes

Desalination is being increasingly used in the U.S. and world-wide, indicating that it is a technically feasible alternative. 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 U.S. has approximately 16 percent of world desalination capacity (Burros, 1999).

Energy Requirements

Desalination processes require large amounts of thermal or electric energy, as the process to separate pure water from a saline solution is energy-intensive. For seawater (total dissolved solids of 35,000 milligrams per liter [mg/L]), this minimum energy needed for this process 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 desalination processes, the actual energy requirements for desalination systems are substantially higher than this theoretical minimum value. Advances in desalination technology continue to improve energy efficiency.

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. Other alternative, renewable energy sources available for desalination are wind-turbines, geothermal, biogas, and landfill gas-to-energy systems. The International Desalination Association has inventoried 100 small-scale, alternative energy source desalination systems in 25 countries around the world (Buros, 1999). Dual-purpose plants, where the desalination plant is connected to a conventional electric power generating station, can use the waste heat from the station as an energy source (Buros, 1999; Goosen et al., 2000).

Infrastructure Development Requirements

Two main types of desalination processes are currently in use: (1) membrane methods and (2) thermal methods. Membrane technologies are improving and membrane processes are gaining a larger share or the new desalination plants being constructed, particularly in the U.S. An early thermal desalination plant using vacuum distillation was constructed and operated in Roswell, New Mexico, during the early 1960s, under a U.S. Department of Interior funded pilot project.

Membrane processes consist of various types, with the most effective membrane selected depending primarily on the level of source water salinity and the potential for supersaturation and precipitation of silica, carbonates, or other less soluble constituents in the reject brine.

- The most common membrane process is reverse osmosis (RO), in which pure water passes through a semipermeable membrane under pressure, leaving the dissolved salts (minerals) behind in a more concentrated brine solution.

- A related technology, nanofiltration membranes, also has a demonstrated ability to remove salts, though not as completely as RO.

- Electrodialysis (ED) uses charged electrodes to cause dissolved ions to pass through semipermeable membranes, leaving behind water of lower salinity.

The most well-known thermal process is distillation, in which saline water is heated to increase its vapor pressure, and subsequent condensation of the resulting water vapor yields fresh water. Thermal processes are applied most often to water with high salinity; more than half of the world's sea water desalination takes uses thermal processes (Buros, 1999). Thermal processes include (Buros, 1999):

- Multi-stage flash (MSF) distillation, in which water is initially boiled to produce steam, then passed through a series of vessels, each with a lower pressure and correspondingly lower boiling point, causing the water to immediately boil as it passes into each vessel.

- Multi-effect distillation (MED), which also uses a series of vessels with successively lower pressures to produce steam. The MED process uses a variety of designs of misters or water films to enhance the evaporation process.

- Vapor compression (VC) distillation uses an electric or diesel powered compressor to condense steam produced by spraying water on a heated surface. VC systems are reliable to operate and have been used most commonly for small-scale applications such as industries and resorts.

Most existing desalination plants use RO and MSF processes (Ettouney, et al., 2002). Membrane processes (RO or ED) are generally the preferred technologies for desalination where brackish water containing less than 10,000 parts per million (ppm) dissolved salts is available. ED tends to be more economical at salinities less than about 3,000 ppm, whereas RO may be more appropriate at salinities between 5,000 and 10,000 ppm (U.S. Congress, 1988). The decision between ED and RO is also influence by the individual water chemistry and potential for precipitation in highly concentrated RO reject streams and the possible need for the positive contaminant barrier provided by RO. Treatment of brackish water by RO is the most commonly used desalination technology in the U.S. (Buros, 1999). In New Mexico, the preferred treatment would vary depending on the degree of source water salinity, with RO or ED most favorable for brackish water and thermal methods more favorable for highly saline water.

An emerging technology for smaller scale desalination systems is solar humidification. This process uses a solar "still" that consists of a clear glass or plastic roof covering a pool of saline water, thereby using natural solar energy to evaporate fresh water, which is condensed on a cool surface and collected. Solar desalination requires large land areas for the amount of water produced. For a large-scale 1-million gallons per day (gpd) plant, approximately 250 acres of land is required (Buros, 1999). In locations with abundant sunshine, such as New Mexico, solar desalination is a potentially viable option, especially for small-scale plants in remote locations. Solar desalination systems are simple and easy to operate and maintain. They are also environmentally friendly because they do not require fossil fuels (Voivontas et al., 1999; Chaibi, 2000).

Additional infrastructure required for a desalination project includes:

- Production wells in saline or brackish aquifers
- Pipelines from a supply well or well network to the treatment plant and to connect into existing water distribution network(s)
- Brine disposal systems (discussed in “Impacts to Water Quality,” below)

The specific characteristics of these infrastructure components will depend on the size and location of the desalination project. Two potential project scenarios are described below in Section 3.2, Financial Feasibility.

Total Time to Implement

The time needed to implement a desalination project is highly variable depending on the nature and scale of the project.

- Small-scale projects involving the installation of commercially available RO equipment or solar humidification could be implemented in 1 to 2 years.
- Large-scale projects involving plant construction, bringing new power supplies on-line, and drilling new wells could require 5 to 10 years.

Additional time may be needed to implement large-scale projects that require the investigation of saline aquifers, energy supply development, public involvement, regulatory permitting, or other issues.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

In general, desalination will not affect water demand, except for possible minor reductions related to the relatively high cost for treatment.

Effect on Water Supply (surface and ground water)
Sources of brackish and saline groundwater are available within the MRG planning region, and desalination can provide for use of this new water source that is currently unused. The ability to develop these sources depends largely on whether pumping the brackish or saline groundwater will affect existing freshwater sources within the central Rio Grande Basin. Withdrawal of groundwater from Santa Fe Group sediments within the basin may ultimately lead to increased water level declines in the basin-fill aquifer and contribute to reduced flows in the Rio Grande. Therefore, this analysis focuses on identifying brackish and saline groundwater resources that are sufficiently isolated from the central basin to effectively provide new water sources that are currently unused.

The occurrence of saline and brackish groundwater generally indicates that these waters are not receiving significant recharge and salt concentrations have increased over a long period of time. Pumping this water for desalination will constitute mining of this finite resource, although sufficient quantities of saline and brackish water may be available such that the depletions are considered acceptable. Most importantly, the New Mexico Office of the State Engineer (OSE) will have authority over pumping of saline and brackish groundwater to prevent impairment of existing users of fresh water supplies that may be in connection with the groundwater pumped for desalination.

Pumping of brackish or saline groundwater has the potential to alter conditions in an aquifer in a manner that could lead to adverse impacts on fresh water resources. Brackish and saline groundwater exists in the lower Santa Fe Group sediments of the Middle Rio Grande Basin, below approximately 3,000 feet below ground surface (U.S. Department of the Interior, 1970). Pumping this deep groundwater within the basin could draw shallow groundwater of good quality into deeper portions of the aquifer, adversely impacting the fresh water quality and contributing to water level declines in the upper fresh water aquifer.

Potential source waters must be sufficiently disconnected from the Middle Rio Grande surface water and aquifer system so that groundwater pumping will not deplete the central basin. Favorable source waters are located outside the Middle Rio Grande Administrative Area (MRGAA), which was designated by the OSE for compliance with the Rio Grande Compact (OSE, 2000). The defined boundaries of the MRGAA include the areal extent of the alluvial aquifer known to be in hydrologic connection with the Rio Grande in the Middle Rio Grande Basin.

Most of the suitable brackish and saline aquifers that are sufficiently disconnected from the MRGAA are located in the western part of the MRG region, including portions of Sandoval, Bernalillo, and Valencia Counties. The following contain brackish and saline groundwater:

- Middle Rio Grande Basin; Santa Fe Group aquifer (Bexfield, 2001)
  - Rio Puerco drainage basin
  - Laguna Bench
  - Sierra Ladrones Formation Piedmont
- Glorieta Sandstone (Geoscience Consultants, 1986)
- San Andres Limestone (Geoscience Consultants, 1986)

This analysis focuses on the feasibility of desalination within the MRG planning region. Importation of water from saline or brackish aquifers outside the region could also be considered; with costs escalating as water conveyance distances increase.

Water Saved/Lost (consumption and depletions)

Desalination has the potential to produce new water supplies by making use of water that is currently unappropriated to other water rights holders. Brackish and saline groundwater resources may exist that are currently unappropriated, and an application to appropriate this water for beneficial use may be filed with the OSE, if it can be shown that other water rights will not be impaired by the new appropriation. Development of new water sources should be performed in a manner that will not impair existing groundwater users or reduce flow in the Rio Grande.

Water rights are not required by the OSE for saline groundwater (total dissolved solids [TDS] concentration exceeding 10,000 mg/L) in deep aquifers more than 2,500 feet below ground surface (NMSA 1978, §72-12-25). However, brackish groundwater (TDS of 1,000 to 10,000 mg/L) is subject to the same New Mexico water law that governs the use of fresh water. The

Glorieta Sandstone and San Andres Limestone are important aquifers in some parts of New Mexico, but within the MRG planning region they contain saline groundwater. The deep, saline portions of the Glorieta Sandstone and San Andres Limestone exceed 2,500 feet below ground surface; however, portions of these formations further west are at shallower depths, where they are used for water supply. The OSE requirements will need to be explored to develop brackish or saline groundwater.

Impacts to Water Quality (and mitigations)

The major environmental concern for desalination is the disposal of brine, which is a byproduct of all desalination processes. Brine disposal must be conducted in a manner that protects water quality. Alternatives for disposal of brine include (1) deep subsurface injection, (2) discharge to sanitary sewer, (3) disposal of brine in evaporation ponds, and (4) evaporation, crystallization, and disposal of solid salt in a solid waste landfill (Winter et al., 2000).

- Deep subsurface injection wells require permitting as either Class I (non-hazardous industrial wastewater) or Class V (other non-hazardous wastewater) wells under the New Mexico Environment Department's (NMED) Underground Injection Control (UIC) Program. Obtaining permits for such wells is a cost consideration and would require a hydrogeologic study to ensure that the proposed injection well(s) would not impact freshwater aquifers.

- Brine disposal to sanitary sewers is permissible if flow is small enough to not cause a significant salinity change in the 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.

- Lined evaporation ponds are a relatively simple approach to brine disposal where sufficient land is available. Depending on the site's hydrogeologic conditions, a groundwater discharge plan will most likely be required from NMED to address protection of underlying groundwater from potential brine seepage.

- 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.

A unique brine management approach used for some desalination projects in Texas is to mix the brine with irrigation water (Burkstaller, 2003). To be successful, the blend of brine and irrigation water must be of suitable quality and irrigation managed to avoid negative effects on crop production or soil salinity.

An additional brine disposal option that may be feasible is discharging brine to one of the permitted and lined solid waste landfills in the region. This approach would use an emerging technology known as a "bioreactor landfill," in which water is added to degrade the solid waste, increasing methane production for a landfill gas-to-energy project. Development of a cogeneration desalination/gas-to-energy project would combine two emerging technologies and would use landfill gas to meet the energy requirements of desalination and groundwater pumping. This approach may prove feasible for the City of Albuquerque Cerro Colorado Landfill, which is currently developing a landfill gas collection system and also has brackish water resources available in the area.

Watershed/Geologic Impacts

A well planned desalination project should not cause any watershed or geologic impacts.

3.1.2 Environmental Impacts

Impact to Ecosystems

Local ecosystems will not be affected, aside from the immediate effects resulting from facility construction. Indirectly, the energy requirements for desalination could have an effect on ecosystems due to the associated power generation impacts, including the use of fossil fuel and air emissions.

Implications to Endangered Species

Desalination will not affect endangered species.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Several considerations influence the cost of desalination per volume of fresh water produced, including: (1) feed water salinity, (2) energy costs, and (3) economies of scale. 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.

Costs rise significantly with increasing salinity of the feed water; the cost of desalting seawater (TDS of 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). It is advantageous to make use of the freshest feed water available; with brackish water aquifers providing lower cost treatment than saline water sources.

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 scale are evident in all desalination processes, but to different extents. RO exhibits the smallest economies due to scale, and RO facilities for small communities, such as the mid-size RO project implemented in Grand Junction, Colorado, can be cost-effective. Distillation processes show the greatest economies of size, as is seen in the large-scale desalination/power generation dual-use projects in the Middle East.

RO plants are generally the preferred choice for desalting brackish water in most small to medium-size communities in the U.S. RO plants offer simpler operation, lower energy consumption, and resultant lower fresh water unit costs as compared with other desalination methods (Glueckstern, 1999). The overall cost of fresh water from an RO 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 provide improved cost and efficiency, membrane technologies will continue to be the preferred choice for new desalination plants.

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.

Costs for desalination processes typically fall in the range of $1.90 to $4.43 per 1,000 gallons of water produced ($620 to $1,440 per ac-ft) (Ettouney, et. al., 2002). Costs reported for sea water desalination plants in Florida and California are in the range of $2.00 to $2.40 per 1,000 gallons (Krishna, 2002). These costs do not typically include pipeline costs of the magnitude that may be required for the MRG planning region, where saline and brackish water sources are located at considerable distance from the areas of water demand.

At present, costs for traditional water supplies generally remain lower than the cost of desalination. However, the gap between the two might narrow with (1) reductions in the cost of desalination (e.g., through reduced energy costs or increased energy efficiency) and/or (2) increases in the cost of traditional water sources.

3.2.2 Potential Funding Source

Potential funding sources for desalination projects include:

- New Mexico Legislative appropriation
- New Mexico Finance Authority loan
- NMED Construction Programs Bureau loan
- U.S. Department of Agriculture Rural Utilities Service
- Local financing (revenue bonds)
- Public private partnerships

The U.S. EPA is providing $7 to $21 million to help fund the Hueco Bolson desalination project to serve El Paso, Texas. Funding for this project is also being provided by the U.S. Department of Defense, in return for additional capacity to serve Fort Bliss, an adjacent military installation (Burkstaller, 2003).

3.2.3 Ongoing Cost for Operation and Maintenance

Operation and maintenance (O&M) costs are directly affected by the quality of the feed water (Morin, 1999). In practice, energy costs often represent 50 to 75 percent of operating costs (Mesa et al., 1996), and energy costs are directly linked to feed water quality. Membrane processes are often more attractive than distillation because they typically have the lowest energy requirements (Sackinger, 1982; Glueckstern, 1999), and rising energy prices tend to increasingly favor RO or ED.

Ongoing costs for brine disposal are a significant component of desalination O&M costs. Disposal of brine in lined evaporation ponds can be relatively inexpensive in arid regions where land is readily available. Brine evaporation ponds in Texas add costs of $0.05 to $0.25 per 1,000 gallons of fresh water (U.S. Congress, 1988). Brine disposal using deep injection wells is often more expensive, and the feasibility of injection wells depends on whether existing geologic conditions can confine the brine. Salt crystallization and solid waste disposal can result in additional costs of $1.15 to $1.85 per 1,000 gallons of fresh water produced (U.S. Congress, 1988). Brine disposal using deep injection wells is often more expensive, and the feasibility of injection wells is highly dependent on the geologic conditions at the site providing confinement of the injected brine. Drilling and maintenance of deep injection wells is costly, if very deep wells are needed at a site, and regulatory costs associated with permitting injection wells is a further consideration. Salt crystallization and solid waste disposal can result in additional costs of $1.15 to $1.85 per 1,000 gallons of fresh water produced (U.S. Congress, 1988).

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.

3.2.4 Cost Evaluation Scenarios

To provide a preliminary cost feasibility analysis for desalination projects in the region, two representative cost evaluation scenarios were developed. These cost scenarios are based on hypothetical small- to large-scale projects that may be used to augment water supplies for communities in the region. The cost evaluation scenarios are intended to provide a preliminary examination of the expected costs for water production through desalination. However, the cost evaluation completed for this analysis does not represent an analysis of actual project plans and is not intended as a complete feasibility analysis.

Small-Scale Project

The cost evaluation scenario for a small-scale desalination project is based on an RO system that is intended to supplement the water supply available to a small community. The community is assumed to be experiencing growth and additional connections are needed to the community operated water system. The desalination system would add an additional capacity of 100,000 gpd (112 acre-feet per year [ac-ft/yr]), enough to serve approximately 300 additional households.

The small-scale scenario includes costs for the following project components:

- *Supply Well:* A brackish water supply well assumed to be 1,000 feet deep would be drilled into an aquifer containing water with a TDS concentration of 5,000 mg/L. It is assumed that this aquifer is present locally, but is not being used because of the poor water quality.

- *RO Treatment Plant:* A commercially available RO treatment plant would be purchased and set up, with all ancillary facilities constructed (building, roadways, electric connections, system controls, chlorination facilities, storage tank, connection to existing supply system, etc.).

- *Evaporation Ponds:* Evaporation ponds would be constructed for brine disposal. The ponds are assumed to be 5 acres in size and lined with high-density polyethylene (HDPE).

- *Land Purchase:* A 40-acre tract of land for the treatment plant would be purchased on the outskirts of the local community for a cost assumed to be $5,000 per acre.

- *Design and Permitting:* The engineering design for the RO plant is assumed to be 10 percent of construction cost and permitting is assumed to be 5 percent of construction cost.

- *Operation and Maintenance:* A 40-year operating life for the desalination plant is assumed for O&M of the facility. O&M costs would include: electric power for plant operation and groundwater pumping, as well as labor, parts, chemicals, equipment, and other expenses.

Large-Scale Project

The cost evaluation scenario for a large-scale desalination project considers a major infrastructure project, assumed to provide 20 million gpd of treated water to the region's urban corridor. This water supply rate is equivalent to 22,400 acre-feet per year (ac-ft/yr) or approximately 20 percent of the City of Albuquerque's total annual water use of 120,000 ac-ft/yr.

The treated water would go to urban uses rather than agriculture, because of the relatively high cost of the new water supply.

The large- scale scenario considers costs for the following project components:

- *Supply Wells:* A well field assumed to consist of 30 supply wells would be drilled into a saline aquifer to a depth of 3,000 feet. The well field would be located in the western part of the region, with wells penetrating the Glorieta Sandstone and San Andres Limestone, at depths below 2,500 feet, producing water with a TDS concentration of 25,000 mg/L. Wells are assumed to be capable of producing in excess of 500 gallons per minute.

- *RO Treatment Plant*: An RO treatment plant would be designed and constructed, using a series of commercially available RO treatment units. Construction would include all ancillary facilities such as a building, roadways, system controls, chlorination facilities, storage tanks, etc. A new electric power supply line would be needed to serve the plant, and a power network would be needed to all of the wells.

- *Evaporation Ponds:* Evaporation ponds would be constructed for brine disposal. The ponds are assumed to be 320 acres in size and lined with high-density polyethylene (HDPE). Evaporation rates are assumed to be tripled by using a misting sprayer system.

- *Pipeline:* A conveyance pipeline would be constructed from the western part of the region to the central region urban corridor. The pipeline is assumed to be 30 miles long and constructed of 36-inch diameter pipe with two pump stations.

- *Land Purchase*: A 640 acre tract of land would be purchased for the treatment plant site and evaporation ponds, and lease agreements are assumed to be established for the well field and pipelines. Water could be made available to local land owners as an incentive to promote economic development in the area.

- *Design and Permitting:* The engineering design for the RO plant is assumed to be 5 percent of construction cost and permitting is assumed to be 5 percent of construction cost.

- *Operation and Maintenance*: A 40-year operating life is assumed for O&M of the desalination facility. O&M costs would include electric power for plant operation and pumping of groundwater and treated water as well as labor, parts, chemicals, equipment, and other expenses.

3.2.5 Cost Summary

The cost evaluation scenarios are summarized in Table 39-2. This preliminary evaluation of the costs for desalination projects provides an initial estimate of the range of costs that may be expected. The cost estimates are preliminary and intended for planning purposes only; therefore, the cost estimates for each alternative are based on 2003 costs for comparison, and adjustments for present worth have not been considered.

The preliminary cost evaluation for desalination projects provides costs in the range of $9.76 per 1,000 gallons ($3,180 per ac-ft) for a small-scale project to $3.98 per 1,000 galllons ($1,300 per ac-ft) for a large-scale project. These costs are relatively high as compared to reported costs for sea water desalination because the latter does not include the added costs for well installations, groundwater pumping, evaporation ponds, and pipelines. Desalination costs are much higher than current water prices; augmenting existing water supplies with desalinated water would be costly.

The cost estimates are intended only for the purpose of a preliminary evaluation of the desalination option as compared to other water supply alternatives considered. Therefore, the cost estimates for each alternative are for 2003 costs, and adjustments for present worth have not been considered. Much additional study is needed to develop desalination plans more fully before a complete feasibility analysis can be made for specific projects.

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Technical and Physical Feasibility Fact Sheet
Alternative 45: Reservoir Management

Acknowledgements: This fact sheet was written by Robert Leutheuser of Leutheuser Consulting as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-45: Reduce open water evaporation in storage reservoirs by retaining water at higher elevations or latitudes, or by reducing surface areas.

45A—Move stored water to reservoirs at higher elevations / more northern latitudes:

i. Move water to an *existing storage space*
ii. Move water to *currently unauthorized storage space in an existing reservoir*
iii. Move water to a *new reservoir*

45B—Reduce reservoir surface area for a given volume of water by dredging

45C—Apply surfactant to Elephant Butte Reservoir water surface to reduce evaporation

2. Summary of Alternative Analysis

2.1 Alternative 45A: Move Stored Water to Higher/More Northern Reservoirs

The principal of reducing reservoir losses to evaporation by storing water at higher elevations and/or more northern latitudes is sound. In addition to the locations having lower average annual temperatures, the topography of the landscapes in which the reservoirs are or would be located *generally* tend to provide for a higher volume-to-surface area ratio, which would also contribute to reductions in evaporation per unit of water stored.

2.2 Alternative 45B: Reduce Reservoir Surface/Volume Ratio by Dredging

It is economically infeasible to use dredging as a reservoir management tool to reduce evaporative losses on the large reservoirs that effect middle Rio Grande water management. However, where sediment deposition negatively interferes with a reservoir's mainstem delivery of water due to the formation of deltas, such as at the upper end of Elephant Butte Reservoir, dredging is a viable alternative to improve the efficiency of water delivery to the reservoir

2.3 Alternative 45C: Apply Surfactant to Elephant Butte to Reduce Evaporation

Surfactants that would be effective in reducing evaporative losses from large reservoirs are still in the research stage. It is unknown whether or not such a product will ever be developed. However, because of the potential water savings benefits and potential cost effectiveness, research should be continued in this area. Funding is a limitation, so the supporting public should, in coordination with universities and other research organizations such as Sandia National Laboratories, petition legislators for federal and stated efforts by increasing funding for continued research in this area.

Details and further discussion of these alternatives are provided in Exhibit 45A.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

45A (Move water). None required.

45B (Dredge). Available technology is not a limiting factor. Equipment is constantly being modernized for widespread dredging applications for river and harbor maintenance, offshore drilling, construction, etc. Conventional equipment such as draglines and amphibious excavators are still used, as well as hydraulic pumps, robotic dredges, and bucket dredges. "Silt curtain" technology has also been developed to contain silts mobilized during dredging operations.

45C (Apply surfactant). A chemical film that creates a molecular monolayer when applied to a water surface to reduce evaporative losses has been developed for small impoundments. In an experimental setting, this commercial product has reduced evaporation on a 7.5-acre pond by 25 to 40 percent. No product is currently available that would be effective on a large reservoir. Sandia National Laboratories has conducted laboratory experiments on two surfactant formulae with encouraging results.

Infrastructure Development Requirements

45A.i (Move to existing storage space). None.

45.A.ii (Move to currently unauthorized storage space in existing reservoirs). Relocation of reservoir-associated facilities; possible relocation of road and private residences.

45.A.iii (Move to new reservoirs). Construction of new dam, reservoir, and appurtenant structures.

45B (Dredge). Any large-scale dredging operation would require the construction of large staging areas for heavy equipment storage, maintenance and repair, fueling, and mobilization, as well as for contractor offices. Fuel storage and dispensing facilities would also be required, as would power lines to service the entire area.

45C (Apply surfactant). None.

Total Time to Implement

45A.i (Move to existing storage space). Total time could be five years to several decades. Institutional critical pathway for Abiquiu Reservoir includes Rio Grande Compact and State of New Mexico storage permits. Same considerations for Cochiti Lake, but add federal legislation and government-to-government negotiations with Cochiti. Pueblo

45A.ii (Move to currently unauthorized storage space in existing reservoirs). Could take ten years to several decades. Same considerations as above, plus need for federal legislation for Abiquiu Reservoir and obtaining flood easements.

45A.iii (Move to new reservoirs). This alternative could take many decades.

45B (Dredge). Using 20 cubic-yard-capacity trucks, it would take about 45 years to haul 50,000 acre-feet (ac-ft) of material, running 10 trucks/hour, 24 hours/day, 365 days/year.

45C (Apply surfactant). It is not possible to predict whether or not a surfactant that would be effective on large reservoirs can be developed, much less how long it would take to develop such a product.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

None.

Effect on Water Supply

Increased water supply.

Water Saved/Lost

45A.i (Move to existing storage space). Ranges from a low of about 3,000 ac-ft/yr (moving 50,000 ac-ft to El Vado Reservoir from a more-full Elephant Butte), to a high of 6,200 ac-ft/yr (moving 100,000 ac-ft to Abiquiu Reservoir from a less-full Elephant Butte).

45A.ii (Move to currently unauthorized storage space in existing reservoirs). Ranges from a low of 750 ac-ft/yr (adding 50,000 ac-ft to Cochiti Lake from a more-full Elephant Butte), to a high of 7,300 ac-ft/yr (moving 100,000 ac-ft to Abiquiu Reservoir from a less-full Elephant Butte).

45A.iii (Move to new reservoirs). Moving 100,000 ac-ft to the not-yet-built Wagon Wheel Gap Reservoir could save 11,700 ac-ft/yr.

45B (Dredge). Dredging of 50,000 ac-ft of material from a 150,000 ac-ft Abiquiu Reservoir pool would result in an average annual savings of 1,600 ac-ft of evaporative losses. Dredging 50,000 ac-ft from a 50,000 ac-ft Cochiti Lake pool, thereby doubling the capacity but maintaining the same water surface area, would result in an average annual savings of 4,500 ac-ft.

45C (Apply surfactant). If such a product could be developed, and assuming a reduction in evaporation from Elephant Butte Reservoir of 50 percent (range from 25 to 70 percent), there could be an average annual savings of about 63,500 ac-ft from a 1-million ac-ft Elephant Butte pool.

Impacts on Water Quality

45A.i (Move to existing storage space). None.

45A.ii (Move to currently unauthorized storage space in existing reservoirs). None.

45A.iii (Move to new reservoirs). Reduction of water temperatures below new reservoir. For Wagon Wheel Gap Reservoir, there are no significant impacts on sediments below reservoir because of the paucity of sediment in the system above the proposed location.

45B (Dredge). If dredging occurred "in the wet," there would be an increase of sediments in the reservoir and downstream riverine environment.

45C (Apply surfactant). The commercial product on the market is a food-grade chemical (fatty alcohol) that has received the designation of an "Environmentally Sound Technology" from the United Nations International Environmental Technology Center. Sandia National Laboratories experiments showed no decrease in dissolved oxygen during treatments, and fish in the experimental tanks showed no apparent ill effects.

Watershed / Geologic Impacts

45A (Move). None.

45B (Dredge). The deposition of massive quantities of dredged materials (about 80 million cubic yards) could cause increased sediment inflow from the watershed unless extensive land *surface remediation was undertaken.*

45C (Apply surfactant). None.

3.1.2 Environmental Impacts

45A.i (Move to existing storage space). Alteration of hydrographs between Elephant Butte and "move-to" reservoir. Effects on riverine and riparian communities and on associated endangered species could range from detrimental to beneficial. Impacts on reservoir communities could also be beneficial to detrimental. In total, nature and magnitude of environmental impacts would be largely influenced by the quantities of "moved" storage and the subsequent water management decisions.

45A.ii (Move to currently unauthorized storage space in existing reservoirs). Same as "existing storage space" with additional impacts on the "move-to" reservoir. Lands near Cochiti Lake and Abiquiu Reservoir that have never been inundated or have been subject to inundation only by shorter duration flood storage events, would be subjected to prolonged inundation. There would be a loss of terrestrial ecosystems during inundation, and a permanent change in these ecosystems during periods of lower water levels. The reservoirs' aquatic ecosystems would be enlarged and would benefit. Elephant Butte would generally have less water, and the impacts on the more perennially exposed delta area could be beneficial with active management.

45A.iii (Move to new reservoirs). Same as "existing storage space" plus complete direct alteration of the reservoir site and long-term secondary impacts to the area due to anticipated population influx. Downstream riverine and riparian environments would be altered in response to changes in the hydrographs.

45B (Dredge). The most enduring environmental impacts would be associated with the spoil site permanently altering the landscape. Because of the volume of material to be moved, the construction activities, in and of themselves, would be significant. If sediments were mobilized and transported into the downstream riverine environment, the impacts to the aquatic ecosystem would be devastating.

45C (Apply surfactant). To date, no adverse environmental impacts have been identified.

Implications to Endangered Species

Depending on decisions regarding how saved water is managed, impacts to endangered species in the riverine and riparian ecosystems (Rio Grande silvery minnow and Southwestern willow flycatcher) could either be beneficial to detrimental.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

45A.i (Move to existing storage space). If terms of current temporary storage agreements for El Vado Reservoir were obtained for the City of Albuquerque's space in Abiquiu Reservoir, implementation would cost about $130/ac-ft of water saved per year. For the 18,000 ac-ft of storage space managed by the U.S. Army Corps of Engineers (USACE), it would cost about $5 per ac-ft per year (ac-ft/yr) for the 1,000 ac-ft of water saved annually through reduced evaporation.

45A.ii (Move to currently unauthorized storage space in existing reservoirs). Based on a 1987 USACE report, the average annual cost of adding storage space to Abiquiu Reservoir was about $30 to $35 per acre foot of stored water (adjusted to 2002 dollars for inflation only). This would result in a cost of about $440 per ac-ft of water saved per year. These estimates could be quite low, as the costs for obtaining easements have certainly increased much more than the rate of inflation.

45A.iii (Move to new reservoirs). Using the Bureau of Reclamation construction cost indices to convert cost estimates from original planning documents, a 500,000 ac-ft Wagon Wheel Gap Dam and Reservoir would cost about $150 million, and the 5,500 ac-ft Indian Camp Dam and Reservoir would cost about $35 million. (These estimates are likely quite low as current dam safety and environmental mitigation standards are much more stringent than in the past.)

45B (Dredge). Using very conservative estimates, the initial cost to dredge 50,000 ac-ft from a reservoir would be about $375 million. Depending on the reservoir, the cost would be between about $85,000 and $235,000 per ac-ft of water saved annually, based on evaporative savings.

45C (Apply surfactant). The costs to develop a surfactant that would be effective on large reservoirs are unknown. Continued research and development will be required. However, extrapolating data from the preliminary results at Sandia National Laboratories, it would cost about $30 per ac-ft of water saved (product only; does not include application costs). For the commercial product, the cost is about $250 per ac-ft of water saved.

3.2.2 Potential Funding Source

45A.i (Move to existing storage space). Local or state-level funding would be possible.

45A.ii (Move to currently unauthorized storage space in existing reservoirs). Federal funding would be required, with some percentage of non-federal cost-sharing from project beneficiaries. Repayment for the federal portion would be negotiated under federal guidelines.

45A.iii (Move to new reservoirs). Federal funding would be required, with some percentage of non-federal cost-sharing from project beneficiaries. Repayment for the federal portion would be negotiated.

45B (Dredge). None.

45C (Apply surfactant). The most promising and logical avenue for continued research and development is for Sandia National Laboratories to form a partnership with the private sector, or to obtain grants from other public agencies.

3.2.3 Ongoing Cost for Operation and Maintenance

45A.i (Move to existing storage space). The terms of the agreements with the owners of the storage spaces would include O&M expenses.

45A.ii (Move to currently unauthorized storage space in existing reservoirs). The USACE charges San Juan-Chama contractors who store water in Abiquiu Reservoir's "discretionary pool" $0.30 per ac-ft to cover operation and maintenance costs.

45A.iii (Move to new reservoirs). Annual O&M costs for a dam and reservoir such as El Vado, can amount to $100,000 without any extraordinary maintenance or replacement activities.

45B (Dredge). To maintain the dredged spaces would cost about $7.5 million per year.

45C (Apply surfactant). Because of biodegradation, surfactants need to be frequently applied to water surfaces. The commercial product requires reapplication every 2 to 2½ days. A year-round application of this product to a 1-million ac-ft Elephant Butte pool would require about 700 tons of product. Extrapolating experimental data from India (see Exhibit 45A), the annual cost of product and application by boat would be about $6.5 million dollars, or about $100 per ac-ft/yr.

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Alternative 45

Exhibit A
Detailed Discussion

Exhibit 45A: Detailed Discussion of Alternative 45—Reservoir Management

Acknowledgements: This discussion, which follows the same basic format as the fact sheet it accompanies, provides additional details and information that support the conclusions presented in the fact sheet. It was written by Robert Leutheuser of Leutheuser Consulting as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc.

1. Definition of Alternative

"Reduce open water evaporation in storage reservoirs by retaining water at higher elevations or latitudes, or by reducing surface areas."

> *"Under the provisions of the Rio Grande Compact, NM must reserve a certain amount of water in the Elephant Butte Reservoir for use by Texas. Both the shape of the reservoir, which has been compared to a champagne glass, and the location, which is in a hot area of the state, contribute to a high percentage of evaporation. Water lost to evaporation is not counted toward the deliverable to Texas. Proposal is to reduce the amount of water lost to evaporation by any of various means, including,*
>
> > *1. Cover Elephant Butte Lake with surfactants, a thin layer of goop that would reduce evaporation. SNL is working to develop a non-hazardous product that would do this.*
> >
> > *2. Store some or all of the water in a cooler region. With a better management plan, it might be possible to minimize the water sent to Elephant Butte and keep it in a cooler region of the state. Or, it may be possible to negotiate a new agreement with Texas and Colorado within the Compact.*
> >
> > *3. Aquifer storage and recovery may solve some of the legal obstacles to alternative storage."* (Middle Rio Grande Water Assembly)

There are several groups of alternative actions that are evaluated in this analysis:

45A Move stored water to reservoirs at higher elevations / more northern latitudes;

a. Move water to an existing storage space
b. Move water to currently unauthorized storage space in an existing reservoir
c. Move water to a new reservoir

45B Dredge reservoirs to improve volume-to-surface area ratios

45C Apply surfactants to stored water surfaces.

The moving of water stored in Elephant Butte Reservoir to the Albuquerque aquifer is addressed in Alternative A-46, "Inject water treated to drinking water standards for aquifer storage and recovery (ASR) in appropriate locations throughout the water planning region."

2. Approach

- Develop ranges of water savings that could be realized by remanaging the storage of water in existing reservoirs under hypothetical conditions, and moving the storage to higher elevation/latitude reservoirs.

- Index documented construction and O&M costs, as available, for unbuilt reservoirs at higher elevations / more northern latitudes, to current year dollars.

- Obtain easement acquisition costs for Abiquiu Reservoir from the City of Albuquerque.

- Obtain costs for reservoir dredging and calculate hypothetical water savings.

- Complete a literature search and consult with Sandia National Laboratories regarding the treatment of water surfaces with products to reduce rate of evaporation.

- Identify environmental issues through the review of contemporary environmental documents.

3. Alternative Analysis: 45A—Move Storage to Higher Elevations/More Northern Latitudes

3.1 Technical Feasibility

Background: The principal of reducing reservoir losses to evaporation by storing water at higher elevations and/or more northern latitudes is sound. In addition to the locations having lower average annual temperatures, the topography of the landscapes in which the reservoirs are or would be located *generally* tend to provide for a higher volume-to-surface area ratio, which would also contribute to reductions in evaporation per unit of water stored.

The Middle Rio Grande water planning region is currently served by a system of reservoirs which have been constructed over the last 70 years to enhance water supply and provide flood control. Figure 45A-1 shows the location of reservoirs; Table 45A-1 summarizes the key reservoirs in the system. Elephant Butte Reservoir is included in Table 45A-1 because of its importance to the Middle Valley's (i.e., the valley between Cochiti Dam and Elephant Butte Reservoir) water budget vis-a-vis the Rio Grande Compact accounting procedures[1]. The once-planned, but never-constructed Wagon Wheel Gap and Indian Camp reservoirs are included because they are considered in the analysis.

Of the total upstream storage capacity of 465,760 acre-feet (ac-ft)[2], 424,369 ac-ft[3], or about 90 percent, is dedicated to Middle Valley water users. All flood control facilities upstream of the Middle Valley directly or indirectly benefit the Middle Rio Grande planning area.

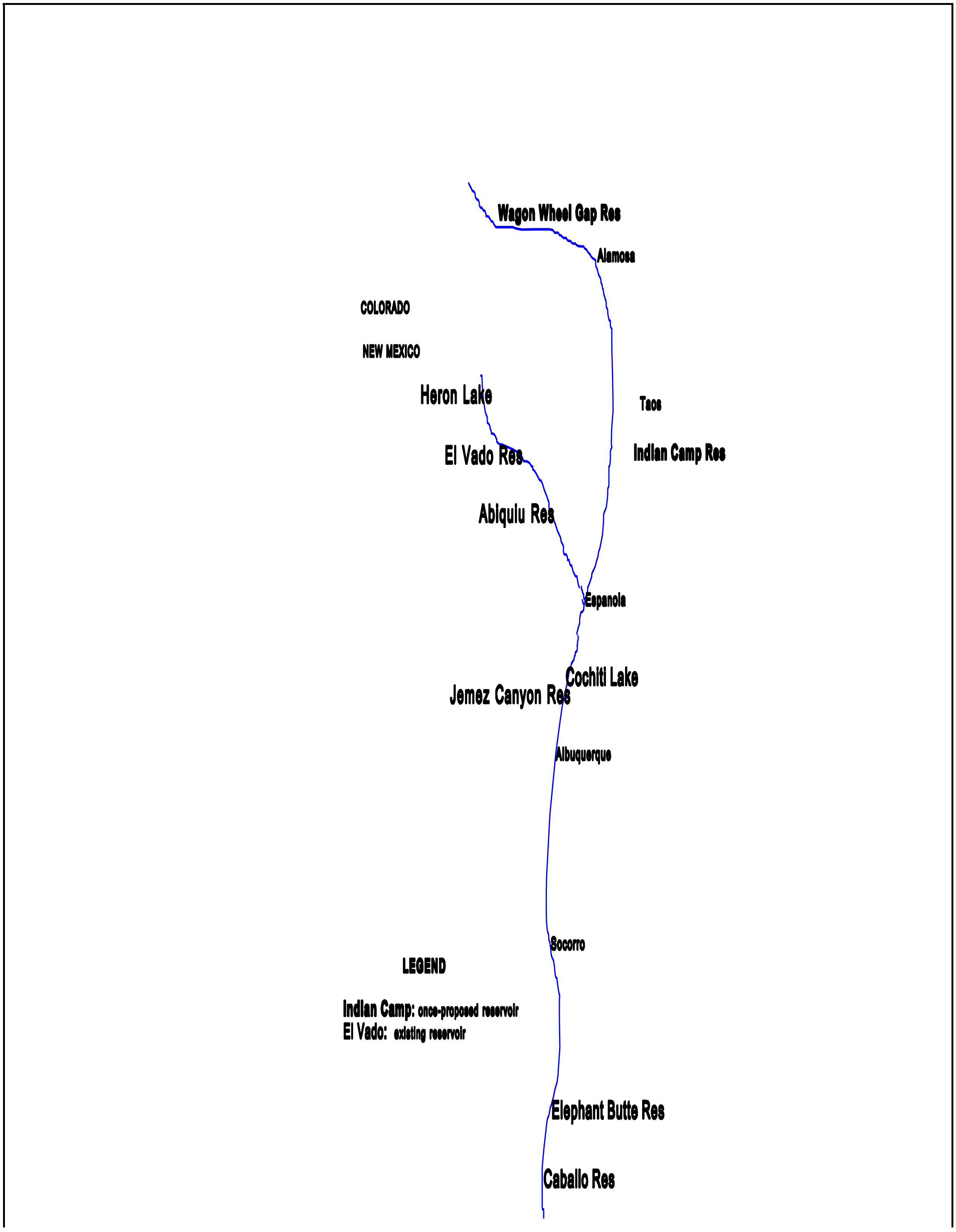

Figure 45A-1: Location of Reservoirs and Selected Once-Planned Reservoirs

Table 45A-1: Key Reservoirs that Influence Water Management in the Middle Rio Grande Planning Area

Reservoir	Owner/ Operator	Capacity (ac-ft)				Elevation Top of Max. Pool (ft msl)
		Total	Conservation	Flood Pool	Designated Sediment Pool	
Wagon Wheel Gap [a]	NA	500,000	300,000	200,000	0	8,700
Indian Camp [a]	NA	5,500	3,000	2,000	330	7,325
Heron	Reclamation	401,000	401,000 [b]	0	0	7,186
El Vado	Reclamation MRGCD	180,560	180,560	1,200 [c]	0	6,879
Abiquiu	USACE	1,215,000	640,000 [d]	502,000	77,000	6,350
Cochiti	USACE	582,019	0 [e]	492,000	105,000	5,460
Jemez Canyon	USACE	97,425	0	73,000	44,213	5,232
Elephant Butte	Reclamation	2,065,000	2,065,000	50,000/ 25,000 [f]	0 [g]	4,407

[a] Reservoir once planned, but never constructed.
[b] Storage provides for an annual firm yield of 96,200 ac-ft for San Juan-Chama Project water. No storage of native water authorized.
[c] November-April flood pool within the 180,560 ac-ft conservation pool.
[d] Current authorization: 200,000 ac-ft of conservation storage
[e] About 50,000 ac-ft is stored to maintain authorized 1,200 surface-acre recreation pool.
[f] Considered to be discretionary flood space within conservation storage: 50,000 ac-ft May-October; 25,000 ac-ft November-April.
[g] No official sediment pool was designed into Elephant Butte. Since construction, there has been about 558,000 ac-ft of lost storage capacity (Reclamation, 2000).

ft msl = Feet above mean sea level   Reclamation = Bureau of Reclamation   USACE = U.S. Army USACE

Because of its importance to water management in the Middle Rio Grande planning area, an additional explanation of conservation storage in Abiquiu Reservoir is warranted. Public Law 97-140 (1981) authorized the storage of 200,000 ac-ft of San Juan-Chama Project water in the reservoir. The City of Albuquerque obtained the necessary inundation easements, up to an elevation of 6,220 feet above mean sea level (ft msl). In 1999, the volume of available space was about 184,000 ac-ft because of sediment deposition. The City and the U.S. Army Corps of Engineers (USACE) signed a storage agreement allowing the City to store up to 170,900 ac-ft, and the USACE manages the remaining conservation storage space. In 1988, Public Law 100-52 was passed also allowing the storage of “native” water (not imported from another river basin) in the previously authorized space, for which New Mexico State Engineer permits would be required. No such permits have been issued to date.

New Technologies and Status

No new technologies are required to transfer water storage from downstream reservoirs to *existing storage spaces*, or *additional spaces in existing reservoirs*. The shifting of storage depends on available water supplies and available space in reservoirs. The ability to move storage in the Rio Grande Basin is highly influenced by institutional and legal considerations, most notably state water law, federal law, Native American law, the Rio Grande Compact and environmental laws.

Nor are new technologies required for the *construction of new dams and reservoirs*. Such construction, however, would take advantage of new technologies that may lead to reductions in construction costs. These technologies are not on the critical pathway to making decisions regarding whether or not new reservoirs would be constructed. Institutional, legal, and economic considerations would ultimately determine whether or not a new reservoir would be constructed.

Infrastructure Development Requirements

In the case of moving storage from one reservoir to another's *existing storage space*, there are no infrastructure development requirements *Using currently unauthorized storage space in an existing reservoir*, i.e. Cochiti Lake or Abiquiu Reservoir, would require the modification of reservoir-associated facilities, such as boat ramps, camping and picnicking grounds, etc., possible relocation of roads (depending on storage quantity added), and possible relocation of residences at Abiquiu Reservoir. The *construction of a new dam*, reservoir, and appurtenant structures requires considerable infrastructure development.

Total Time to Implement

Total time required to "move" Elephant Butte Reservoir storage to *existing upstream reservoir space* is dependent on hydrologic cycles and the resolution of legal and institutional issues. Both are beyond the scope of this effort to predict.

To *use currently unauthorized storage space to an existing reservoir* (e.g. Abiquiu or Cochiti) would require the acquisition of lands and/or easements and the relocation of facilities. This could take 5 to 10 years. However, it would also require, as a prerequisite, Federal legislation which would be predicated on the resolution of legal, water rights, Native American, and environmental issues. Contemporary experience in the West indicates that this could take 15 to 20 years to accomplish, if possible at all.

The total time required to plan, design, and construct *new reservoirs* (in this analysis, at the Wagon Wheel Gap site in southern Colorado and the Indian Camp site south of Taos) is equally difficult to predict. In a political and legal vacuum, the dams and appurtenant structures could be constructed in maybe 5 years following the completion of all planning, design, and land acquisition activities. However, the Western United States is rife with contemporary examples of new water projects being tied-up for three decades in the planning phases, e.g. the Animas-La Plata Project in southwestern Colorado.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Increasing water supplies through the reduction of evaporative losses would have no effect on water demand.

Effect on Water Supply

The purpose of reducing reservoir evaporative losses is to increase water supply.

Water Saved

There are numerous factors beyond surface evaporation rates that influence the amount of water that would be saved by storing water in reservoirs at higher elevations and/or more northern latitudes. From a physical standpoint, the ratio of volume-to-surface area is extremely important. From a management standpoint, water management decisions based on professional interpretation and institutional/legal requirements dictate amount of storage, duration of storage, rates of releases, timing of releases, water exchanges, etc. All of these have tremendous impacts on how much water is actually saved, if any at all.

The volume-to-surface ratio is determined by the shape of the reservoir basin and how much water is in the reservoir at any given time. For example, a reservoir that has a surface area of 10 acres for 100 ac-ft of stored water has a volume-to-area ratio of 10. Another reservoir with a surface area of 10 acres for a volume of 50 ac-ft of stored water has a volume-to-area ratio of 5. Assuming the same evaporation rate, the second reservoir would suffer twice the evaporation *per unit of stored water* as the first reservoir. Reservoirs are not regularly shaped, therefore the volume-to-surface ratio changes constantly with changes in the volume of the water stored. Generally, evaporation per unit of water decreases with more-full reservoir conditions.

This analysis relies heavily on the USACE, Albuquerque District's 1989 report entitled *Reevaluation of the Rio Grande Operating Plan*. The purpose of the study was ". . . to analyze the operation of Federal reservoirs in the Upper Rio Grande Basin above Fort Quitman, Texas for the purpose of identifying areas for improving flood control protection and optimizing beneficial use of the waters of the Rio Grande." *All evaporation data used in this analysis, except for Wagon Wheel Gap and Indian Camp reservoirs, are presented in or derived from this report and reflect 1981-1987 evaporation rates.*

Static Analysis: Table 45A-2 summarizes the amounts of water that could be saved annually (assuming constant reservoir elevations) by moving stored water from Elephant Butte Reservoir to upstream reservoirs. The hypothetical cases presented are the more plausible scenarios that could be considered in the future, such as moving 50,000 ac-ft, not 100,000 ac-ft to El Vado Reservoir due to that reservoir's total capacity.

As can be seen, there are a range of opportunities to reduce evaporative losses. The savings increase when water is moved from less-full Elephant Butte conditions, where the evaporative losses are greater (as expressed as a percentage of stored volume). For example in moving the 100,000 ac-ft from a 1-million ac-ft pool, to a 100,000 ac-ft Abiquiu pool, there is an annual savings of 6,200 ac-ft. But when the same quantity of water is moved from a 2 million ac-ft pool, the annual savings are reduced to 4,200 ac-ft. Similarly, water savings are increased when like quantities of water are moved to more-full receiving reservoir conditions.

In the cases arrayed in Table 45A-2, the highest percentage savings occur in moving 50,000 ac-ft of storage from a less full Elephant Butte (1-million ac-ft pool) to a more full El Vado pool (100,000 ac-ft). The lowest percentage savings—14 percent—occurs when water is moved from a more-full Elephant Butte Reservoir to a less-full Cochiti Lake. The most attractive water savings opportunities involve moving water from a less-full Elephant Butte Reservoir to a more-full Abiquiu Reservoir.

Table 45A-2. Hypothetical Water Savings Realized Reductions in Evaporation Resulting from the Transfer of Storage from Elephant Butte Reservoir to Upstream Reservoirs

Elephant Butte				Destination Reservoir				Water Savings	
Volume (ac-ft)		Evaporation				Evaporation			
Storage Volume	Water Moved	% of Storage	Annual (ac-ft)	Name of Reservoir	Volume Before / After Move (ac-ft)	% of new storage	Annual for Moved Water (ac-ft)	(ac-ft)	percent
1,000,000	50,000	12.7	6,350	Cochiti	50,000/100,000	9.2	4,600	1,750	28
1,000,000	50,000	12.7	6,350	El Vado	50,000/100,000	5.0	2,500	3,850	61
1,000,000	50,000	12.7	6,350	El Vado	100,000/150,000	4.6	2,300	4,050	64
1,000,000	100,000	12.7	12,700	Cochiti	50,000/150,000	8.1	8,100	4,600	36
1,000,000	100,000	12.7	12,700	Abiquiu	100,000/200,000	6.5	6,500	6,200	49
1,000,000	100,000	12.7	12,700	Abiquiu	200,000/300,000	5.4	5,400	7,300	57
2,000,000	50,000	10.7	5,350	Cochiti	50,000/100,000	9.2	4,600	750	14
2,000,000	50,000	10.7	5,350	El Vado	50,000/100,000	5.0	2,500	2,850	53
2,000,000	50,000	10.7	5,350	El Vado	100,000/150,000	4.6	2,300	3,050	57
2,000,000	100,000	10.7	10,700	Cochiti	50,000/150,000	8.1	8,100	2,600	24
2,000,000	100,000	10.7	10,700	Abiquiu	100,000/200,000	6.5	6,500	4,200	39
2,000,000	100,000	10.7	10,700	Abiquiu	200,000/300,000	5.4	5,400	5,300	50
1,000,000	100,000	12.7	12,700	Wagon Wheel	300,000/400,000	1.0 [a]	1,000	11,700	92
2,000,000	5,000	10.7	535	Indian Camp	500/5,500	7.6 [b]	380	155	29

[a] Data derived from “Appendix E - Water,” assumed to be companion material to U.S. Bureau of Reclamation’s 1955 report, *Revised Supplemental Report on Rio Grande & Weminuche Pass Divisions, San Luis Valley Project, Rio Grande Basin, Colorado.* Source dates of evaporation unknown.

[b] Data derived from U.S. Bureau of Reclamation, 1970, *Volume 2A Definite Plan Report San Juan-Chama Project*. Source dates of evaporation unknown.

The volume of water saved is proportional to the volume of storage that is "moved" upstream. In considering the 5,500 ac-ft Indian Camp Reservoir, once proposed as part of the unbuilt San Juan-Chama Project's Taos Unit, it is evident that in spite of its relatively high elevation and low evaporation rate, there would not be enough water savings, about 155 ac-ft, to justify its construction.[5]

The Wagon Wheel Gap Reservoir was once proposed as a feature of the Bureau of Reclamation's Closed Basin Project. As a large reservoir located both at a high elevation and a more northerly latitude (on the Rio Grande near Creede, Colorado), the evaporation savings could be tremendous: around 90 percent.

Water Operations Analysis: The *Reevaluation of the Rio Grande Operating Plan* (USACE, 1989) used the reservoir/routing model HEC-5 to evaluate three sets of water management plans: 1) enhance flood control; 2) add conservation storage; and; 3) move Elephant Butte Reservoir storage upstream. All plans were compared to current operations at the time. The analyses included all operational variables, including dynamic reservoir storage, conveyance losses, and evaporation losses.[6] Although the results were principally influenced by operational decisions, they included a Wagon Wheel Gap Reservoir and can shed some light on magnitudes of savings *as expressed in reductions of excess releases from Elephant Butte Dam,* defined as releases greater than downstream irrigation demands (USACE, 1989). As summarized in Table 45A-3, moving 100,000 ac-ft of Elephant Butte storage to Cochiti Lake reduced the average annual excess releases from Elephant Butte by 1,250 ac-ft. In plans to *add* conservation storage to the Upper Rio Grande Basin, adding 100,000 ac-ft of storage to Abiquiu Reservoir or Cochiti Lake reduced average annual excess releases by 2,700 to 3,200 ac-ft, and added about 95,000 ac-ft of water annually to the Middle Rio Grande Valley water supply. Care needs to be exercised in using this information in that the operational assumptions used in the model do not reflect current operational constraints. The greatest reductions in average annual excess releases, about 7,500 ac-ft, occurred when storage is added to Wagon Wheel Gap Reservoir. In the USACE analysis, however, this water was managed for the benefit of Colorado water users.

Table 45A-3: Scenarios Evaluating Effects of the Remanagement of 100,000 Acre-Feet in the Rio Grande System [a]

Destination Reservoir	Total Excess Releases (1,000 ac-ft)	Reduction from "Current Operation"[b] (1,000 ac-ft)	Percent Change from "Current" Operation	Ave. Annual Reduction in Excess Releases (ac-ft)	Addition to Middle Rio Grande Valley water supply [c]
Plans to Move 100,000 ac-ft of Elephant Butte Reservoir Water to Upstream Reservoirs					
Abiquiu	295.3	11.1	3.6	569	0
Cochiti	282.0	24.4	8.0	1,251	0
Wagon Wheel Gap	292.1	14.3	4.7	733	0
Plans to Add 100,000 ac-ft of Conservation Storage to Upstream Reservoirs					
Abiquiu	254.2	52.2	17.0	2,677	95.0
Cochiti	243.4	63.0	20.1	3,231	96.5
Wagon Wheel Gap	159.8	146.6	47.8	7,518	0 [d]

Source: All data from, or derived from, USACE (1989), Table 26, assuming a 1,000 cfs channel capacity at Fort Quitman.

[a] Excess releases are defined in the report as releases from Caballo Reservoir in excess of downstream (Rio Grande Project) irrigation demands. These releases did not begin until Elephant Butte Reservoir filled.

[b] Current operations were defined as projected hydrology being managed by established flood control and Rio Grande Compact operating rules. For these analyses, the total excess releases under the current operations for the period of study was 306,400 ac-ft, or an annual average of 15,700 ac-ft.

[c] Only the alternatives which added conservation storage increased usable water supplies. In the study it was assumed the water would be used for irrigation, but it could have been destined to any water use in the Middle Rio Grande Valley.

[d] It was assumed all additions to water supplies due to Wagon Wheel Gap Reservoir were used in Colorado.

3.1.2 Environmental Impacts

45a. Existing Storage Space

The most significant environmental effects of "moving" stored water to upstream reservoirs in existing conservation pools would be the alteration of the shape of the hydrographs downstream from the points of storage and release. Depending on the management decisions, this would have the potential to affect both the riverine and riparian communities throughout the system between the change in storage points, such as between Abiquiu Dam and Elephant Butte Reservoir. The obligate endangered species that occupy the environments, such as the Rio Grande silvery minnow and the Southwestern willow flycatcher, could likewise be affected. In the past, water managers have been able to coordinate dynamic operational decisions so as to minimize the impacts, although increasingly regulatory compliance with the Endangered Species Act is required. There would be opportunities to deliver the upstream-stored water to the benefit of the communities and species. For example, late-spring deliveries could create periods of high flows for silvery minnow spawning, or overbank flooding for bosque rejuvenation or renovation.

The effects on the ecosystems associated with the reservoirs could also be mixed, depending on the water management decisions. If the management regimes promoted more stable water levels, the aquatic ecosystems would benefit. If the reservoir levels were managed so as not to have drawdowns during the fisheries' spawning seasons, the effects would be beneficial. However, if the resultant water level fluctuations were of greater magnitude and frequency, it would be harmful to the aquatic community. The same logic extends to the riparian areas associated with the reservoirs: water levels and timing of inundation can have direct effects on the riparian species composition. For the Southwestern willow flycatcher, proximity to water is also an important habitat quality variable. However, because the existing reservoir conditions are predicated on water level fluctuations and the "moved" water would managed within the established operational latitudes, the effects of moving stored water to upstream reservoirs would be expected to be *relatively* insignificant.

45b. Currently Unauthorized Storage Space in Existing Reservoirs

Adding storage space to an existing reservoir would have similar potential effects to the downstream riverine and riparian ecosystems as remanagement of water within existing spaces. The role of water management decisions would also continue to largely determine the nature and magnitude of the effects. However, there would also be additional impacts to the reservoir-associated environment where the additional storage is created. Categories of impact would include the reservoir lacustrine community, the general surrounding terrestrial environment, and the riverine and riparian communities associated with the inflowing river.

The USACE looked at the environmental impacts that would result from adding 467,000 ac-ft (total space available at that time) of conservation storage to Abiquiu Reservoir (USACE, 1987). As with the initial inundation of any land area by a reservoir, there would be a period of increased biological productivity as the soil nutrients are released into the aquatic environment. Additionally, the increase in the size of the reservoir would numerically add volume to the aquatic environment. The USACE projected that a larger Abiquiu Reservoir could attract more bald eagles. It would also be likely that more waterfowl and shore birds would be attracted to the reservoir. For the additional storage of 467,000 ac-ft, the USACE estimated that an additional 2,600 acres of land would be inundated. (By comparison, the addition of 100,000 ac-ft of storage would result in the inundation of about 1,000 acres of land at full-reservoir conditions.) As water levels recede, all vegetation associations (annual grasses and forbs, piñon-juniper grassland, shrub-grassland, and canyon bottom/riparian forest) would experience some recolonization, but would be significantly different than their pre-inundation character. The fauna associated with the vegetation associations would likewise be altered. Of particular importance would be the riparian community associated with the Rio Chama at its point of inflow. Not only would prolonged inundation kill the existing vegetation, but the deposit of sediments would create new conditions, possibly favorable, for riparian recolonization during prolonged periods of drawdown.

Although not strictly an "environmental impact," consideration of adding storage space to Abiquiu Reservoir must anticipate effects on the Rio Chama's designation as a "Wild and Scenic River" upstream from the reservoir. Although the authorizing legislation (Public Law 100-633) specifically recognized Abiquiu Reservoir's operational requirements, additional storage would conflict with other legislated and public use values.

For Cochiti Lake, a report prepared under the auspices of the Rio Grande Initiatives in the early 1990s is illustrative of impacts that can be anticipated when added storage space to a reservoir (Allen et al., 1993). An interagency team looked at the biological effects of a proposal which would occasionally and temporarily store an additional 5,000 ac-ft of water in Cochiti Lake June through October. As a result of higher water levels in Cochiti Lake from 1985 to1988, sediments formed a delta area upstream on the Rio Grande at the headwaters of White Rock Canyon. In the intervening 5 years between the last inundation and the preparation of the report, a riparian and wetland community developed in the delta which was emerging as important habitat for riparian-obligate species, waterfowl, and the bald eagle. The team concluded that the proposal would "have significant, negative impacts" on the delta riparian and wetland because of the periodic inundation.

It is assumed that Elephant Butte Reservoir would *generally* have less water in it (recognizing the more-full to full reservoir conditions would still occur but less frequency and for shorter durations). The magnitude of the effects would depend on the quantity of water moved upstream. However, a smaller pool of water would decrease the area of the lacustrine environment, and would increase the exposure of the riparian/wetland community below the reservoir's maximum surface elevation. Much of this community is located along the 23-miles of the Rio Grande Valley between San Marcial and "The Narrows" of Elephant Butte Reservoir. According to data presented in a Draft Environmental Statement prepared by the U.S. Bureau of Reclamation (Reclamation, 2000), at the time of report preparation there were about 8,500 acres of riparian and wetland communities in this reach, of which about 25 percent were monotypic stands of salt cedar. About 20 percent of the total area was rated as being "highly suitable" Southwestern willow flycatcher habitat. The water management decisions would significantly influence on the resultant character of the area.

45c. New Reservoirs

Construction of new reservoirs would have immediate, dramatic, and permanent environmental impacts on the terrestrial, riverine, and riparian environments inundated. The specific nature and extent of the impacts would depend on the location and size of the reservoir. A new reservoir would also change the downstream hydrographs and water temperatures, affecting both the riverine and riparian communities. Temporary effects would be experienced during the construction period, and additional indirect long-term impacts would accrue as the result of population influxes to the area, as are common around Western reservoirs. As with other options to store water at locations to reduce evaporative losses there would be the potential through water management decisions, to operate the reservoirs for environmental benefits.

3.2 Financial Feasibility

45a. Existing Storage Space.

The costs associated with moving Elephant Butte storage upstream to existing storage spaces in Abiquiu or El Vado reservoirs would be determined through negotiations with the managing entities of the storage spaces, the City of Albuquerque and the Middle Rio Grande Conservancy District (MRGCD), respectively.

In the past the MRGCD has charged other entities $2 to $5 an ac-ft per year plus 10 to 20 percent of the stored water to store water in El Vado Reservoir. The agreements also have stipulated that the owner of the stored water absorb a proportional share of the evaporative losses, and the MRGCD retains the first right to use the water if it was needed (Shah, 2001). It must be remembered, however, that the "water surcharge" is ultimately used in the Middle Rio

Grande planning area; the net transaction *for the planning area* would be differential evaporation rates and monetary payments. If 10,000 ac-ft were moved from a 1-million ac-ft Elephant Butte Reservoir pool to a 100,000 ac-ft El Vado Reservoir pool, the net savings in evaporation would be about 400 ac-ft for a year's storage. Assuming a charge of $5/ac-ft and an average annual evaporative loss of 20 ac-ft, the cost per ac-ft of avoided evaporation would be about $130. Similar arrangements could possibly be made with the City of Albuquerque to store water in its Abiquiu Reservoir conservation pool, with similar resultant costs.

Also in Abiquiu Reservoir, the USACE allows other San Juan-Chama contractors to store their water in the remaining 13,000 ac-ft of conservation storage space (within the authorization and City-owned easements, but above the City of Albuquerque's 170,900 ac-ft contracted pool). Storing entities are charged a pro rata share of operation and maintenance costs, which were $0.30 per ac-ft in 2001. If this entire space were to be used for water moved from a 1-million ac-ft 1- pool, the annual cost per ac-ft of the 1,000 ac-ft of evaporation avoided would be about $5 per ac-ft.[7]

45b. Currently Unauthorized Storage Space in Existing Reservoirs

In 1987, the USACE, Albuquerque District, issued a report reviewing the feasibility of adding conservation storage within Abiquiu Reservoir's maximum pool in addition to the authorized 200,000 ac-ft conservation pool. The cost estimates, *adjusted for inflation only*, in 2002 dollars, are presented in Table 45A-4. These costs include proportional construction repayment obligations to the USACE.

Table 45A-4: Cost Estimates for Adding New Storage Space to Abiquiu Reservoir (USACE, 1987)

Total Additional Storage (ac-ft)	Total Cost [a]	Average Annual Cost per Ac-ft
50,000	$14,920,000	$33.25
100,000	$28,730,000	$32.00
200,000	$56,825,000	$31.50
467,000 [b]	$151,270,000	$36.00

[a] Adjusted to 2002 dollars for inflation only.
[b] The maximum possible additional conservation storage.

If the additional storage was used to move 100,000 ac-ft of water from a 1 million ac-ft Elephant Butte Reservoir pool to a 200,000 ac-ft Abiquiu Reservoir pool in order to reduce evaporative losses, the annual cost per ac-ft of water saved 7,300 ac-ft) would be about $440.

One of the expenses in increasing storage behind existing dams would be obtaining easements. To add 100,000 ac-ft of conservation storage to Abiquiu Reservoir, easements would be required for an additional 1,000+ acres.

During the Abiquiu Dam and Reservoir pre-construction phase, the USACE obtained flowage easements for all lands that are subject to temporary inundation associated with the flood control operations, up to the reservoir's maximum water surface elevation. These easements disallow the construction of any permanent structures on the lands (Satz, 2003).

For Abiquiu Reservoir, the City of Albuquerque obtained 2,310 acres of storage easements up to elevation 6,220 feet msl in the 1980s. The agreements provided annual payments in the form of the right of each landowner to use a specified quantity of the City's San Juan-Chama Project-contracted water, all together totaling 433 ac-ft per year (Kelly, 2002). Using the current costs of $100/ac-ft/ year for San Juan-Chama Project water, as established by contemporary Endangered Species Act compliance program leases, the current leases would cost, on average, about $20/acre/year. The City of Albuquerque is exploring options to convert the existing 55-year easements to permanent easements through offering property owners cash payments in lieu of water payments. As these agreements have yet to be negotiated, no cost estimates are available.

In 2001 the USACE purchased in fee title about 16 acres of land for which it previously held a flowage easement, at a cost of about $2,300 per acre. Based on a cursory review, unimproved upland land prices in the general Abiquiu area *not associated with the reservoir or the Chama River*, were in the range of $3,000 - $5,000 per acre.

Using the USACE's recent transaction, acknowledging that because of the myriad of variables in the real estate market that it is only valid to establish a point of reference, the cost of obtaining the necessary additional storage easements to increase the storage in Abiquiu Reservoir by 200,000 ac-ft would be in the neighborhood of $2.5 million.

45c. New Reservoirs

In 2002 dollars, the cost to construct the 500,000 ac-ft Wagon Wheel Gap Dam and Reservoir would be about $150 million dollars[8]; the 5,500 ac-ft Indian Camp Dam and Reservoir would be about $35 million. These costs were derived from original Bureau of Reclamation planning document (Reclamation, 1955 and 1970) cost estimates, indexed to current dollars using the Bureau of Reclamation Construction Cost Trend data. The costs reflect the projects as they were designed at the time; they do not anticipate any additional contemporary features or mitigation measures that would likely be required. No cost estimates were available for operation and maintenance.

3.3 Conclusions

Moving water stored in Elephant Butte Reservoir to reservoirs with lower evaporation rates is sound water management and needs to be pursued at every given opportunity. The most realistic prospects from financial and environmental perspectives are storing additional water in Abiquiu Reservoir, either in the currently authorized space or in currently unauthorized conservation storage space.

4. Alternative Analysis: 45B—Dredging

4.1 Technical Feasibility

Background: Reservoirs trap sediments transported by inflow water. The rate and pattern of deposition and the character of the sediment is governed by the upslope watershed, river morphology, inflow hydrographs, reservoir shape, and reservoir operations. Deposited sediments infringe upon the water storage capacity of a reservoir and alter the shape of a reservoir's bottom. It should be noted that the reservoirs that effect middle Rio Grande valley water management are large, and all have "sediment pools" designed into them (Table 45A-1) to accommodate sediment deposition.

As previously discussed, one of the variables influencing the amount of water lost through evaporation is the volume-to-surface area ratio; the higher the ratio, the lower evaporative losses for every unit of water stored. Sediment removal in the context of this discussion therefore, is limited to altering the evaporation per unit of stored water, not to recover lost storage space.

A review of literature revealed that, to date, reservoir dredging has been accomplished for the following purposes:

- Regain storage space in smaller reservoirs, primarily for municipal and industrial water supplies
- remove contaminated sediments
- restore capabilities of small sediment catchment impoundment
- improve or restore fisheries habitat
- reestablish inflow conveyance efficiencies

No documentation was found where dredging was pursued to reduce evaporative losses, nor on the scale that need to be anticipated in the Upper Rio Grande Basin. The largest scale dredging operation located in this literature search was 3,000 ac-ft from 1985-1995, removed from a 187,000 ac-ft reservoir in Taiwan.

4.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Increasing water supplies through dredging would have no effect on water demand.

Effect on Water Supply

It is possible to increase a reservoir's volume-to-surface area ratio through dredging, thereby decreasing the rate of evaporation per unit of water stored. This can be best demonstrated through several examples involving two reservoirs that impact water management in the Middle Rio Grande planning area.

- *Example 1*, Abiquiu Reservoir: Average annual evaporation for a reservoir volume of 200,000 ac-ft is, as expressed as percentage of storage, is 6.5; for a volume of 150,000 ac-ft, evaporation is 7.6 percent. Assume that 50,000 ac-ft of material is dredged from the 150,000 ac-ft pool thereby providing 200,000 ac-ft of storage with the same surface area. As shown in Table 45A-5, there would be a 1,600 ac-ft annual reduction of evaporative losses.

Table 45A-5: Hypothetical Examples of Effects of Dredging Abiquiu Reservoir on Annual Evaporative Losses

Storage Space	Volume (ac-ft)	Surface Area (acres)	Annual Evaporation as % of storage	Volume:Area	Annual Evaporation (ac-ft)
unmodified 150,000	150,000	3,689	7.6	41:1	11,400
unmodified 200,000	200,000	4,207	6.5	48:1	13,000
dredged 150,000	200,000	3,689	5.7	54:1	11,400

- Example 2, Cochiti Lake: Following the same methodology, this time increasing the volume of a 50,000 ac-ft pool to 100,000 ac-ft pool by dredging, the annual water savings would be 4,500 ac-ft, as shown in Table 45A-6.

Table 45A-6: Hypothetical Examples of Effects of Dredging Cochiti Lake on Annual Evaporative Losses

Storage Space	Volume (ac-ft)	Surface Area (acres)	Annual Evaporation as % of storage	Volume:Area	Annual Evaporation (ac-ft)
unmodified 50,000	50,000	1,187	9.4	42:1	4,700
unmodified 100,000	100,000	2,323	9.2	84:1	9,200
dredged 50,000	50,000	1,187	4.7	43:1	4,700

4.1.2 Environmental Impacts

The most enduring environmental impacts of a dredging operation are associated with the disposal of the dredged material. Because of the quantities of material required to save significant volumes of water, massive areas of land would be required for a disposal site. For example, on a flat surface, 50,000 ac-ft of dry spoil deposited on a Section of land (1 mile square; 640 acres), would create a truncated 85-foot tall pyramid with 3:1 side slopes.

The environmental effects of such an area, with annual additions of 1,000 ac-ft of spoil, would be enormous to the terrestrial ecosystem. Wet dredging presents additional challenges for spoil disposal, as disposal sites would have to located and designed to allow the draining of water from the material which could present water quality issues.

With wet dredging, there would be a mobilization of sediments in the surrounding water that would have a temporary effect on the reservoir ecosystem and likely long-term and severe impacts on the downstream riverine ecosystem (Monterrey Peninsula Water Management District, 1998).

The effects of the hauling of the sediment to the disposal site would significant because of the scale of the operation. In addition to the disruption of any fauna in immediate area because of the prolonged activity (for California example, the removal 620 ac-ft of sediment would take 5.7 years of hauling, 10 trucks/hour for 8-hour days [Monterrey Peninsula Water Management District, 1998]), there would be noise and air pollution issues.

4.2 Financial Feasibility

Recent estimates for New Mexico reservoir dredging include:

- Santa Cruz Reservoir: ~$7,500/acre foot (Resource Technology, Inc., 2002)
- Santa Cruz Reservoir: ~$14,500/acre foot (Reclamation, 1983) [9]
- Miami Lake (wet dredging): $7,000-$14,000/acre foot (DBS&A, 2002)
- Miami Lake (dry dredging): $2,500-$4,000/acre foot (DBS&A, 2002)
- Lake Alice (dry dredging): $9,500/acre foot (DBS&A, 2002) [10]

A contemporary estimate from California for removing 854 ac-ft of sediment, without mitigation costs, was $13,000 to $47,000 per acre foot (Monterey Peninsula Water Management District, 1998). The same high-end estimate was prepared for dredging 800 ac-ft from a reservoir in British Columbia, Canada (Ootsa-Nechako Watershed Protection Committee, 2002).

Offsite disposal is a major component of the costs, often constituting more than half of the total costs. This makes it very tenuous to project dredging costs on a non-site specific basis. However, for the purposes of this evaluation, a total cost of $7,500/acre foot is used for dredging in the dry, including disposal. This is very close to the average of the above values for dry dredging in New Mexico.

- Example 1. The cost for dredging 50,000 ac-ft in Abiquiu Reservoir would be $375,000,000. For the annual savings of 1,600 ac-ft, the cost per ac-ft of water saved would be approximately $234,000.

- Example 2: The cost for dredging 50,000 ac-ft in Cochiti Lake would also be $375,000,000, but because the annual water savings would be 4,500 ac-ft, the cost would be about $83,000/acre foot saved.

Maintenance costs would reoccur due to inflowing sediments refilling the dredged space, the rate of filling being influenced by the location of the dredge site, reservoir management, inflow hydrology, watershed condition, etc. The average annual sediment deposition in Abiquiu Reservoir from 1963 to 1997, was 978 ac-ft/yr. Assuming the same rate of deposition *in the dredged space*, the space would be filled in 51 years. The maintenance of the space (and annual evaporation savings) would cost $7,335,000/year. For Cochiti Lake, the 1972-1998 average annual rate of sediment deposition was 1,007 ac-ft. With the same assumptions, it would cost about $7,500,000 per year. These results are summarized in Table 45A-7.

Table 45A-7: Hypothetical Costs and Water Savings Associated with Dredging Existing Reservoirs

Reservoir	Initial Quantity Dredged (ac-ft)	Annual Quantity of Water Saved (ac-ft)	Estimated Project Cost	Initial Cost per acre foot water saved	Annual Dredging Quantity (ac-ft)[a]	Annual Dredging Cost
Abiquiu	50,000	1,600	$375 million	$234,000	978	$7.3 million
Cochiti	50,000	4,500	$375 million	$83,000	1,007	$7.5 million

[a] To maintain original 50,000 ac-ft dredged space.

4.3 Conclusions

It is economically infeasible to use dredging as a reservoir management tool to reduce evaporative losses on the large reservoirs that effect middle Rio Grande water management. However, where sediment deposition negatively interferes with a reservoir's mainstem delivery of water due to the formation of deltas, such as at the upper end of Elephant Butte Reservoir, dredging is a viable alternative to improve the efficiency of water delivery to the reservoir.

5. Alternative Analysis: 45C—Surfactants To Reduce Surface Evaporation

5.1 Technical Feasibility

Background: Barriers between water surfaces and climatic variables can reduce the amount of water lost to evaporation. In the simplest of cases, plastic covers can be placed over relatively small bodies of water up to 5 to 10 acres in size (Hightower and Tadros, 2002). For large bodies of water, research and development in the past has been directed to application of surfactants (chemical films or molecular monolayers) to water surfaces to decrease evaporation by increasing surface tension. The testing conducted in the 1960s demonstrated that the technologies could limit evaporation, but were susceptible to wave action degradation necessitating reapplication every couple of days, rendering the process uneconomical. Advances in surfactant and polymer chemistry suggest that new products and techniques may prove to be more economical. The principal factors that must be addressed for surfactants to large reservoirs are: the stability of the film on the water; the film's self-healing properties; and, the ability to spread the film on the water surface (Gupta et al., 2002).

New Technologies and Status

There are commercial products using advanced surfactant chemistry now available on the market to apply to water surfaces to reduce evaporation. One such product is Water$aver®, produced by Flexible Solutions International, a U.S. firm. Using food-grade chemicals (fatty alcohol) to form a molecular monolayer, it claims evaporation reductions of up to 40 percent with application every 2 to 2½ days. The largest water surface to which Water$aver has been applied, for which documentation could be located, was a 3 hectare (7.4 acre) industrial pond in Chennai, India, where experiments conducted by the Anna University (Flexible Solutions International, 2002) resulted in 25 to 40 percent savings (Capitol Reports, 2002).

Specifically referencing the needs for reducing evaporative losses from large reservoirs in arid climates, the Department of Energy's Sandia National Laboratories (SNL) completed initial research on two surfactant formulations (Gupta et al., 2002). The researchers conducted controlled small-scale experiments in laboratory and out-of-door settings evaluating the molecular monolayers mixed with organic solvents.

The SNL is also interested in exploring biosurfactants, organic surfactants produced by bacteria. Contemporary work with biosurfactants has resulted in evaporation retardation at about half the efficiency of other surfactants. If the efficiencies could be improved, there is the potential that the costs per unit of surfactant manufactured could be reduced dramatically, along with the possibility of onsite surfactant production (Hightower, 2002).

Infrastructure Development Requirements

It is likely that any surfactant product that would be used for regional water management purposes would be developed, marketed, and applied by the private sector. Accordingly, all infrastructure development would not be an issue for water managers. However, should the potential of onsite production be realized for biosurfactants, water management interests could be involved in the construction and management of the production facilities.

Total Time to Implement

Although the molecular monolayer approach to reduce evaporation is well-established, it is impossible to predict when, or even if, a surfactant will be developed that is effective in reducing evaporative losses from large reservoirs. It is apparent that more research and development of surfactants is required. Additional funding within the private sector will be driven by business decisions; funding within the public sector will be driven by public policy, national budget, and priority considerations. This is an attractive area for public/private funding partnerships, as well as interagency funding collaboration.

5.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Increasing water supplies through the application of surfactants would not affect water demand.

Effect on Water Supply

The purpose of reducing reservoir evaporative losses is to increase water supply.

- *Water Saved*

The Middle Rio Grande Water Assembly's intent of exploring the feasibility of using surfactants is to reduce evaporative losses from Elephant Butte Reservoir. Although there is not a surfactant proven to work effectively on large reservoirs, for the purposes of this discussion, current product information is extrapolated to Elephant Butte Reservoir.

The range of water savings that could be realized is dependent upon the effectiveness of the surfactant, the volume of water in the reservoir, and evaporation rates. Assuming a 50 percent reduction in evaporation (range 25 to 70 percent), and a year-round application of the surfactant to Elephant Butte Reservoir, annual savings as summarized in Table 45A-8 could be realized.

Table 45A-8: Hypothetical Evaporative Savings Using a Surfactant on Elephant Butte Reservoir

Elephant Butte Pool Size (ac-ft)	Untreated Average Annual Evaporation Losses (ac-ft)	Treated Average Annual Evaporation / Evaporative Savings (ac-ft)	Annual Tons of Product [a]
200,000	45,000	27,500	244
1,000,000	127,000	63,500	689
2,000,000	214,000	107,000	1,160

[a] Assuming application rates recommended by Water$aver, with year round applications every 2½ days.

5.1.2 Environmental Impacts

Environmental impacts of molecular monolayer surfactants still require research. However, Water$aver has received the designation as an "Environmentally Sound Technology" from the United Nation's International Environmental Technology Center (Capital Reports, 2002). Flexible Solutions International states that the use of food-grade chemicals results in no negative impact on the oxygen levels in the water, water temperature, nor aquatic life. The product "can be used safely and effectively to preserve water resources including raw water supplies, reservoirs, canals, lakes, ponds and recreation areas." (Capital Reports, 2002).

The SNL, in its recent experiments, simply had a gold fish in each of the out-of-door pools. The fish did not appear to be affected by the surfactant. Additionally, no differences were observed in dissolved oxygen measurements between the treated and untreated pool during the multiple-month experiment (Gupta et al., 2002).

5.2 Financial Feasibility

It must be stated clearly and unequivocally that *presently there is no surfactant available with a proven ability to function on a large reservoir*. With that said, the cost for the surfactant alone in the SNL's controlled small-scale experiments, was about $30 per acre foot of evaporative water saved (Gupta et al., 2002). The application of Water$aver in the example cited above, cost about $250 per acre foot of evaporative water saved (Flexible Solutions International, 2002).

5.2 Conclusions

Surfactants that would be effective in reducing evaporative losses from large reservoirs is still in the research stage. It is unknown whether or not such a product will ever be developed. However, because of the potential water savings benefits and potential cost effectiveness, research should be continued in this area. Funding is a limitation, so the supporting public should, in coordination with universities and other research organizations such as Sandia National Laboratories, petition legislators for federal and stated efforts by increasing funding for continued research in this area.

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[1] The City of Albuquerque also has the right to store up to 50,000 ac-ft of San Juan-Chama Project water in Elephant Butte Reservoir.

[2] Includes 96,200 ac-ft (annual firm yield) of San Juan-Chama Project water from Heron Reservoir.

[3] Includes 2,510 ac-ft of middle Rio Grande valley San Juan-Chama Project water in Abiquiu Reservoir under short-term contracts with the USACE in 2001.

[5] The Indian Camp Dam was proposed to be built on the Rio Grande del Rancho, about 10 miles south of the Town of Taos. The 155 ac-ft of annual water savings would be realized if the entire capacity of the reservoir (less a small "dead pool") were dedicated to Elephant Butte storage, moving 5,000 ac-ft from a 100,000 ac-ft Elephant Butte.

[6] The analyses were based on 1967 to 1987 actual flow records, which were projected 19½ years from a start date of, and reservoir conditions as of, September 1988.

[7] Public Law 100-52 authorized the storage of native water in the 200,000 ac-ft conservation space previously authorized solely for the storage of San Juan-Chama Project water.

[8] The USACE, in its 1989 *Reevaluation of the Rio Grande Operating Plan Report* estimated at the time that the construction costs for Wagon Wheel Gap Dam and Reservoir would be $300 million to $500 million. The source of the estimate is unknown.

[9] Additional cost due to a more distant sediment disposal site.

[10] Actual 1993 costs of removing and disposing 53 ac-ft of sediment in the dry at $7,517/acre foot, indexed to January 2002 costs.

Technical and Physical Feasibility Fact Sheet
Alternative 46: Aquifer Storage

Acknowledgements: This fact sheet was written by Mark Miller of Daniel B. Stephens & Associates, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-46: Inject water treated to drinking water standards for aquifer storage in appropriate locations throughout the water planning region.

2. Summary of the Alternative Analysis

Aquifer storage and recovery (ASR) applications could potentially prove beneficial for water supply in the Middle Rio Grande (MRG) planning region. ASR is traditionally defined as the injection and recovery of water using dual-purpose ASR wells (Pyne, 1995). However, this analysis considers a broader definition of ASR applications, including additional approaches to increase aquifer recharge that have been implemented successfully in ASR projects nationwide.

ASR can be used as a tool for better management of existing supplies, such as saving water lost to evaporation or reusing treated wastewater. In general, water in the Rio Grande is fully appropriated; however, ASR approaches may help to improve the management of available supplies.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

ASR is being used increasingly in the U.S. to assist in managing water resources, particularly in the arid southwest and in coastal areas. In the southwest, projects have been implemented in El Paso, Texas; Phoenix and Tucson, Arizona; Orange County, California; Las Vegas, Nevada;

and Salt Lake City, Utah. ASR has not yet been implemented on a large scale in New Mexico, but the Cities of Albuquerque and Alamogordo have ASR projects in the planning stage. In the coming years, ASR is likely to become increasingly important in New Mexico, as it has in other parts of the southwest.

ASR can provide a tool for conjunctive use of groundwater and surface water resources, and can offer the following advantages for improved water management:

- Replenishment of aquifer depletions
- Reduction of land subsidence rates
- Storage of excess surface water including flood flows
- Storage of water during low-demand seasons for use during high-demand seasons
- Reuse of treated wastewater effluent
- Storage of water without the evaporative losses of surface reservoir storage
- Acquisition of return flow credits to groundwater
- Improved water quality during the transport of water through a porous geologic medium

Enabling legislation that allows for ASR was passed by the New Mexico Legislature in 1999. The Ground Water Storage and Recovery Act (NMSA 1978, §72-5A-20) provides the legal mechanism for public entities to retain rights to withdraw water that is recharged to an aquifer. Water can be stored and recovered only by permit (NMSA 1978, §72-5A-6).

ASR must be conducted in conformance with the permit requirements of the New Mexico Office of the State Engineer (OSE) Underground Storage and Recovery Regulations (19.25.8 NMAC, effective January 31, 2001). The OSE decides whether recharged water is fully recoverable or whether an unrecoverable loss occurs. The OSE will also have to approve appropriations and/or examine possible surface flow impacts, depending on the type of ASR project.

Infrastructure Development Requirements

ASR involves artificial recharge to an aquifer and subsequent recovery of the water for later use. Various types of artificial recharge facilities are described below.

Infiltration basins: Infiltration basins (spreading basins or recharge basins) are shallow ponds with permeable bottoms that are designed to maximize downward infiltration of water. Infiltration basins also provide a beneficial effect on water quality as a result of soil-aquifer treatment (SAT) (Bouwer, 1992), and infiltration basins are the most common recharge method for treated municipal wastewater. Although evaporation is sometimes perceived as a drawback of infiltration basins, evaporative losses for properly functioning infiltration basins total no more than 1 to 2 percent of inflow. Enhanced recharge along surface water channels using in-channel or off-channel infiltration basins is successful at many locations in Arizona and California.

Injection wells: Injection wells may be used for aquifer recharge and groundwater recovery (Bouwer, 1996). Injection wells are categorized into three basic types:

- *Vadose zone wells* (also called "dry wells") are large-diameter wells completed above the water table.
- *Infiltration galleries* (also called seepage trenches) are trenches backfilled with permeable, coarse gravel with perforated pipe to introduce water.
- *Groundwater injection/withdrawal wells* (also called ASR wells) are dual-purpose wells, which can be converted from existing supply wells.

Water injected directly into an aquifer must comply with U.S. Environmental Protection Agency (EPA) drinking water standards and New Mexico Water Quality Control Commission (NMWQCC) groundwater standards. To meet these standards, water from various surface water or wastewater sources will require various levels of treatment prior to injection.

Total Time to Implement

Because of the importance of site-specific hydrogeologic variables, ASR projects are best implemented using a phased approach that begins with pilot studies and progresses to implementation of the full-scale system (ADWR, 1999). A pilot scale project is required under the OSE regulations (19.25.8 NMAC) prior to full-scale implementation.

The timeframe to implement an ASR project varies depending on the nature and scale of the project. General implementation times are as follows:

- Enhanced arroyo recharge: 1 to 2 years
- Recharge treated municipal or industrial wastewater through infiltration basins: 4 to 6 years
- Recharge treated Rio Grande water through ASR wells: 5 to 10 years

The City of Albuquerque is about midway through a seven-year schedule for an ASR project using treated San Juan-Chama Project water injected and recovered using existing supply wells (COA Public Works, 2002).

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

ASR will not affect water demand.

Effect on Water Supply (surface and groundwater)

ASR may enable improved management of water supplies within the MRG planning region. Water sources that may be used for ASR in the region include:

- San Juan-Chama Project water
- Seasonal surface water and storm water flow
- Water transferred from surface reservoirs to subsurface storage
- Treated municipal and/or industrial wastewater

The effect of using these sources for ASR is described in the Water Saved/Lost section.

Water Saved/Lost (consumption and depletions)

The effectiveness of ASR at sites around the U.S. and the world is well documented. ASR can save and store water that would otherwise be lost to evaporation or would be lost downstream during flood events (Bouwer and Rice, 2001).

There may be legal limitations (i.e., Rio Grande Compact and water rights) to the use of water from ASR projects, as discussed in the legal fact sheets (*Evaluation of Alternative Actions for Legal Implications, Issues, and Solutions)*. The estimates provided in this section address only the physical availability of additional supplies. The amount of water saved depends on the type and scale of the ASR project:

- Small-scale enhanced recharge projects can potentially provide recharge on the order of 100 to 10,000 acre-feet per year (ac-ft/yr), a fraction of the annual flow measured in some of the region's larger arroyos (Thorn et. al., 1993). These savings are based on the assumption that any recharged water results in additional water supply to the MRG planning region, since normally much of the water is lost to evaporation without reaching the Rio Grande or groundwater supplies. Hence any additional supply from this alternative represents a net gain.
- Large-scale ASR projects can potentially recharge approximately 100,000 ac-ft/yr. This is comparable to the difference in evaporative losses from Elephant Butte Reservoir at low lake levels (50,000 ac-ft/yr evaporation) and at high lake levels (250,000 ac-ft/yr evaporation) (S.S. Papadopulos & Associates, Inc., 2000).
- ASR is one method of storing excess water that may be available during Elephant Butte spill years. Discussion of the magnitude of spills is provided in Alternative 38, Surface Modeling.

Impacts to Water Quality (and mitigations)

Treatment requirements for stored water must meet drinking water standards at the point of use in the aquifer. This can be done in two ways:

- Water that will be injected directly to an aquifer through recharge wells must be treated to meet drinking water standards before injection, or
- Water that will recharge through infiltration basins will be "polished" to achieve drinking water quality at the compliance point in the aquifer (Bouwer, 1996; Amy et. al., 1993).

Aquifer storage must comply with the requirements of the NMWQCC and the Underground Injection Control (UIC) Program. These regulatory requirements are administered by the New Mexico Environment Department (NMED) under the Water Quality Act (NMSA 1978, §74-6-1 et seq.), and the NMWQCC and UIC regulations (20.6.2.5000 NMAC). If the water source contains contaminants that could potentially impact groundwater (as determined by NMED), an approved groundwater discharge plan is required.

Two major health effects studies in California have shown that 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, even if the treated influent water meets all drinking water standards, there may still be concerns over the possible presence of pharmaceuticals and endocrine disrupting chemicals, and consideration of the need for reverse osmosis treatment to remove them (Sedlak, 1999). In the MRG region, the recent analyses of Rio Grande surface water and City of Albuquerque wastewater effluent has shown the concentration of nearly all measurable synthetic organic compounds to be below detection limits (Thompson and Chwirka, 2002).

Watershed/Geologic Impacts

ASR can offset water level declines and reduce land subsidence rates (Bouwer, 2002). Areas with significant drawdown will benefit from increased recharge. These areas also provide water table conditions that are conducive to ASR, because recharged water will be fully captured (Thorn et al., 1993).

3.1.2 Environmental Impacts

Impact to Ecosystems

ASR could impact flows in the Rio Grande and its tributaries, and specific projects should evaluate these impacts. Using ASR to replace storage in surface reservoirs will impact the habitat associated with the reservoir.

Implications to Endangered Species

ASR projects should not have a direct impact on endangered species. However, depending on the source water and the timing of releases to and from storage, endangered species in the Rio Grande may be positively or negatively impacted. Reduced flows in the Rio Grande could affect endangered species and should be managed to avoid adverse affects. Conversely, endangered species could benefit from an ASR project to transfer Elephant Butte evaporative savings to aquifer storage, by including an option to pump water to the river during low flow periods.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

The cost to implement an ASR project will depend on many site-specific factors, including site hydrogeology and the water quality of the proposed influent. Costs to implement ASR at a given location may include expenditures associated with:

- Pilot testing
- Land acquisition
- Influent water pretreatment
- Permitting
- Design and construction

Table 46-1 outlines costs for three active projects in Arizona. These costs can be used to approximate design and construction costs for a system of infiltration basins.

Table 46-1. Example Infiltration Basin Costs

Project Name	No. of Basins	Total Basin Acreage	Infiltration Rate (ac-ft/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, or monitoring network.
[b] Granite Reef Underground Storage Project (Lluria, 1999; Bouwer, 2002.)
[c] Central Avra Valley Storage and Recovery Project (CAVSARP) and Sweetwater Project information from Marie Light (Tucson Water), personal communication, 1999.

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

3.2.2 Potential Funding Source

- New Mexico Legislative appropriation
- New Mexico Finance Authority loan
- NMED Construction Programs Bureau loan
- U.S. Department of Agriculture Rural Utilities Service
- Local financing (revenue bonds)

3.2.3 Ongoing Cost for Operation and Maintenance

Operation and maintenance (O&M) costs for the Granite Reef Underground Storage Project infiltration basins in Arizona are $250,000 per year for 100,000 ac-ft/yr recharged or $2.50 per ac-ft/yr. Additional O&M cost details are provided below.

Cost Evaluation Scenarios

To provide a preliminary basis for determining the cost feasibility for ASR projects in the MRG planning region, a variety of cost evaluation scenarios were established for a range of possible small- and large-scale projects. These cost evaluation scenarios are not intended as the basis for a complete feasibility analysis. The scenarios are described below, and Table 46-2 summarizes preliminary project cost estimates.

Enhanced arroyo recharge. The cost evaluation scenario for enhanced arroyo recharge considers capture of storm water along one or more major arroyos in the MRG planning region. Infiltration basins would be constructed adjacent to the arroyo(s) and small diversion structures would be used to divert storm flows into the basin. An OSE diversion permit would be required to capture the storm water. The project would benefit the aquifer and reduce groundwater depletions. The enhanced arroyo recharge scenario includes costs for the following project components:

- Infiltration basins covering 4 acres with a storage capacity of 50 ac-ft for recharge and a 0.5-acre sedimentation basin
- Diversion structure across the arroyo to route storm water into the infiltration basin
- Purchase of a 10-acre tract of land
- Engineering design and permitting
- Operation and maintenance to clean accumulated sediments

Enhanced arroyo recharge could provide significantly higher recharge to the underlying aquifer than is experienced under natural infiltration through arroyo bottoms. Previous studies of recharge from arroyos show that short-duration storm events contribute little recharge, but the impoundment of water in deeper basins can recharge significant volumes (Hansen and Gorbach, 1997). Large arroyos in the region that are gaged have average annual flows of a few

Table 46-2. Preliminary Cost Projection
Cost Evaluation Scenarios for Aquifer Storage and Recovery Projects
Mid-Region Council of Governments

Item No.	Item Description	Unit		Unit Cost	Quantity		Cost
	Enhanced Arroyo Recharge						
1.0	Infiltration basin	acre	$	54,000.00	5	$	259,200
2.0	Diversion structure	lump sum	$	100,000.00	1	$	100,000
3.0	Land purchase	acre	$	10.00	5000	$	50,000
4.0	Design and permitting	lump sum	$	34,000.00	1	$	34,000
5.0	Operation and maintenance	annual	$	2,000.00	40	$	80,000
					Subtotal	*$*	*523,200*
					Contingency @ 20%		*104,640*
					Grand Total	**$**	**627,840**
		Annual water stored (acre-feet)					**200**
		Water cost per 1000 gallons (stored)					**$0.24**
	Treated Municipal Wastewater Recharged via Infiltration Basins						
1.0	Tertiary wastewater treatment upgrades	lump sum	$	11,000,000.00	1	$	11,000,000
2.0	Pipeline	mile	$	71,000.00	5	$	355,000
3.0	Infiltration basins	acre	$	54,000.00	15	$	810,000
4.0	Extraction wells	foot	$	6,000.00	70	$	420,000
5.0	Land purchase	acre	$	10,000.00	40	$	400,000
6.0	Design and permitting	lump sum	$	1,260,000.00	1	$	1,260,000
7.0	Operation and maintenance	annual	$	3,200,000.00	40	$	128,000,000
					Subtotal	*$*	*142,245,000*
					Contingency @ 20%		*28,449,000*
					Grand Total	**$**	**170,694,000**
		Annual water produced (acre-feet)					**5,500**
		Water cost per 1000 gallons (produced)					**$2.38**
	Transfer Elephant Butte Storage and Flood Waters to Aquifer Storage						
1.0	Infiltration galleries	mile	$	500,000.00	7	$	3,500,000
2.0	Pipelines	mile	$	1,550,000.00	50	$	77,500,000
3.0	Infiltration basins	acre	$	54,000.00	250	$	13,500,000
4.0	Extraction wells	foot	$	28,000.00	70	$	1,960,000
5.0	Land purchase	acre	$	10,000.00	500	$	5,000,000
6.0	Design and permitting	lump sum	$	955,000.00	1	$	955,000
7.0	Operation and maintenance	annual	$	5,850,000.00	40	$	234,000,000
					Subtotal	*$*	*336,415,000*
					Contingency @ 20%		*67,283,000*
					Grand Total	**$**	**403,698,000**
		Annual water stored (acre-feet)					**100,000**
		Water cost per 1000 gallons (stored)					**$0.31**

Notes: Costs are preliminary estimates for planning purposes only. Because the estimates are preliminary, the Water Assembly requested that costs for each alternative be compared based on 2003 dollars with no present worth adjustment.

hundred to a few thousand ac-ft/yr (Thorn et. al., 1993), and a significant fraction of the storm flow in an arroyo might be captured and converted to recharge.

Treated municipal wastewater recharged via infiltration basins. The cost evaluation scenario for recharging treated municipal wastewater using infiltration basins considers the addition of tertiary treatment capabilities to an existing wastewater treatment plant, construction of infiltration basins, and installation of extraction wells to recover the recharged water. The cost evaluation for this scenario considers the following project components:

- Tertiary wastewater treatment upgrades to produce 5 million gallons per day (mgd) at an existing wastewater treatment plant
- 5-mile conveyance pipeline to carry treated wastewater to the infiltration basins
- Infiltration basins covering 15 acres, subdivided by interbasin berms to provide operating flexibility
- Six extraction wells, each capable of producing 1,000 gallons per minute (gpm) to recover the recharged groundwater
- Purchase of a 40-acre tract of land
- Engineering design and permitting
- Operation and maintenance including: operation of the tertiary wastewater treatment system, effluent pumping, pipeline maintenance, cyclic flooding and drying of the basins, and groundwater pumping.

ASR with treated wastewater potentially provides a method to use wastewater for future groundwater supply, following additional polishing of the water through SAT. This scenario describes a mid-sized project with a total flow to the infiltration basins of 5,600 ac-ft/yr. Evaporative losses are expected to be in the range of 50 to 100 ac-ft/yr, or 1 to 2 percent of total flow. For a site in the Middle Rio Grande Basin, where potable groundwater is present in the aquifer, the entire recharge volume is expected to be recoverable from the aquifer (Pyne, 1995). Treated wastewater ASR projects of various sizes may potentially be feasible, depending on the wastewater flow rates available in a give community and the community's balance of groundwater rights and return flow requirements to surface water.

Aquifer storage for Elephant Butte evaporation savings and Rio Grande flood waters. This cost evaluation scenario envisions a significant change in water management practices for the MRG planning region. The scenario involves lowering the average Elephant Butte lake level to reduce average reservoir storage by approximately 1,000,000 ac-ft, which would provide an average evaporative savings of approximately 100,000 ac-ft/yr. This would result in lake levels similar to the average level for the 30-year period from about 1950 to 1980 (S.S. Papadopulos, 2000). In addition, under this scenario some supplemental water might be captured from excess flood flows in the Rio Grande during years when spills are forecast at Elephant Butte dam and no Compact credit or debit is computed.

The estimated evaporative savings and period flood waters would be diverted from the middle Rio Grande far upstream of the reservoir, and recharged in the Albuquerque Basin aquifer. New production wells would be needed to deliver water from aquifer storage to the Rio Grande during times of low flow, to meet Compact obligations and make up for reduced surface reservoir storage. The cost evaluation scenario considers the following project components:

- 7 miles of infiltration galleries to collect Rio Grande water from shallow alluvium near the river
- Five conveyance pipelines, each 10 miles long and capable of carrying 22,000 ac-ft/yr (20 mgd) to the infiltration basins
- Five infiltration basins each covering 50 acres to recharge the aquifer.
- 40 extraction wells, each capable of producing 1,000 gpm to deliver storage to the Rio Grande during times of low flow.
- Purchase of five 100-acre tracts of land
- Engineering design and permitting
- Operation and maintenance including: infiltration gallery and pipeline pumping and maintenance, cyclic flooding and drying of the basins, and periodic groundwater pumping to the Rio Grande during low-flow years.

In addition to the costs listed above, there would also be costs to address institutional, legal, economic, and social issues that would result from a large-scale water management change of this type.

The elimination of 100,000 ac-ft/yr in evaporative losses represents a 25 percent increase in available water supply over the average allocation to the MRG region under Compact delivery requirements (400,000 ac-ft/yr) (S.S. Papadopulos, 2000). To implement this alternative, significant legal and Compact issues would need to be addressed to establish the MRG region's right to use evaporative savings for actual wet-water uses. Additionally, concerns regarding recreational use of the Elephant Butte supply and economic impacts to the area surrounding the reservoir would need to be addressed.

Cost Summary

The cost evaluation scenarios are summarized in Table 46-2. This preliminary evaluation of the costs for ASR projects provides an initial estimate of the expected cost range. The two lowest cost scenarios are for enhanced arroyo recharge and transfer of Elephant Butte evaporation savings and flood waters to aquifer storage. These costs scenarios would provide water storage, but do not include pumping of the water to put the water to use. For aquifer storage, these scenarios have costs in the range of $0.24 to $0.31 per 1,000 gallons ($78 to $101 per ac-ft). The scenario for treated municipal wastewater recharged via infiltration basins includes extraction wells that deliver produced water for use. The cost projection for this scenario is $2.38 per 1,000-gallons ($775 per ac-ft).

The cost estimates are intended only for the purpose of a preliminary evaluation of the ASR option as compared to other water supply alternatives considered. Therefore, the cost estimates for each alternative are for 2003 costs, and adjustments for present worth have not been considered. Much additional study is needed to develop ASR plans more fully before a complete feasibility analysis can be made for specific projects.

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Alternative 46

Exhibit A
Detailed Discussion

Exhibit 46A: Detailed Discussion of Alternative 46—Aquifer Storage

Acknowledgements: This discussion, which follows the same basic format as the fact sheet it accompanies, provides additional details and information that support the conclusions presented in the fact sheet. It was written by Mark Miller of Daniel B. Stephens & Associates, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-46: Inject water treated to drinking water standards for aquifer storage in appropriate locations throughout the water planning region.

2. Summary of the Alternative Analysis

Aquifer storage and recovery (ASR) applications could potentially prove beneficial for water supply in the Middle Rio Grande (MRG) water planning region. ASR is traditionally defined as the injection and recovery of water using dual-purpose ASR wells (Pyne, 1995). However, this analysis considers a broader definition of ASR applications, including additional approaches to increase aquifer recharge. A variety of aquifer recharge methods have been successfully implemented in ASR projects nationwide.

ASR can be used as a tool for better management of existing supplies, such as saving water lost to evaporation or reusing treated wastewater. In general, water in the Rio Grande is fully appropriated; however, ASR approaches may help to improve the management of available supplies.

The analysis of ASR feasibility for the MRG water planning region includes the following:

- Potential water sources for ASR were examined that may provide increased wet water supplies. Such sources may include under-utilized surface water, evaporative savings, or treated wastewater.

- Applications of alternative ASR groundwater recharge methods were examined, including:

  - Injection wells (wells penetrating the aquifer, vadose zone or "dry" wells, and horizontal infiltration galleries)
  - Infiltration basins (also referred to as soil aquifer treatment or SAT)

- Successes and drawbacks of similar ASR projects in the western U.S. were investigated.

- The determination of ASR feasibility by the City of Albuquerque and plans to implement the ASR water treatment and injection system were examined.

- A preliminary cost assessment was completed using cost data from comparable projects. Costs for the following scenarios were considered:

  - Enhanced arroyo recharge using infiltration basins
  - Wastewater treated to sufficient standards for recharge with infiltration basins (SAT)
  - Rio Grande surface water recharged with infiltration basins to transfer Elephant Butte evaporation savings to aquifer storage

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

ASR is being used increasingly in the U.S. to assist in managing water resources, particularly in the arid southwest and in coastal areas. In the southwest, projects have been implemented in El Paso, Texas; Phoenix and Tucson, Arizona; Orange County, California; Las Vegas, Nevada; and Salt Lake City, Utah. In the region around Phoenix, Arizona, more than 20 full-scale artificial recharge projects are currently operating, with several of these having storage capacities in excess of 100,000 acre-feet (ac-ft) (Unangst et al., 1999). Source water for these projects is derived either from surface water or treated wastewater effluent. ASR has not yet been implemented on a large scale in New Mexico, but the City of Albuquerque is currently developing an ASR project to recharge treated San Juan-Chama water using the City's existing well field. The City of Alamogordo is developing plans for ASR, and has conducted pilot studies to recharge winter flow from springs that otherwise flows into the Tularosa Basin where it is lost from possible use. In the coming years, ASR is likely to become increasingly important in New Mexico, as it has in other parts of the southwest.

ASR can provide a tool for conjunctive use of groundwater and surface water resources, and can offer several advantages for improved water management. Potential benefits of ASR include:

- Replenishment of aquifer depletions
- Reduction of land subsidence rates
- Storage of excess surface water including flood flows
- Storage of water during low-demand seasons for use during high-demand seasons
- Reuse of treated wastewater effluent
- Storage of water without the evaporative losses of surface reservoir storage
- Acquisition of return flow credits to groundwater
- Improved water quality during the transport of water through a porous geologic medium

Enabling legislation that allows for ASR was passed by the New Mexico Legislature in 1999. The Ground Water Storage and Recovery Act, NMSA 1978, §72-5A-2 (Act), provides the legal mechanism for public entities to retain rights to withdraw water that is recharged to an aquifer. 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).

ASR must be conducted in conformance with the requirements of the New Mexico Office of the State Engineer (OSE) Underground Storage and Recovery Regulations (19.25.8 NMAC, effective January 31, 2001). These regulations govern the application process, the hydrologic, technical and financial capability report requirements, and the permit terms and conditions authorized under the Act. The OSE will decide whether recharged water is fully recoverable or whether an unrecoverable loss occurs. The OSE will also have to approve appropriations and/or examine possible surface flow impacts, depending on the type of ASR project considered.

Additional discussion of the enabling new technologies for ASR is presented in the following section on infrastructure development.

Infrastructure Development Requirements

ASR involves artificial recharge to an aquifer and subsequent recovery of the water for later use. Artificial recharge facilities include infiltration basins (recharge basins or spreading basins), infiltration galleries (recharge trenches), vadose zone recharge wells (dry wells), and combination groundwater recharge/recovery wells (ASR wells) (Bouwer, 1996). The various types of artificial recharge facilities are described below.

Infiltration basins: Infiltration basins, also know as spreading basins or recharge basins, are shallow ponds with permeable bottoms that are designed to maximize the downward infiltration of water. Where favorable geology exists, infiltration basins are generally the least costly means of recharging groundwater. Basins require (1) the presence of permeable soils or sediments at or near the land surface (2) an unconfined aquifer beneath, and (3) sufficient depth to groundwater. Shallow basins are generally used in order provide for periodic maintenance, consisting of draining the basin to remove the thin layer of sediment that accumulates on the basin floor, in order to maintain rapid infiltration rates.

Although evaporation is sometimes perceived as a drawback of infiltration basins, evaporative losses for properly functioning infiltration basins total no more than 1 to 2 percent of inflow. Infiltration rates from basins are generally in the range of 1 to 10 feet per day during periods of inundation (Bower et. al., 1990). Considering an average infiltration rate on the order of 2 feet per day for planning purposes in the MRG water planning region (Hansen and Gorbach, 1997) and typical evaporative losses of approximately 0.25 inch per day, then the evaporative loss amounts to just 1 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. Because of the water quality improvement provided by infiltration basins, recharge of surface water from the Rio Grande or other rivers in the MRG water planning region could potentially be performed without further treatment. Infiltration basins are also the most common recharge method used for treated municipal wastewater.

A disadvantage of infiltration basins is that they require relatively large areas of land to construct, as compared with recharge wells. Hansen and Gorbach (1997) indicate that the recharge required to balance withdrawals from the Middle Rio Grande Basin is 86,000 acre-feet per year (ac-ft/yr), which would require infiltration basin areas covering approximately 120 acres (or 717 ac-ft recharge per acre per year). Similar acreage requirements are shown for operating infiltration basins in Arizona, as described in more detail in Section 3.2.1.

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 to increase recharge of storm water flows. In-channel recharge is being successfully performed at several locations in Arizona and California.

Injection wells: Injection wells may also be used for aquifer recharge. Injection wells are categorized into three basic types:

- Vadose zone wells (also called “dry wells”)
- Infiltration galleries (also called seepage trenches)
- Groundwater injection/withdrawal wells (also called ASR wells)

Vadose zone wells (dry wells): Vadose zone recharge wells, also known as dry wells, are large-diameter wells completed above the water table. 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 and well depths of 100 to 200 feet are common. Thus, dry wells can be used in settings where low-permeable sediments may be present at shallow depths. Vadose zone wells require only a minimum amount of land, which is a particular advantage in urban settings.

The infiltration capacity of injection wells can be impaired by long-term clogging, which must be avoided since only limited maintenance of vadose zone wells is possible. 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.

Infiltration galleries (seepage trenches): Infiltration galleries or seepage trenches for recharge purposes are typically excavated using a trackhoe to depths of up to 15 or 20 feet below surface. The trench is backfilled with permeable coarse sand or gravel. Perforated pipe laid within 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. 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. 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.

Groundwater injection/withdrawal (ASR) wells: Groundwater recharge wells penetrate an aquifer and can be used either for injection or withdrawal of water. These wells are also referred to as ASR wells (Pyne, 1995). Because water can also be pumped out of the well, maintenance by periodic well redevelopment is possible. Existing water supply wells can be converted to allow injection as well as recovery, providing dual-use wells at a low cost. As with all wells, land requirements are minimal.

Water injected directly into the aquifer must comply with U.S. Environmental Protection Agency () drinking water standards or New Mexico Water Quality Control Commission (NMWQCC) groundwater standards. To meet these standards, water from surface water sources or wastewater effluent requires treatment prior to injection. For wastewater effluent, tertiary treatment is required, using methods such as reverse osmosis or other membrane filtration. Surface water, treated to drinking water standards can be injected and withdrawn from the same well. Treated wastewater is never withdrawn from the same well where it is injected; instead it is used to recharge groundwater that is withdrawn at some distance away, providing additional treatment and mixing of the injected water.

Total Time to Implement

Because of the importance of site-specific hydrogeologic variables, experience has shown that ASR projects are best implemented using a phased approach that begins with pilot studies and progresses to implementation of 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 with assurance that it will function as expected. A pilot scale project is required under the OSE regulations (19.25.8 NMAC) prior to full-scale implementation.

The timeframe to implement an ASR project varies depending on the nature and scale of the project. A range of example projects illustrates typical timeframes for planning purposes.

- *Enhanced arroyo recharge (1 to 2 years).* Project involves excavation of shallow basins and construction of small check dams, to retain and spread storm flows for increased recharge. Recovery would be indirect from existing supply wells in the area. The project would benefit the aquifer and reduce depletions; however, credit for the recharged water might not be sought from the OSE under the Underground Storage and Recovery Regulations.

- *Recharge treated municipal or industrial wastewater with recharge through infiltration basins (4 to 6 years).* Project involves design and construction of treatment works and infiltration basins. Land must be acquired for the basins and pipelines constructed. A supply well network must be designed and constructed to recover the water. A permit for the project must be obtained from the OSE, including the pilot test phase.

- *Recharge treated Rio Grande water through groundwater injection/withdrawal wells (5 to 10 years).* This is the approach planned by the City of Albuquerque, which involves design and construction of a water treatment plant and pipelines to existing supply wells that will be converted to injection wells. A diversion from the Rio Grande is required using a check dam or subsurface infiltration gallery. A permit for the project must be obtained from the OSE for the ASR aspects of the project, as well as approval for the water appropriation. The City of Albuquerque is about midway through a 7 year schedule for this project (COA, 2002).

Thus, simple enhanced recharge projects could be implemented quickly. However, any large scale ASR project will require several years for the design, permitting, and construction efforts.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

ASR will not affect water demand, except in a minor way, if demand is reduced because of the incrementally higher cost for this water under some scenarios (see Alternative 21, Urban Water Pricing).

Effect on Water Supply (surface and groundwater)

ASR may enable improved for management of water supplies within the MRG water planning region, allowing beneficial use of water sources that otherwise may be underutilized. Water sources that may be available in the region for potential ASR management include:

- San Juan-Chama Project water
- Seasonal surface water and storm water flow
- Water transferred from surface reservoirs to subsurface storage
- Treated municipal and/or industrial wastewater

ASR can provide a tool for improved management of existing water supplies, within the context of existing water rights, by storing water available during wet seasons or years, making this water available when needed. For example, the City of Albuquerque's planned ASR project provides for use of San Juan-Chama Project water, which will be injected during winter months, when demand is low, and pumped from the aquifer during summer months when demand is high. ASR can capture seasonal surface water flows, by increasing recharge of storm-water flows in arroyos. Certain ASR projects may reduce surface water flows, by capturing storm water or reducing wastewater return flows.

Because evaporative losses at Elephant Butte reservoir and other reservoirs are high, there could be potential water savings by lowering the lake level to reduce evaporative losses, making the evaporation savings available for other uses. The magnitude of evaporative losses that could be saved by changing surface reservoir storage is presented in the fact sheet for Alternative 45, Reservoir Management. ASR could also potentially be used to store excess Rio Grande flows and/or tributary flows, during times of flood conditions, when a spill is expected or occurring at Elephant Butte dam, and Rio Grande Compact credits and debits are not computed for the spill year. Additional information regarding the frequency and magnitude of Elephant Butte spills is provided in S.S. Papadopulos & Associates (2000).

Water Saved/Lost (consumption and depletions)

The effectiveness of ASR at sites around the U.S. and the world is well documented. ASR can provide water savings from improved conjunctive use management schemes, and ASR can save and store water that would otherwise be lost to evaporation or lost downstream when surface flows are under-utilized. ASR is effective at 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. Storm-water flood flows represent another potential water source for recharge of aquifers using ASR (Bouwer and Rice, 2001).

There may be legal limitations (i.e. Rio Grande Compact and water rights) to the use of water from ASR projects, as discussed in the legal fact sheets. The estimates provided in this section address only the physical availability of additional supplies. The amount of water saved depends on the type and scale of the ASR project:

- Small-scale enhanced recharge projects can potentially provide recharge on the order of 100 to 10,000 ac-ft/yr, a fraction of the annual flow measured in some of the MRG water planning region's larger arroyos (Thorn et. al., 1993). The enhanced recharge would add to the 10,000 to 30,000 ac-ft/yr recharge estimated under natural conditions from mountain front arroyos in the region [Anderholm, 2001]). These savings are based on the assumption that any water recharged results in additional water supply to the region, because normally, much of the flow in arroyos is lost to evaporation without reaching the Rio Grande or groundwater supplies (Hansen and Gorbach, 1997). Hence, any additional supply from this alternative represents a net gain. Additional information on the potential magnitude of recharge is provided in Section 3.2.3.

- Large scale ASR projects can potentially recharge on the order of a 100,000 ac-ft/yr (comparable to the difference in evaporative loss from Elephant Butte Reservoir of 50,000 ac-ft/yr evaporation at low lake levels to 250,000 ac-ft/yr evaporation at high lake levels [S.S. Papadopulos & Associates, 2000]).

- ASR is one method of that could potentially store a portion of the excess water available during Elephant Butte spill years, when Rio Grande Compact credits and debits are not computed. Discussion of the magnitude of spills is provided in Alternative 38, Surface Modeling.

Perhaps the greatest water savings that could be provided by ASR in the MRG water planning region would be to reduce Elephant Butte evaporation by maintaining consistently lower lake levels and store the water saved in subsurface aquifers. This type of large scale project would involve not only technical challenges, but would also have to overcome complex institutional issues such as recreational, agricultural, and environmental concerns, as well as legal issues such as Compact water delivery obligations.

Evaporation from Elephant Butte Reservoir amounts to approximately 20 percent of all water depletions in the Middle Rio Grande from Cochiti to Elephant Butte Reservoir (S.S. Papadopulos & Associates, 2000). Reducing storage in Elephant Butte Reservoir and transferring the evaporative savings to storage in the Albuquerque Basin could provide a significant quantity of water that is available for use. This approach would substantially reduce the water in storage in Elephant Butte Reservoir, and water would be withdrawn from the Rio Grande upstream for aquifer storage. S.S. Papadopulos & Associates (2000) shows that during the period of 1950 to 1980, storage in Elephant Butte was maintained at relatively low levels that kept evaporation losses in the range of approximately 30,000 to 130,000 ac-ft/yr. However, since 1980, storage has been maintained at much higher levels, with evaporation losses in the range of approximately 130,000 to 260,000 ac-ft/yr (S.S. Papadopulos & Associates, 2000). Annual evaporation losses are variable, but exceed 10 percent per year (see Alternative 45, Reservoir Management). Therefore, reducing surface reservoir storage by approximately 1,000,000 ac-ft and maintaining consistently lower average water levels in Elephant Butte, can save on the order of 100,000 ac-ft/yr. This is an average evaporative savings, which will be variable from year to year depending on surface water availability and seasonal reservoir management needs.

Many hurdles would have to be overcome to make this approach a reality. The infrastructure would have to be developed to draw Rio Grande water and recharge the water to the aquifer. A system of wells would also be needed to pump water to the river in order to deliver water downstream to meet Compact obligations during low-flow years, since less storage would be available for release from Elephant Butte. A drawback to this approach is that the rights to water saved from evaporation are not clearly defined at this time, and legislation addressing this issue may be needed. Using ASR in conjunction with transfers from Elephant Butte could be viewed favorably by the Interstate Stream Commission, because of the advantages obtained in managing instream flows to meet Compact obligations. Additional discussion of reservoir storage options is provided in Alternative 45, Reservoir Management.

Impacts to Water Quality (and mitigations)

Treatment requirements for stored water must meet drinking water standards at the point of use in the aquifer. This can be done in two ways:

- Water that will be injected directly to an aquifer through recharge wells, must be treated to meet drinking water standards before injection, or

- Water that will recharge through infiltration basins will be "polished" to achieve drinking water quality at the compliance point in the aquifer (Bouwer, 1996).

ASR provides an effective means of improving or "polishing" water quality with removal of contaminant as the water migrates through porous geologic media. Water quality improvements can be achieved by two mechanisms:

- Recharge using infiltration basins has been shown to reduce some trace constituents through soil aquifer treatment (SAT) as the water seeps from the basin to the aquifer (Nellor et al., 1984; Amy et. al., 1993; Sloss et al., 1996).

- Travel of injected water through an aquifer provides water quality improvement by mixing and dispersion within the native groundwater and chemical equilibration of the injected water with the native aquifer materials.

From a water quality standpoint, aquifer storage must comply with the requirements of the NMWQCC and the Underground Injection Control (UIC) Program. These regulatory requirements are administered by the New Mexico Environment Department (NMED) under the Water Quality Act (NMSA 1978, §74-6-1 et seq.), and the NMWQCC and UIC regulations (20.6.2.5000 NMAC). The regulations control liquid discharges to protect groundwater that has an existing concentration of 10,000 mg/L or less of total dissolved solids. If the water source contains contaminants that have a potential to impact groundwater, as determined by NMED, an approved groundwater discharge plan is required. The following summary presents general discharge plan requirements for ASR projects, subject to a final determination by NMED.

- Recharge to injection wells: Surface water or wastewater sources will require treatment to meet drinking water standards prior to discharge to the subsurface.

- Recharge of treated wastewater to infiltration basins: Municipal or industrial wastewater will require treatment prior to discharge to infiltration basins. Treatment to drinking water standards may be required, or treatment to a lesser standard may be permissible if SAT is demonstrated to provide sufficient treatment before the water reaches the aquifer.

- Recharge of surface water to infiltration basins: Treatment requirements for surface water diverted to infiltration basins will depend on the water quality and site-specific hydrogeologic setting where recharge will occur. This type of recharge may be considered by regulators to be similar to the recharge that occurs naturally in arroyos or seepage from irrigation canals.

The environmental implications of ASR projects depend largely on the quality of the proposed influent water. ASR projects using source water with relatively good quality, such as enhanced storm-water recharge, can be conducted without treatment of the recharged water (Bouwer et al., 1990). Projects involving reuse or recharge of wastewater effluent are receiving increasingly favorable public perception, because of the environmental benefits of recycling water for multiple uses. 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).

Assuming permitting issues for recharge of treated effluent can be resolved, ASR may potentially be an inexpensive and effective means of "polishing" water quality, using SAT, to remove trace constituents prior to consumption. 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.

Even if the treated influent water meets all drinking water standards, there may still be concerns over the possible presence of pharmaceuticals and endocrine disrupting chemicals in the treated surface water or effluent and consideration of the need for reverse osmosis treatment to remove them (Sedlak, 1999). These concerns over unregulated trace constituents are probably most significant for influent sources from treated wastewater, Rio Grande water, or storm water from developed areas. However, in the MRG water planning region, the recent analyses of Rio Grande surface water and City of Albuquerque wastewater effluent has shown the concentration of nearly all measurable synthetic organic compounds to be below detection limits (Thompson and Chwirka, 2002). Recharge of storm water flow in arroyos in relatively undeveloped areas will pose little concern with regard to trace pharmaceuticals. Additional discussion of wastewater treatment is provided in Alternative 27, Reuse Treated Effluent.

Watershed/Geologic Impacts

ASR can offset water level declines and reduce land subsidence rates (Bouwer, 2002). Areas with significant drawdown will benefit from increased recharge. These areas with substantial water level declines are conducive to ASR, because the water table conditions will fully capture the recharge (Thorn et al., 1993).

The technical feasibility of ASR within the study area depends primarily on (1) locating a suitable water source and (2) identifying a hydrogeologically suitable recharge site. In particular, arroyos and stream channels containing thick sequences of coarse-grained alluvium are ideal candidates. The extensive area of water table declines underlying the eastern portion of Albuquerque provide a basin that will capture recharged groundwater. The City of Albuquerque is considering this area for its ASR project. Suitable ASR project areas are potentially available at sites throughout the MRG water planning region.

Assuming that a suitable water source is available, the technical feasibility of ASR depends largely on hydrogeologic conditions underlying the area of interest, and site-specific hydrogeologic studies will be required within a given sub-basin to identify the preferred sites. Pilot testing is required to meet OSE regulations and to provide information necessary for developing a full-scale system that ensures that the chosen design will work at the site. Pilot testing provides information regarding hydraulic capacities, water table responses, water travel times, and water quality changes that may occur in the vadose (unsaturated) zone.

3.1.2 Environmental Impacts

Impact to Ecosystems

ASR could impact flows in the Rio Grande and its tributaries, and specific projects should be evaluate these impacts. Using ASR to replace storage in surface reservoirs will impact the habitat associated with the reservoir.

Implications to Endangered Species

ASR projects should not have a direct impact on endangered species. However, depending on the source water and the timing of releases to and from storage, there is a potential for either positive or negative impacts to endangered species in the Rio Grande. Reduced flows in the Rio Grande could potentially affect endangered species and should be managed to avoid adverse affects. Endangered species could potentially benefit from an ASR project to transfer Elephant Butte evaporative savings to aquifer storage, by including an option to pump water to the river during low flow periods.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

The cost to implement an ASR project 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, although costs for groundwater recharge wells are reduced substantially when existing water supply wells are converted to ASR wells (Pyne, 1995).

Costs to implement ASR at a given location may include expenditures associated with:

- Pilot testing
- Land acquisition
- Influent water pretreatment
- Permitting
- Design and construction

Permitting costs include both OSE and NMED permit requirements. OSE permits for ASR projects include requirements for pilot testing of the proposed technology at the site. While this is a cost factor for consideration, the information gained from pilot testing can result in much larger savings during implementation of full-scale ASR. OSE permitting for ASR projects is only allowable under New Mexico law, for government entities that meet certain financial capability requirements described in 19.25.8 NMAC. It is assumed for the purposes of this analysis of options, that local government entities within the MRG water planning region will be able to meet the financial capability requirements. Costs to obtain NMED permits for recharge of treated waste water effluent or surface water should also consider long-term permit compliance, including monitoring and permit renewals.

Table 46-1 outlines costs for three active projects in Arizona. These costs can be used to approximate design and construction costs for a system of infiltration basins.

Table 46-1. Example Infiltration Basin Costs

Project Name	No. of Basins	Total Basin Acreage	Infiltration Rate (ac-ft/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, or monitoring network.
[b] Granite Reef Underground Storage Project (Lluria, 1999;Bouwer, 2002)
[c] Central Avra Valley Storage and Recovery Project (CAVSARP) and Sweetwater Project information from Marie Light (Tucson Water), personal communication, 1999.

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

The capital costs for design and construction for two infiltration basin ASR projects have the following costs:

- Central Avra Valley Storage and Recovery Project: $9.3 million for 100,000 ac-ft/yr project or infrastructure cost of $94 per ac-ft/yr

- Sweetwater Project: $2 million for 14,000 ac-ft/yr project or infrastructure cost of $143 per ac-ft/yr

These typical costs for actual ASR projects are on the order of $100 to $150 per acre-foot of recharge water. Cost details for ASR scenarios that may be applied in the MRG water planning region are discussed below.

3.2.2 Potential Funding Source

- New Mexico Legislative appropriation
- New Mexico Finance Authority loan
- NMED Construction Programs Bureau loan
- U.S. Department of Agriculture Rural Utilities Service
- Local financing (revenue bonds)

3.2.3 Ongoing Cost for Operation and Maintenance

Operation and maintenance (O&M) costs for the Granite Reef Underground Storage Project infiltration basins in Arizona are $250,000 per year for 100,000 ac-ft/yr recharged or $2.50 per ac-ft/yr. Additional O&M cost details are provided below.

Cost Evaluation Scenarios

To provide a preliminary basis for determining the cost feasibility for ASR projects in the MRG water planning region, a variety of cost evaluation scenarios were established for a range of possible projects that may be considered. The hypothetical projects include small- scale and large-scale projects that may be used to augment water supplies and increase water management options. These cost evaluation scenarios are intended to provide a preliminary examination of the expected costs for various ASR projects. However, the cost evaluation completed for this analysis does not represent an analysis of actual project plans and is not intended as a complete feasibility analysis.

Detailed evaluations of ASR projects have been completed by the City of Albuquerque. The projects evaluated include:

- Treating Rio Grande water to drinking water standards with injection and recovery of the water using ASR wells. This project is currently being implemented by the City of Albuquerque.

- Treating municipal waste water for ASR. This project was analyzed in 1995, but has not been pursued.

Because these projects have been evaluated in detail, they are not included in the cost evaluation scenarios presented here. Three hypothetical ASR project scenarios are described below that are representative of other projects that may be feasible and warrant more detailed consideration. Table 46-2 summarizes preliminary project cost estimates.

Enhanced Arroyo Recharge

The cost evaluation scenario for enhanced arroyo recharge considers capture of storm water along one or more major arroyos in the MRG water planning region. Infiltration basins would be constructed adjacent to the arroyo(s) and small diversion structures would be used to divert storm flows into the basin. Bouwer et al. (1990) indicates that hundreds of successful enhanced recharge projects are in use in California. The project would provide enhanced aquifer recharge to improve the production and longevity of existing supply wells, but new supply wells are not assumed to be added as a component of the project. The project would benefit the aquifer and reduce groundwater depletions, but water rights credits would not be sought through OSE permitting of an ASR system. An OSE diversion permit would be required to capture the storm water. The project could be implemented at many locations in the region, but mountain front arroyos with the largest and most frequent flows may be the best candidates for an enhanced arroyo recharge project.

The enhanced arroyo recharge scenario considers the following project components:

- *Infiltration basin construction:* An infiltration basin that covers 4 acres would be excavated to a depth of 15 feet, providing a maximum storage capacity of approximately 50 ac-ft. In addition, a 0.5 acre sediment catch basin would be excavated to provide retention time to collect a majority of the suspended sediment to prevent clogging and reduced infiltration capacity in the main basin. Construction would involve primarily earthwork with only minor additional facilities such as site fencing and an access road.

- *Diversion structure:* A diversion structure would be constructed across the arroyo to route storm water into the sedimentation basin and infiltration basin. The diversion structure would be sized to capture most storm water, except providing a spillway for extreme flood events. A flow return from the infiltration basin to the arroyo would also be provided to prevent the basin from overtopping in flood events.

- *Land purchase:* A 10 acre tract of land would be purchased for a cost assumed to be $5,000 per acre. (In many cases, public entities may already own suitable property to eliminate the land purchase cost.)

- *Design and permitting:* The engineering design for the infiltration basin is assumed to be 10 percent of construction cost and permitting is assumed to be 5 percent of construction cost.

- *Operation and maintenance:* O&M would consist of annual cleaning of accumulated sediments by scraping a thin soil layer from the infiltration basin and removal of more extensive deposits from the sedimentation basin. Basin cleaning would be accomplished during a dry portion of the year. It is assumed that off-site uses of the sediment for fill purposes are available.

Enhanced arroyo recharge performance. Enhanced arroyo recharge could potentially provide significantly higher recharge to the underlying aquifer than experienced under natural infiltration through arroyo bottoms. Previous studies of recharge from arroyos shows that short-duration storm events contribute little recharge, but the impoundment of water in deeper basins can recharge significant volumes (Hansen and Gorbach, 1997). Estimates of mountain front recharge under existing conditions on the east side of the Middle Rio Grande Basin range from 11,000 to 38,000 ac-ft/yr (Anderholm, 2001). However, this is only a small fraction of the overall storm water flows, with recharge rates being quite low due to the losses to evaporation and plant transpiration. By diverting the flow into a relatively small and deep infiltration basin, with no vegetation, the majority of storm water diverted to the basin will become deep infiltration and continue downward migration to the aquifer.

Most arroyos in the MRG water planning region are not gauged, leaving uncertainty as to the amount of storm water potentially available for enhanced recharge. Of the three largest arroyos in the Albuquerque Basin, only Tijeras Arroyo is gauged, while Abo Arroyo and Las Huertas Creek are not (Thorn et al., 1993). No arroyo draining the west side of the Albuquerque Basin is gauged (Thorn et al., 1993). The average annual flow for Tijeras Arroyo at the gauging station approximately 1.5 miles upstream of the Rio Grande is 432 ac-ft/yr (Thorn et al., 1993). The Abo Arroyo flow was gauged for a period of one year from October 1996 to September 1997, when a total flow of 12,400 ac-ft/yr was measured (Anderholm, 2001). Additional arroyo flow data are available for the Albuquerque metropolitan area, where storm water from many small arroyos is captured by two main storm conveyance channels. The North Floodway Channel carries an average annual flow of 5,900 ac-ft/yr and the South Diversion Channel carries an average annual flow of 520 ac-ft/yr (Thorn et al., 1993).

Enhanced arroyo recharge would only be able to capture a portion of the total storm flow, with the efficiency affected by the location and design of the facility. Also, a small portion of the flow already contributes to recharge under natural conditions. Where suitable soil conditions exist, infiltration from the basins may be on the order of 1 to 10 feet per day (Bouwer et al., 1990; Hansen and Gorbach, 1997). Evaporative losses from the free water surface will occur when water is present, and evaporative losses will also occur from the soil during dry periods. If a possible goal of 50 percent of the storm flow in an arroyo is captured and converted to recharge, enhanced arroyo recharge projects may provide recharge to the aquifer on the order of a few hundred to a few thousand ac-ft/yr, depending on the location and scale of a selected project.

Treated Municipal Wastewater Recharged via Infiltration Basins

The cost evaluation scenario for recharging treated municipal wastewater using infiltration basins considers the addition of tertiary treatment capabilities to an existing wastewater treatment plant, construction of infiltration basins, and installation of extraction wells to recover the recharged water. A permit for the project would be obtained from the OSE to protect the rights of the project owner to recover the recharged water. Treatment would provide for water quality that meets primary drinking water standards for the influent to the infiltration basins.

Under this scenario, SAT would provide for polishing of the water quality for secondary parameters, so that water quality in the aquifer and water derived from extraction wells is in compliance with all drinking water standards. Because existing wastewater treatment plants tend to be located in areas with relatively shallow water tables, where recharge basins will not perform well, the treated effluent would be pumped to a suitable location in an upland area, where the infiltration basins and extraction well field would be constructed.

The cost evaluation scenario for treated municipal wastewater recharged via infiltration basins considers the following project components:

- *Tertiary wastewater treatment additions:* Tertiary wastewater treatment would be added to an existing wastewater treatment plant with an average flow rate of 10 million gallons per day (mgd). However, because of obligations to return water to the Rio Grande system, it is assumed that only 5 mgd is available for ASR. Wastewater treatment standards for effluent reuse are described further in Alternative 27, Reuse Treated Effluent.

- *Pipeline:* A conveyance pipeline would be constructed to carry treated wastewater from the treatment plant to the infiltration basins. The pipeline is assumed to be 5 miles long and constructed of 18-inch diameter pipe with one pump station.

- *Infiltration basin construction:* A series of infiltration basins would be constructed that cover a total of 15 acres, subdivided by interbasin berms to provide operating flexibility. On-site facilities would consist of flow distribution piping, flow control systems, access roads, fencing, and a small operations building.

- *Extraction wells:* A well field of assumed to consist of 6 supply wells would be installed to recover the recharged groundwater. The wells are assumed to be installed to a depth of 1,000 feet, with each capable of producing flows of up to 1,000 gallons per minute (gpm).

- *Land purchase:* A 40 acre tract of land for the treatment plant would be purchased for the plant site at a cost assumed to be $10,000 per acre. It is assumed that existing municipal easements are available to allow installation of extraction wells and water lines. (In many cases, public entities may already own suitable property to eliminate the land purchase cost.)

- *Design and permitting:* The engineering design for the infiltration basin is assumed to be 10 percent of construction cost and permitting is assumed to be 5 percent of construction cost.

- *Operation and maintenance:* O&M would consist of cyclic flooding and drying of the basins, with periodic restoration of infiltration capacity by tilling or scraping a thin soil layer from the basin. O&M would also include operation of the tertiary wastewater treatment system, effluent pumping, pipeline maintenance, and groundwater pumping.

Treated municipal wastewater recharge performance. ASR with treated wastewater potentially provides a method to use wastewater for future groundwater supply, following additional polishing of the water quality through SAT. This scenario describes is a mid-sized project with a total flow to the infiltration basins of 5,600 ac-ft/yr. Evaporative losses are expected to be in the range of 50 to 100 ac-ft/yr or 1 to 2 percent of total flow. For a site in the Middle Rio Grande Basin, where potable groundwater is present in the aquifer, the entire recharge volume is expected to be recoverable from the aquifer (Pyne, 1995). The extraction wells may pump a total volume even greater than the recharge, producing a mix of native and recharged water under a combination of water rights for aquifer pumping and recharge. Treated wastewater ASR projects of various sizes may potentially be feasible, depending on the wastewater flow rates available in a give community and the community's balance of groundwater rights and return flow requirements to surface water.

Aquifer Storage for Elephant Butte Evaporation Savings and Rio Grande Flood Waters

This cost evaluation scenario to use aquifer storage for Elephant Butte evaporation savings from reduced surface reservoir storage and for capture of Rio Grande flood waters, envisions a significant change in water management practices for the MRG water planning region. Additional discussion of Elephant Butte reservoir storage options is provided in Alternative 45, Reservoir Management, and a discussion of Compact delivery requirements is provided in S.S. Papadopulos & Associates (2000).

The scenario involves lowering the average Elephant Butte lake level to reduce average reservoir storage by approximately 1,000,000 ac-ft, which would provide an average evaporative savings of approximately 100,000 ac-ft/yr. This may prove feasible from the standpoint of Compact compliance, since the lake was at this lower average lake level for a 30 year period from about 1950 to 1980 (S.S. Papadopulos & Associates, 2000). The estimated evaporation savings would be diverted from the Rio Grande far upstream of the reservoir, and recharged in the Albuquerque Basin aquifer. This scenario represents the probable upper limit of evaporative savings that could be achieved, with ASR providing storage of the water saved. Alternative 45 (Reservoir Management) also presents a smaller scale ASR project, with reductions in Elephant Butte reservoir storage of 50,000 to 100,000 ac-ft to provide evaporative loss savings of approximately 5,000 to 13,000 ac-ft/yr.

In addition, under this scenario some supplemental water might be captured from excess flood flows in the Rio Grande during years when spills are forecast at Elephant Butte dam, and no Compact credit or debit is computed. These spills have occurred during just six years since 1940 (S.S. Papadopulos & Associates, 2000); therefore, these additional gains would occur only rarely, as a secondary component of the aquifer storage project.

To collect 100,000 ac-ft/yr of Rio Grande water, this scenario assumes that this could be achieved using infiltration galleries parallel to the river (Hansen and Gorbach, 1997). However, other approaches for diversion may prove more advantageous, and the feasibility of infiltration galleries would depend on hydrologic conditions in the locations selected for the infiltration galleries. In this scenario, infiltration galleries were selected in order to collect water that is free of suspended sediment and suitable for recharge (Hansen and Gorbach, 1997). Water withdrawals would be continuous, not just during flood flows. During low flow periods of drought, withdrawals from the infiltration galleries might need to cease to minimize river depletions.

The water would be recharged through a series of infiltration basins at various locations selected for their suitable soils and geologic conditions and to distribute the recharge within the basin. The water is assumed to be recovered by existing supply wells, so no new recovery wells are included in the scenario.

In addition, new production wells would be needed to deliver water from aquifer storage to the Rio Grande during times of low flow, to meet Compact obligations and make up for the reduced surface reservoir storage downstream. During the Compact history, debits have exceeded 70,000 ac-ft/yr only five times (S.S. Papadopulos & Associates, 2000). This scenario assumes a capacity to provide a flow rate of 50,000 ac-ft/yr as a reasonable expectation of the delivery rate to the Rio Grande, with debits occurring in years with higher delivery requirements. Management of the Rio Grande's surface reservoirs would be altered (see Alternative 45, Reservoir Management) and combined deliveries of surface water and groundwater would need to be sufficient to meet long-term Compact delivery obligations. Additional evaporative losses would occur during downstream delivery of water pumped from aquifer storage.

The cost evaluation scenario for transfer of Elephant Butte evaporation savings and Rio Grande flood water to aquifer storage considers the following project components:

- *Infiltration galleries:* A series of infiltration galleries would be constructed to collect Rio Grande water from shallow alluvium near the river. Based on a flow rate of 21 cubic feet per second (cfs) per mile (Hansen and Gorbach, 1997) a minimum of 7 miles of galleries would be needed to collect 100,000 ac-ft/yr. Costs are $500,000 per mile (Hansen and Gorbach, 1997).

- *Pipelines:* Conveyance pipelines would be constructed to carry water to the infiltration basins. Five pipelines are assumed to be constructed to the various basins, with each pipeline averaging 10 miles in length and constructed of 36-inch diameter pipe with two pump stations. Each pipeline is assumed to be capable of providing a flow of 20 million gallons per day (gpd) or 22,000 ac-ft/yr.

- *Infiltration basin construction:* Five infiltration basins would be constructed so that each would include 50 acres of basin area, subdivided by interbasin berms to provide operating flexibility. On-site facilities would consist of flow distribution piping, flow control systems, access roads, fencing, and a small operations building.

- *Extraction wells:* A series of 40 supply wells would be installed to produce water for discharge to the Rio Grande during times of low flow. The wells would be located in the inner valley in close proximity to the river. The wells are assumed to be installed to a depth of 700 feet, with each capable of producing flows of 1,000 gpm. Discharge to the river would be either by direct outfalls or existing irrigation drains.

- *Land purchase:* Five 100 acre tracts of land would be purchased for the infiltration basins at an assumed average cost of $10,000 per acre, with some basins constructed within existing public property. It is assumed that existing municipal easements are available to allow installation of extraction wells and water lines.

- *Design and permitting:* The engineering design for the infiltration basin is assumed to be 10 percent of construction cost and permitting is assumed to be 5 percent of construction cost.

- *Operation and maintenance:* O&M would consist of the following:

  - Periodic maintenance of the infiltration galleries.
  - Pipeline pumping from the infiltration galleries via a pump station at the source and second pump station along the pipeline. Periodic pipeline maintenance would be required.
  - Cyclic flooding and drying of the basins, with periodic restoration of infiltration capacity by tilling or scraping a thin soil layer from the basin.
  - Periodic groundwater pumping and discharge to the Rio Grande during low-flow years. Periodic well maintenance would be required.

A 40-year operating life is assumed in the cost evaluation scenario for O&M of the system. O&M costs include: electric power for all pumping components, labor, parts, equipment, and other expenses.

In addition to the costs listed above, there would also be costs to address institutional, legal, economic, and social issues that would result from a large-scale water management change of this type.

Performance of Aquifer Storage for Elephant Butte Evaporation Savings and Rio Grande Flood Waters

Transferring evaporation savings from reduced surface reservoir storage to groundwater storage could potentially provide, perhaps, the greatest quantity of additional water supply of any alternative that might be implemented in the MRG water planning region. Eliminating evaporative losses of 100,000 ac-ft/yr represents an increase in available water supply of 25 percent, over the average allocation to the region under Compact delivery requirements of approximately 400,000 ac-ft/yr (S.S. Papadopulos & Associates, 2000). In order to implement this alternative, significant legal and Compact issues would need to be addressed that establish the region's right to use evaporative savings for actual wet-water uses. Additionally, concern's regarding recreational use of the Elephant Butte supply and economic impacts to the area surrounding the reservoir would need to be addressed. The project described in this scenario would be a very large scale project, but the transfer of Elephant Butte storage to groundwater storage could also be done on a smaller scale, or could be implemented in various stages.

An important aspect of aquifer storage would be the added ability for water supply managers to use this water during drought years, when surface supplies are depleted. The scenario envisions an ability to pump stored groundwater to the Rio Grande to sustain flows during drought. The proposed well field of 40 wells is assumed to provide a flow to the Rio Grande of approximately 80 cubic feet per second (cfs). This could potentially benefit the silvery minnow and other endangered species, by providing this water from evaporative savings, rather than using other stored water supplies. Storage could be released from the aquifer at anytime, whereas supporting the endangered species with surface supplies during drought increases demand on already strained supplies.

Cost Summary

The cost evaluation scenarios are summarized in Table 46-2. This preliminary evaluation of the costs for ASR projects provides an initial estimate of the expected cost range. The cost estimates are preliminary and intended for planning purposes only; therefore, the cost estimates for ASR and each alternative considered are based on 2003 costs for comparison, and adjustments for present worth have not been considered.

The two lowest cost scenarios are for enhanced arroyo recharge and transfer Elephant Butte evaporation savings and flood waters to aquifer storage. These cost scenarios would provide water storage, but do not include pumping of the water to put the water to use. For aquifer storage, these scenarios have costs in the range of $0.24 to $0.31 per 1000-gallons ($78 to $101 per ac-ft). The scenario for treated municipal wastewater recharged via infiltration basins includes extraction wells that deliver produced water for use. The cost projection for this scenario is $2.38 per 1000-gallons ($775 per ac-ft). The major cost under this scenario is the cost of tertiary wastewater treatment, making this a relatively expensive option.

The cost estimates are intended only for the purpose of a preliminary evaluation of the ASR option as compared to other water supply options. Many ASR projects are potentially feasible, from small-scale projects that are relatively easy to finance, to large-scale projects that will probably require a combination of funding sources. Much additional study is needed to develop ASR plans more fully, before a complete feasibility analysis can be made for specific projects.

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Technical and Physical Feasibility Fact Sheet

Alternative 47: Water Quality

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1. Definition of Alternative

A-47: Identify, protect, and monitor areas vulnerable to contamination, and restrict domestic wells in sensitive areas.

2. Summary of the Alternative Analysis

The purpose of this alternative is to assess the potential for contamination to affect the water supply within the Middle Rio Grande (MRG) water planning region and to identify programs that can assist in protection of groundwater within the region. Contamination of water supplies is an issue particularly in areas with a high density of shallow wells, septic systems, leaking storage tanks, or other contaminant sources, and monitoring and protection programs are often focused on addressing these issues. This alternative is technically and physically feasible. However, substantial additional efforts to pursue this alternative are unnecessary as it largely falls under existing regulatory programs.

Much of the work necessary to identify vulnerable areas within the region has already been completed during preparation of the *Albuquerque/Bernalillo County Ground-Water Protection Policy and Action Plan* (Policy Coordinating Committee, 1995). Groundwater vulnerability for Bernalillo County has been assessed through use of the DRASTIC method (Aller et al., 1987), in which a numerical ranking system is applied to several parameters, including depth, recharge, aquifer and soil media, topography, vadose zone impact, and hydraulic conductivity. The results of this analysis, including a map of relative groundwater vulnerability for the county, are presented in the report *Vulnerability of Bernalillo County Ground-Water Resources* (CH2M Hill, 1990, Figure 3-3). The most highly vulnerable areas identified are those overlying the shallow valley-fill aquifers within the unconsolidated sediments along the Rio Grande and Rio Puerco. Four additional categories of relatively lower vulnerability were identified in this study.

However, detailed analysis of this type has not been performed in Sandoval and Valencia Counties. To date, the best analysis of aquifer vulnerability for these counties was conducted by Lee Wilson and Associates, Inc. (1979), who used a simpler analysis approach based on water depths and vadose zone protection. A map of relative groundwater vulnerability for the entire state is included in their report (Lee Wilson and Associates, Inc., 1979, Plate 2). The results for the Bernalillo County area shown in this map were very similar to those determined with the DRASTIC method, with the most highly vulnerable areas overlying the shallow valley-fill aquifer along the Rio Grande. Three additional categories of relatively lower vulnerability were identified in this study. Given the similarity of this study's Bernalillo County results to those determined from the DRASTIC method, the vulnerability zones defined for Sandoval and Valencia Counties in this study may be adequate for the purpose of pursuing this alternative.

Several existing monitoring programs are conducted under the regulatory jurisdiction of the New Mexico Environment Department (NMED):

- Monitoring of underground storage tank (UST) sites is overseen by the NMED Petroleum Storage Tank Bureau.

- Monitoring of active and closed landfills is overseen by the NMED Solid Waste Bureau.

- Monitoring of hazardous waste generators and hazardous waste treatment, storage, and disposal facilities is overseen by the NMED Hazardous Waste Bureau.

- Monitoring of mining sites and groundwater discharge plans is overseen by the NMED Groundwater Quality Bureau.

- Monitoring of Superfund sites and National Pollutant Discharge Elimination System (NPDES) permits is overseen by the U.S. Environmental Protection Agency (U.S. EPA) in conjunction with the NMED Groundwater Quality Bureau.

Nearly all readily identifiable potential sources of contamination located within identified vulnerable areas fall under the regulatory jurisdiction of one of these programs. Therefore, additional efforts to identify and monitor contaminant sources within vulnerable areas are largely redundant. There may be value, however, in tracking the progress of the existing programs within the region and participating in discussions with regulators regarding program priorities and regional water supply concerns.

The main contaminant sources relevant to the identified vulnerable areas of the planning region that are not completely included under existing regulatory jurisdiction are on-site domestic wastewater treatment systems (i.e., septic tanks). Bernalillo County has recently enacted a strengthened wastewater ordinance (Bernalillo County Municipal Code, 2001) to address this issue. The new ordinance is performance-based in that treatment requirements are determined by on-site physical conditions and an assessment of the potential risk that effluent from the site's system will contaminate groundwater. The risk depends on factors such as the thickness and quality of the soil, depth to water, and the size of the lot. Existing system upgrades are required to be implemented by January 1, 2015 or upon replacement or modification of the system or upon sale of the property, whichever occurs first. Additional requirements include a maintenance contract and operator's permit for each system.

The Bernalillo County wastewater ordinance can be used as a model for similar ordinances in Sandoval and Valencia Counties to address the issue of groundwater contamination from septic tank discharges in vulnerable areas.

The New Mexico Source Water Assessment and Protection Program (SWAPP) can be used to address monitoring and control of potential sources of contamination near public water supplies. This is a federally funded program overseen by the U.S. EPA that assists communities in protecting their drinking water supplies. Specifically, the New Mexico SWAPP will assist local communities in:

- Determining the source water protection area for the water system
- Taking inventory of actual and potential contaminant sources within the source water protection area

- Determining the susceptibility of the source area and water system to contamination
- Reporting the SWAPP findings to the water utility, its customers, and the community
- Working with the community and other stakeholders to implement source water protection measures that safeguard and sustain the water supply into the future

This existing program can thus be utilized to address this issue with minimal additional cost to the local community. Within Bernalillo County, the *Albuquerque/Bernalillo County Ground-Water Protection Policy and Action Plan* (Policy Coordinating Committee, 1995) has already addressed this issue. For Sandoval and Valencia Counties, communities can contact the New Mexico SWAPP (http://www.nmenv.state.nm.us/dwb/swapp.html) to participate in this program.

The issue of restricting wells in sensitive areas is more of a political issue than a technical one. Under New Mexico Water Law, the New Mexico Office of the State Engineer must grant a permit to those wishing to drill a domestic well. Several efforts to change this provision have been advanced in recent years, but all have encountered political opposition.

Furthermore, domestic wells are more of a water rights and aquifer capacity issue than a water quality one. Septic systems, not domestic wells, are the source of groundwater contamination. Restricting wells will limit public exposure to contaminated groundwater, but will not alleviate the regional water contamination issue. As discussed above, enactment in Sandoval and Valencia Counties of strengthened on-site wastewater treatment ordinances modeled after the Bernalillo County ordinance is likely the best approach to address the issue of regional water contamination from septic tanks within the planning region.

If the goal is to protect public health, a program to encourage water testing by domestic well owners, coupled with a public education program that provides information relevant to health hazards associated with contaminated water, would be an effective approach. Bernalillo County formerly offered free water testing for nitrate and coliform bacteria to domestic well owners, but has discontinued this program. A free water testing program would be very helpful in identifying public health problems due to contaminated wells, essentially taking the place of a separate monitoring program.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

No new technologies are required for this alternative.

Infrastructure Development Requirements

No new infrastructure is required for development of groundwater protection programs. However, three issues related to these programs should be addressed:

- Additional monitoring wells may be needed in some locations. The installation of new wells may be best accomplished through an existing regulatory program.

- The development of source water/wellhead protection plans for Sandoval and Valencia Counties will require hiring or contracting technical personnel to work with the New Mexico SWAPP.

- Administrative efforts are required to develop and implement enhanced on-site wastewater treatment ordinances in Sandoval and Valencia Counties. Using the Bernalillo County ordinance as a model will minimize these efforts.

Total Time to Implement

Estimated time frames required to implement the various components of this alternative are:

- Development of source water/wellhead protection plans for Sandoval and Valencia Counties could be completed in less than one year.

- Development and implementation of enhanced on-site wastewater treatment ordinances in Sandoval and Valencia Counties could occur within approximately a one-year time frame, although possible political resistance by the public could affect this timetable.

- Regulatory programs addressing landfills, Superfund sites, USTs, and other sources of contamination are already in place.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

This alternative has no effect on water demand.

Effect on Water Supply (surface and groundwater)

Although this alternative does not create any new water supply, it can preserve the practical usability of the existing water supply.

Water Saved/Lost (consumption and depletions)

This alternative has no effect on the saving or losing of water.

Impacts to Water Quality (and mitigations)

Adoption of new on-site wastewater treatment ordinances in Sandoval and Valencia Counties and continued implementation and enforcement of the Bernalillo County ordinance will eventually improve water quality by limiting contamination from septic system discharges. Continued operation of other existing regulatory programs will be beneficial to the water quality in the region.

Watershed/Geologic Impacts

Water quality improvements resulting from implementation of on-site wastewater treatment ordinances will have a positive environmental impact.

3.1.2 Environmental Impacts

Impact to Ecosystems

This alternative will not impact ecosystems unless additional monitor well installations in identified vulnerable areas are considered.

Implications to Endangered Species

This alternative will not impact endangered species.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Costs for developing the Sandoval and Valencia County wastewater ordinances are minimal. Existing government employees in Sandoval and Valencia Counties can work with the New Mexico SWAPP to develop source water/wellhead protection plans and to develop and implement enhanced on-site wastewater treatment ordinances. Using the Bernalillo County ordinance as a model will minimize these efforts.

Costs for upgrading existing septic systems can be on the order of $5,000 to $20,000, depending on site conditions and system configuration (UNM Water Resources Program, 2001). Individual homeowners are responsible for paying for system upgrades; however, financial assistance may be available for low income families in Bernalillo County (UNM Water Resources Program, 2001). To effectively reduce potential septic contamination, additional financial support for homeowners may be necessary.

The associated costs for additional monitoring of groundwater quality in identified vulnerable areas, should it be desired, are high. Unit costs for recent New Mexico installations of 2-inch schedule 40 polyvinyl chloride (PVC) monitor wells in hollow stem auger borings up to 100 feet deep range from $12.50 to $16.00 per foot. Deeper monitor wells in the 100- to 200-foot range require rotary drilling and generally require 4-inch schedule 40 PVC wells; recent installation costs for such wells in New Mexico have typically been about $38.50 per foot. At greater depths, schedule 80 PVC is required, and a unit cost of about $52.50 per foot was recently incurred for a well of this type in Sandoval County.

3.2.2 Potential Funding Source

Sources of funding for this alternative vary by the component:

- The existing ordinance in Bernalillo County requires that the affected property owner cover all system upgrade expenses. Property tax increases could be used to aid homeowners affected by these enhanced wastewater ordinance upgrade requirements.

- Contaminant monitoring in vulnerable areas is under the jurisdiction of existing regulatory programs, and costs for the monitoring should be covered by the appropriate regulatory program or the responsible party.

- The prevention of contamination from septic tanks could be considered for Clean Water Section 319 nonpoint source grants, which are administered by the EPA.

3.2.3 Ongoing Cost for Operation and Maintenance

Once on-site wastewater ordinances have been established, homeowner assistance and enforcement will be needed to ensure that septic upgrades are completed and that required maintenance occurs. Costs for homeowners to maintain improved on-site wastewater systems range from $10 to $25 per month (UNM Water Resources Program, 2001). Additionally, once monitoring programs are established and monitor wells are installed, periodic sampling and water quality analyses will be needed. Costs for these analyses may range from approximately $200 to $1,000 per sample, depending on the required analyses.

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Technical and Physical Feasibility Fact Sheet

Alternative 52: Growth Management

Acknowledgements: This fact sheet was written by Phyllis Taylor of Sites Southwest as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-52: Develop a sustainable and coordinated growth management plan for adoption and implementation by local governments in the Middle Rio Grande region in order to: (1) reduce water consumption, (2) minimize impact on water resources, (3) encourage conservation oriented economic development, and (4) ensure adequate water supplies for any proposed development.

2. Summary of the Alternative Analysis

Alternative A-30 focuses on linking land use and subdivision development. Because there is overlap between the alternatives, this alternative has focused broader growth management policies and ways to link conservation to growth management. Growth management techniques typically regulate the timing, location, and type of growth. These techniques do not necessarily limit growth, although timing can be a limiting factor.

Growth management programs can be also paired with water management programs. For example, the San Diego region couples growth management with conservation, water recycling, desalination, emergency surface storage, and pursuit of imported water supplies (70 to 95 percent of San Diego's water is imported) (San Diego Association of Governments, 2001). The region's water demand projections are linked to growth forecasts, and water supply is an important component of the regional growth management strategy. The goal/policy of the San Diego region is to ensure the availability of water for future growth. Colorado has taken a similar approach to managing growth and its water supplies.

The City of Albuquerque's Planned Growth Strategy (PGS) takes the approach that growth should be managed in a way that protects the City's infrastructure budget and maintains a balance between investment in fringe development and established areas. The strategy assumes that growth will be the same whether it is managed or not, and therefore implementation of the PGS would only manage, not reduce, growth.

As described by the Water Assembly, Alternative A-52 includes not only land use changes, but also a comprehensive approach to sustainable growth of the region. This alternative addresses the location of growth and land use patterns, but not necessarily the quantity of growth.

Original suggested actions that are incorporated into this alternative are as follows:

- Develop a methodology for sustainable growth management
- Implement water-based managed growth
- Provide public policy consistent with the available resources
- Ensure the availability of water drive land use and planning
- Provide each community with the ability to determine its own regional and local use of land and water
- Promote small community autonomy with or without incorporation
- Integrate future water use and development within a comprehensive land use plan and zoning in the City of Albuquerque and Bernalillo County

Growth management techniques evaluated in this fact sheet are:

- *Management of utility service areas:* This approach would tie urban growth to the capacity and planned extent of public utility systems. Specifically, local governments would base development approvals on the adequacy of public utility systems and their ability to support planned development and water system capacity, including adequate water supply. As part of this approach, a local government would assess the cost of water supply expansion to new development through impact fees for water rights acquisition.

- *Rural water supply:* Proof of adequate water supply would be required for new development in rural areas. Proof of an adequate water supply in new subdivisions in

New Mexico counties is required by the New Mexico Subdivision Act. This approach is not effective for land subdivided prior to the adoption of the Act, but can be used to tie new subdivisions to water availability, if water availability assurances are adequately enforced and cumulative impacts are evaluated.

- *Location of growth*: Municipalities and counties can regulate the location of growth to protect surface water and groundwater quality and to protect aquifer recharge areas.

- *Conservation-oriented economic development:* Water use can be considered when the jurisdictions in the region make decisions about economic development incentives. For example, jurisdictions could increase the incentives available to low water using industries, industries that use water efficiently, and/or industries with a high added value relative to water use.

- *Regional coordination:* Coordination among the jurisdictions in the region is essential if a growth management strategy is to work. Otherwise, development will simply be shifted to jurisdictions with the least restrictions or demands on development. The emphasis on community autonomy may be problematic for regional coordination.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Although municipalities and counties in New Mexico have the authority to implement growth management strategies, jurisdictions in the Middle Rio Grande (MRG) planning region have not implemented growth management programs. The region's largest municipality, Albuquerque, is struggling with the challenges of formally managing its growth through regulations. This has been a controversial effort, and the outcome is not yet determined.. Other jurisdictions in the region with fewer staff and planning resources could have difficulty implementing a comprehensive growth management strategy.

Urban service requirements: City of Albuquerque water and wastewater extension policies require annexation of new developments that will hook up to the municipal water and wastewater systems. Over the past 20 years, this policy has resulted in fairly contiguous urban growth surrounding Albuquerque. Other public systems have enabled growth in northwest Albuquerque, Rio Rancho, Sandia Heights and the East Mountain Area of Bernalillo County, as well as in neighboring municipalities.

Growth boundaries: Some communities, including Portland, Oregon, and San Diego County, have established "urban growth boundaries," that aim to restrict urban growth to these areas. In general, these boundaries were established to protect rural land outside of the boundary. In Oregon, for example, agricultural interests supported state legislation mandating growth management as a means of protecting their industry. Such an approach might work in the MRG planning region where landowners recognize a need for agricultural land protection. However, in much of the region, urban development is the most lucrative use of land for the landowner. As a result, there is limited political support for urban growth boundaries. Additionally for the Albuquerque metro area, any consideration of urban growth boundaries needs to take into account natural boundaries such as Pueblo land; thus, the greatest impact would be on the westside.

Portland has had an urban growth boundary since 1980; a population of 1.3 million lived within the boundary as of the 2000 census. The boundary contains 369 square miles and has been expanded 30 times, with 5,000 acres added over 20 years (Metro Planning Department, 2002). Under state law, Metro, the regional agency that implements Portland's growth management program, must maintain a 20-year supply of land within the growth boundary. The boundary is reviewed at least every five years. Priorities for inclusion in the boundary are:

1. Land designated as urban reserves
2. Exception land (land that does not have value as farm or forest land
3. Marginal farm or forest land that is also designated as exception land
4. Farm and forest land.

The boundary is being expanded in anticipation of population growth of 500,000 people over the next 20 years. Urban reserves have been fully developed in the Portland area and the region is now studying exception lands to determine which are most appropriate to bring into the urban growth boundary to meet growth needs for the next 20 years. Lands are evaluated based on (1) the ease of providing services in an orderly, efficient, and economic matter, (2) the number of new housing units and jobs the land can accommodate, (3) environmental, energy, social and economic issues, and (4) compatibility with surrounding agriculture Concentration of density in centers and along transportation corridors and provision of transportation choices are important aspects of the region's plan for protecting existing neighborhoods and maintaining mobility (Metro Planning Department, 2002).

Experts argue about the success of urban growth boundaries. Proponents believe that urban growth boundaries are a way to maintain contiguous development, promote complete communities with jobs and shopping close to where people live, protect precious open space, and provide public services more efficiently and cost effectively. Opponents state that the artificial limitations placed on land supply result in increasing in housing costs and leapfrog growth to areas outside the boundary. In Portland, developers acknowledge that the urban growth boundary has provided certainty regarding which lands can and cannot be developed and has sped up the development approval process. However, they argue that the cost savings associated with these benefits has been outweighed by cost increases. In Portland, densities have not been as high as expected, partly because of neighborhood opposition. Home prices have risen, and development has been pushed outside of the boundary, including into Washington State where Oregon's laws do not apply.

Development fees: Development fees, which assess the cost of needed infrastructure to new development, are one management tool that is already being used in the MRG planning region. The cost of water rights to ensure an available supply for new development can be included in a jurisdiction's development fees. The City of Rio Rancho, Bernalillo County, and the Village of Los Lunas have implemented development fees, which are intended to help communities pay for the cost of growth—primarily infrastructure and facility expansion costs. The New Mexico Development Fees Act specifies how development fees must be established and administered. Bernalillo County recently reduced its fees.

Jurisdictions can assess variable fees based on differences in cost of service. For example, lower fees can be assessed for areas within a utility service area and higher fees for areas that require service extensions. Presumably, variable fees would provide an incentive for location, timing, and type of growth that minimizes infrastructure cost. No local jurisdiction has adopted variable fees.

Development fees equalize costs to new development rather than apply differential assessments that can result from individually negotiated infrastructure requirements. As a result, they provide up-front certainty to both developers and the jurisdiction regarding the portion of public infrastructure costs that the private sector will pay. Timing problems can arise if, for example, the pace of development slows in an area where infrastructure improvements are only partially funded and a jurisdiction is forced to build improvement before fees are received.

Adequate Public Facilities Ordinance (APFO): Local governments have tied development approvals to the existing or planned availability of adequate public facilities and services through an Adequate Public Facilities Ordinance, also referred to as concurrency. An APFO allows a community to maintain control over the timing and sequence of new development; forces the community to link its comprehensive land use plan with its capital improvement program, a principle of good planning that is often ignored; and can encourage contiguous or even infill development because of its proximity to existing urban infrastructure and services. To the extent that land in areas with public facilities is limited, this ordinance will encourage developers to build at higher densities. However, an AFPO may increase the complexity of the development process and the cost of processing development proposals, which could, in turn, increase housing costs.

Montgomery County, Maryland has had an APFO in place since 1973. Decisions about location, type, density, and mix of development are made through the County's general plan and other land use plans. The APFO affects only the timing of development. Water facilities are considered adequate if service is planned within two years. The County publishes an annual report that provides information about growth areas and infrastructure capacity. Montgomery County has faced problems with lack of funding for planned infrastructure, resulting in lack of capacity and moratoria on development. The moratoria are not politically acceptable.

AFPOs can have unintended consequences if the local government does not follow its capital improvements program or if growth can take place without the jurisdiction's approval. In Ramapo, New York, failure to follow through on planned public facilities investments barred all new development and led to dissatisfaction and eventual repeal of the City's adequate public facilities ordinance. In Sarasota County, Florida, the strategy of refusing to extend public facilities did not prevent new growth. The growth occurred despite this strategy, and the county later had to replace piecemeal and inadequate public services and infrastructure.

Some aspects of an AFPO are included in the City of Albuquerque's Planned Growth Strategy (PGS), and the idea of concurrency is a controversial aspect of the strategy. A proposal to tie development to school capacity received strong opposition from the local business community. Local capacity to follow through on infrastructure commitments and political acceptability is an issue with this approach to growth management.

Infrastructure Development Requirements

- Any type of growth management program requires that local governments plan proactively for adequate infrastructure to meet projected growth and to make an adequate supply of land available for development. Follow-through on commitments to provide infrastructure are critical if infrastructure availability and an adopted infrastructure plan provide a basis for development approvals.

Total Time to Implement

- The impact of this alternative on water demand will not be immediate. This alternative would be implemented over 20 or more years.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

If growth management results in slower growth, projected water demand would be reduced over time since there would be fewer people and jobs. The San Diego Association of Governments (2001) has estimated the impact of public growth management policies on that region's growth. The study evaluated policies that allocate growth, reduce fertility rates, and restrict housing, the economy, and immigration.

This study noted that growth occurs in response to natural increase, economic opportunity, and the desirability of a location. If a location has employment opportunities, a high quality of life, and is a desirable place to live, it is likely to grow as youth elect to stay in the community and new families migrate into the area. The conclusion of the San Diego study is that growth can be managed in a manner that protects the quality of the environment, including water. Although local governments can affect the supply of housing or space available for economic development, their ability to affect population growth is limited. After years of unsuccessfully trying to limit growth, the current policy in the San Diego region is to manage growth, not limit it.

The experience of regions with growth management policies in place has shown that local growth measures have no significant impact on overall population growth rates, but they play an important role in the geographic distribution of growth. No policies have been proposed in the MRG planning region to limit supply, but policies such as impact fees indirectly affect housing stock by increasing prices. In Portland, for example, homebuilders report a 300 percent increase in land prices within the urban growth boundary, which has caused a 35 percent to 40 percent increase in the sales price of homes since 1993 (Metro Planning Department, 2002). This compares to a 25 percent increase in the consumer price index for housing for all urban consumers in the U.S.

Job growth, without equivalent growth in housing availability, encourages people to commute from outside the region. The San Diego study notes that some evidence indicates that as land prices increase in communities with growth boundaries, non-residential uses can outbid residential uses, forcing residential uses to lower priced land outside of the boundary. In the case of the MRG planning region, limits on housing supply could impact water demand in neighboring basins that do not have similar policies in place.

Policies that seek to limit economic growth can have a negative impact on current residents of the region by limiting or reducing job opportunities.

Effect on Water Supply (surface and groundwater)

None.

Water Saved/Lost (consumption and depletions)

Growth management policies can have the effect of slowing growth in the areas to which they apply. However, such policies may simply shift growth outside of their effective boundaries. Thus, uniform implementation of this alternative throughout the region is essential. A regional planning authority could assist in implementing consistent policies throughout the region (see A-67, *Water Authority/Banking)*.

The San Diego study simulated growth-slowing policies to estimate their potential impact on growth. In this study, the following techniques affected growth rates:

- Limits on new housing construction to 40 percent below a current baseline resulted in the following impacts:

  - 10 percent housing shortfall
  - In-commuters requiring housing outside the region
  - 20 percent house price increase, with a variance of 2 to 35 percent among jurisdictions
  - Reduced vacancy rates
  - Change in the jobs housing balance from 1.16 jobs per dwelling unit to 1.29 jobs per dwelling unit (in the middle Rio Grande region, ratio of jobs to housing is 1.22, ranging from 1.32 in Bernalillo County to .92 in Valencia County)
  - Reduction in population growth rate from 1.6 percent per year to 1.4 percent per year over 20 years

- Limit on non-residential construction

  - Reduced non-residential vacancy rates from 5 to 3 percent
  - Increased employment density from 3.3 to 3.5 employees per square foot
  - Increased commercial, office and industrial lease rates

- Shift in the job mix to increase the number of high value added jobs

  - Slowed job growth from 27 percent in 20 years to 24 percent in 20 years, resulting in slowed population growth
  - Increased regional income level
  - Cost involved in training workers, slow to implement because it requires shift in work force characteristics

Impacts to Water Quality (and mitigations)

- None.

Watershed/Geologic Impacts

- None.

3.1.2 Environmental Impacts

Growth management policies could have a positive impact on environmental conditions if they protect critical areas by steering development away from environmentally sensitive areas. The City of Albuquerque, for example, has protected sensitive areas through its Open Space Program. Through this program, the City purchased critical lands, including the steep slopes of the Sandia Foothills and the volcanic escarpment on the City's northwest mesa. Bernalillo County has also implemented a similar program and has protected open space lands through fee simple purchase.

Impact to Ecosystems

- This alternative will not protect ecosystems unless growth management policies specifically address ecosystem protection.

Implications to Endangered Species

- This alternative will not protect endangered species unless growth management policies specifically address protection of endangered species.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

- The initial cost to local governments of implementing this alternative would be the administrative costs associated with a growth management program. Growth management entails a proactive government role in planning and constructing infrastructure in targeted growth areas. Local jurisdictions would need to follow through on capital improvements commitments if a growth management strategy is to work.

- Some of the growth management strategies discussed shift the cost of infrastructure and water supply to new development from local government. Such policies would likely increase housing costs in the region.

3.2.2 Potential Funding Source

- Local government sources, including bond financing of capital improvements, would be the most typical and predictable source of revenue.

- Costs can also be shifted to landowners and developers, and consequently the homebuyer.

3.2.3 Ongoing Cost for Operation and Maintenance

- There is some evidence of lower ongoing costs associated with efficient provision of services; however, the exact impact on ongoing infrastructure costs is unknown.

3.3 Other Considerations

- Local governments will need to technically and politically define "sustainability" and develop a common approach to growth management across the region.

- Growth management is not the same thing as limiting growth.

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Technical and Physical Feasibility Fact Sheet
Alternative A-56: Conservation Education

Acknowledgements: This fact sheet was written by Myra Segal Friedman of EJJ Associates as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-56: Establish region-wide educational programs, including public and private school curricula, to encourage voluntary conservation of water.

2. Summary of the Alternative Analysis

Long-term water conservation starts with children. Teaching children to understand the value of water will help them develop a conservation ethic and the habits to become tomorrow's water-wise adults (NM OSE, 2001). School outreach programs are also an effective way to reach entire families, as children will educate their families about water use and conservation. Effective school outreach includes:

- New school outreach programs in jurisdictions that do not already have such programs and enhanced programs in other jurisdictions. Water resources can be instituted as part of the elementary school curriculum throughout the Middle Rio Grande Water Planning Region.

- A "traveling" trained staff person, who would visit numerous school classrooms each year, participate in water and science fairs, and coordinate other water educational activities.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

Existing school outreach efforts would be used as a starting point. The curriculum should engage students and get them actively involved in water conservation strategies. Many curricula exist, both locally and nationally, that could be used as models (U.S. Bureau of Reclamation, 2000).[1] Also, several existing programs could be used as the basis for a broader water conservation outreach program. For example:

- The City of Albuquerque currently employs a full-time school outreach coordinator who visits 180 classrooms each year and participates in water fairs and science fairs. Approximately 4,500 students, primarily third-graders, are currently reached through school visits.

- Independent water fairs also reach students. For instance the annual Children's Water Festival reaches more than 1,000 students.

Infrastructure Development Requirements

The existing Middle Rio Grande Council of Governments (MRCOG) regional website (http://www.mrgcog.org) could be enhanced to include interactive tools that enable children (and adults) to create water budgets for their homes. Various websites currently offer interactive water calculators to help users understand how much water they use and where they use it. [2] These web calculators provide a simple method for doing a "home water check-up" and allow children to compare their home use with the average use. A link could be established from local jurisdiction websites to the MRCOG website so access is broadened and duplication of efforts is reduced.

One example of student-oriented projects that could be used is to make each student responsible for establishing a household water budget and determining how they can reach that budget (using an interactive web-based calculator). This activity would integrate students' math skills and water conservation knowledge. It would also familiarize students with resources available through local and regional governments by getting them engaged in activities on the enhanced web pages.

Total Time to Implement

A regional school outreach program could be developed in three months (summer recess) and be ready to implement in schools throughout the academic year.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Educating children about water conservation provides double benefits. Not only do the children learn the importance of water conserving habits, they can also influence the water use patterns of their parents and other members of their families.

Precise water demand reductions through school outreach programs are difficult to calculate. Depending on the existing level of conservation awareness and activities, public education can yield between 3 and 15 percent in water savings (Witherspoon, 2001). Assuming a 5 percent reduction applied to total depletions in the region[3], this alternative could result in a 8,670 acre-feet per year reduction in demand. This amount is included in the savings listed in the fact sheet for A-18, *Urban Conservation.* School outreach programs can be responsible for a significant part of the public education effort.

School outreach programs should help reduce water waste and overuse by changing water use habits. For example, children (and their families) will become conscious of wasting water by letting the tap run while they are brushing their teeth or washing dishes. This awareness, and the resultant savings, should help ease the pressure on scarce water supplies.

Effect on Water Supply (surface and groundwater)

This alternative will not affect water supply.

Water Saved/Lost (consumption and depletions)

See the fact sheet for A-18, *Urban Conservation*, for a more thorough analysis of impact of water-conserving activities.

Impacts to Water Quality (and mitigations)

School-based water conservation programs can help students understand how non-point source pollution can start on the street where they live. Students can become aware of how chemicals from landscapes and fluid from vehicles can travel to the river or other water sources. Through this knowledge, they can educate their family members about how daily behavior may be affecting water quality.

Watershed/Geologic Impacts

School curricula could also include watershed information. This will allow students to develop a holistic view of where water comes from and how different practices impact the watershed. Through the use of resources such as *Discover A Watershed: The Rio Grande/Rio Bravo Reference and Activity Guide* (WET, 2000)[4] students can better understand local watershed issues and practices.

3.1.2 Environmental Impacts

There are no specific impacts to ecosystems or endangered species associated with this alternative (see fact sheet for A-18, *Urban Conservation*).

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

To implement this alternative, available school curricula and materials on water would be assessed by staff. Other costs would include:

- Approximately $60,000 annually for a mid-level, trained professional staff person to visit numerous school classrooms each year, participate in water and science fairs, and coordinate other water educational activities. This cost includes overhead and benefits.

- A per student materials costs of approximately $5.00 to $10.00 per year. This cost is based on existing programs. For example, in Albuquerque, to reach 4,500 school children, the cost per student is $5 for materials (such as coloring books, poster, video, pencils) for a total annual cost of $22,500 (Sparks, 2002). Similarly, a theater production on water costs approximately $2.00 per student.

- Under this alternative, the cost per acre-foot of water saved per year is $9.22.[5]

Some free publications are available from the U.S. Environmental Protection Agency and Office of the State Engineer. Other kits are also available for teachers, such as "Every Drop Counts" from the Center for Hands-On Learning ($500 per kit).

3.2.2 Potential Funding Source

Local jurisdictions could contribute a proportional amount for their share of the cost of production, purchase, and/or printing of materials.

3.2.3 Ongoing Cost for Operation and Maintenance

Ongoing costs include staff and materials as stated in Section 3.2.1, *Initial Cost to Implement*.

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1 Water Conservation Module For Educators Sponsored by the Bureau of Reclamation, 2000, pages. Developed for middle and high school educators, this module provides background material, case studies, and activities on the topic of water conservation. Case studies are based on water

conservation scenarios ranging from a rancher in west Texas to an ice cream factory in Massachusetts, and from water's role on the space shuttle to the survival of a sailor adrift in the Atlantic. These real-life examples encourage students to use decision-making skills to work through issues related to water use and conservation. Sidebar material, illustrations, photographs, charts, and a selection of activities complement the background chapters and case studies. Cost $18.95

For other USBR Education resources, contact Kathie Marsh, Environmental Education Program Manager, Denver, Colorado kmarsh@do.usbr.gov http://www.usbr.gov/enved/ books/

Project Wet Curriculum And Activity Guide http://www.montana.edu/wwwwet/

Project WET (Water Education for Teachers) provides training workshops and teaching modules. Project WET is a non-profit water education program designed to facilitate and promote awareness and appreciation of water resources. Funded by the Bureau of Reclamation and co-published by The Watercourse and the Council for Environmental Education (CEE), 1995. 517 pages.

Water Facts are available at:

http://www.pn.usbr.gov/project/wat/facts.html#uses

[2] Examples of websites with water calculators:

http://www.tampagov.net/dept_water/conservation_education/Customers/Water_use_calculator.asp

http://www.ficus.usf.edu/docs/water_calculator/calculator.htm

http://www.provwater.com/conscalc.htm

www.H2ouse.org

www.waterwiser.org

[3] This was calculated based on a total depletion = 173,417 acre-feet per year, which includes depletions in Bernalillo, Valencia, and Sandoval Counties (except for reservoir evaporation in Sandoval County) (Wilson, 2000).

[4] This reference and activity guide for middle and high school educators is published in Spanish and English. This resource begins with a comprehensive overview of the watershed in several chapters which complements and meshes with a selection of interdisciplinary activities. Especially useful for group explorations under the guidance of a teacher or park interpreter, this resource works equally well for independent or family study.

[5] This cost assumes an annual cost of $80,000 to implement this alternative and a water savings of 8,670 acre-feet per year.

Technical and Physical Feasibility Fact Sheet
Alternative 59: Severance Tax

Acknowledgements: This fact sheet was written by Brian McDonald, Ph.D., a private economic consultant, as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-59: Establish a state-based water severance tax for water projects, planning, and conservation.

2. Summary of the Alternative Analysis

A state tax on the consumptive use of water would generate revenue necessary to fund regional water projects, planning efforts, and conservation programs. Water tax policy includes consideration of a tax base and a tax rate. The policy should clearly define what is subject to tax, how the tax program works, and demonstrate uniformity in administration across taxpayers.

The value of water varies today across different water users and different sources of water. Because there is no "true" value for water in the Middle Rio Grande (MRG) planning region and this value cannot be readily determined, it is not advisable to tax the value of water. Instead, the water tax should be applied to the volume or quantity of water used.

A water tax rate should consider issues such as total revenue requirements, fairness among water users, and impact on consumers and businesses. Such a tax would likely be cyclical, fluctuating with meteorological conditions. Since the supply of water is physically and legally constrained within the MRG planning region, a quantity-based water tax would show no growth in water tax revenues over time, unless the water tax rate is periodically increased.

A water tax rate of $100 per consumed acre-foot would raise $20.4 million per year in the MRG planning region. Based on regional consumptive use quantities reported in Wilson(1997)[1] , the agriculture sector would pay $9.61 million (approximately $232 per irrigated acre), while public water supply users would pay $8.47 million (approximately $31 per household), which represents approximately a 10 percent increase in Albuquerque's current water commodity charge. The tax rate on water uses that deplete the aquifer should be higher. However, determination of groundwater withdrawals that result in aquifer depletion would have to be determined in order to assess a higher tax for those withdrawals.

Implementation of this alternative would require metering of all water uses, including agriculture and self-supplied domestic water users (see fact sheet for A-7, *Agricultural Metering*). Using the consumed quantity of water as a tax base would require estimation of consumptive water use among farmers with different crop patterns and irrigation practices. Who would pay the water tax on reservoir evaporation would have to be determined.

2.1 Tax Base and Rate

Any state tax involves the definition of a tax base (what is to be taxed) and a tax rate (how much of the tax base is paid as a tax). For example, the property tax base is the taxable assessed value of a house and the property tax rate is the mill levy ($1 per $1,000 of taxable assessed value) as determined by the city, county, school district or other property tax authorities. The property tax base, that is, the taxable assessed value of the house, is further defined under New Mexico statute as one-third of fair market value less allowable exemptions such as the head of household and veterans' exemptions. The gross receipts tax base is the value of goods and services, defined as taxable by statue, while the gross receipts tax rate is some percentage of the value of those goods and services. The state gasoline tax base is gallons of gasoline purchased times a levy ($0.16) per gallon of gasoline.

There are some subtle distinctions in these examples of tax bases and tax rates. In the case of gasoline, for example, the tax base is a volume or quantity measure (gallons of gasoline), while in the case of property and gross receipts, the tax base is a value measure (the value of the house or the value of goods and services purchased). Over time, a quantity tax base increases only as the quantity or volume of the commodity increases, while a value tax base increases as both the quantity and the price (inflation) of the good increases. In the case of property and gasoline, the tax rate is defined as a set dollar amount per tax base unit—$1 per $1,000 taxable assessed value and so many cents per gallon of gasoline, respectively. In the case of gross receipts (and income), the tax rate is defined as a percentage of the value of the tax base.

The tax base should also be well defined, easily understood, and uniform across taxpayers. In the case of water, the tax base could be either the value of water consumed or the quantity of water consumed. However, the value of water is not uniform across all users, and as discussed in the fact sheet for A-21, *Urban Water Pricing*, the true economic value of water does not exist and cannot be determined in the MRG planning region. The quantity of water consumed would be more reasonable to establish as a tax base, although it too is problematic. For example, agricultural water use is not currently metered, and the consumptive use of agricultural water depends upon the type of crop (see fact sheet for A-11, *Low-Water Crops*) and irrigation methods. Also, it would be difficult to identify the taxpayer in the case of reservoir evaporation and in-stream uses of water for endangered species.

2.2 Policy Issues

There are several policy options when establishing a tax rate for water, all of which should consider issues such as revenue requirements, fairness, and impact on water consumers. First, the need for revenue is the primary driver of all tax rates, and the level of the water tax rate (for example, number of dollars per consumptive acre-foot) should be based upon the revenue needs of the MRG planning region for water projects, planning, and conservation. Second, the tax rate could be a constant rate, a declining block rate (by volume of water usage), or an increasing block rate (by volume of water usage). Also, the tax rate could be set at a different level for different water users (e.g., agricultural use, municipal use, or industrial use), and at a different level for different water planning regions within the state.

Some attention must be paid to who collects, distributes, and enforces a state-based water tax. Ease and uniformity of administration should guide this decision. As with the gross receipts tax, the water tax could be administered by the State of New Mexico. The state would collect the tax and distribute it back to water planning regions based upon the appropriate measure of the region's tax base and tax rate. Or, as in the case of the property tax, a local government could administer the water tax for the local water planning region. It is also possible, as a state-based water tax, that the State of New Mexico would not only collect the water tax but also decide how the water tax revenue was spent. Under this latter scenario a particular water planning region would not necessarily receive all the water tax revenue collected within that water planning region for water projects within the region.

A quantity tax base such as consumptive water use in gallons or acre-feet appears to be the most feasible approach to a water tax. However, such a tax base implies that the water tax revenue source will be cyclical based upon the meteorological cycle. During wet years the amount of water consumed would increase, as would water tax revenues, while in dry years the amount of water consumed would decrease, as would water tax revenues. This built-in cyclical nature of water tax revenues may make it difficult to issue water bonds to finance water capital projects that depend on water tax revenues to pay the debt service. The cyclical nature of water tax revenues would also make it difficult to project future water tax revenues with acceptable accuracy. Finally, since the supply of water in the region is physically constrained in the long run, with a quantity tax base there would be no growth in water tax revenue over time, unless the water tax rate is periodically increased.

A final consideration in the discussion of a state-based water tax is the need for budgeting and management of this new revenue stream. Regional water management would require funding of capital-intensive water projects as well as funding of recurring activities such as water planning and conservation. Some of the water tax revenue would be needed to provide debt service of bonds, issued to finance large capital projects. Other parts of the water tax revenue would be needed to fund annual, recurring expenditures for water planning and conservation efforts. A water management authority would be needed to make these budgetary decisions on behalf of water users and residents of the region.

How much tax revenue can be raised from a water tax in the MRG planning region? To answer this question, we must start with the assumption that the tax base is “all water consumed in the region by all water users.” Table 59-1 provides information about total water depletions (consumptive use) by county and type of water user for the MRG planning region. Total consumptive use in 1995 was 204,701 acre-feet, including both surface and groundwater use. Irrigated agricultural and public water supply accounted for the bulk of water consumption in the region; the former consumed 94,577 acre-feet, while the latter consumed 84,880 acre-feet.

Table 59-1. Water Use By County, Total Depletions 1995 in the Middle Rio Grande Planning Region

Category	Bernalillo	Sandoval	Valencia	Total
Public water supply	70,224	12,490	2,166	84,880
Domestic (self-supplied)	1,084	1,210	1,651	3,946
Irrigated agriculture	20,851	17,684	56,042	94,577
Livestock (self-supplied)	753	353	664	1,770
Commercial (self-supplied)	2,447	502	702	3,650
Industrial (self-supplied)	205	361	21	586
Mining (self-supplied)	90	4	2	96
Power (self-supplied)	163	---	---	163
Reservoir evaporation	---	15,033	---	15,033
Total	95,817	47,637	61,247	204,701

Source: Wilson et al., 1997.

For illustration purposes only, assume that the water tax rate is $100 per consumed acre-foot, which is $0.000307 per gallon of water. Based upon total water consumption of 204,701 acre-feet, a broad-based tax on all regional water consumption would raise $20.4 million per year. The agricultural sector would pay 47.1 percent of this total, or $9.61 million per year, while public water supply users would pay 41.5 percent of the total, or $8.47 million per year. There are approximately 41,494 acres of irrigated farmland in the Middle Rio Grande region so that this annual water tax of $100 per consumed acre-foot would represent a tax of $232 per acre of irrigated agriculture.

In the City of Albuquerque the current water commodity charge in the winter months is $1.1934 per unit of water (748 gallons of water). This water commodity charge is based upon gross withdrawal rather than consumed water use, however. Assuming a 50 percent return flow credit in urban water use, this annual water tax of $100 per consumed acre-foot would require a $0.1148 increase in the water commodity charge per unit of water in the City of Albuquerque.

In setting water tax policy state policymakers would have to consider other issues. For example, the agricultural sector is generally a lower income-producing sector than the public water supply sector. Does the agricultural sector have the same "ability to pay" as the public water supply sector? Should the water tax rate be the same for agricultural water use as it is for public water supply use? There is also a question about how the state would collect the water tax on self-supplied water users, shown in Table 59-1. Domestic, self-supplied wells are generally not metered so that consumptive use for these water users may have to be estimated. Reservoir evaporation accounted for 15,033 consumed acre-feet in the MRG region, or 7.3 percent of total water use, in 1995. It is not clear how the state would collect a water tax on this water use, and who would pay the water tax on reservoir evaporation. Agricultural water use is not generally metered in the MRGCD, and metering would determine only gross water withdrawals. Consumptive use in agriculture is a function of crop patterns and irrigation technology. How would the state determine consumptive water use on a farm-by-farm basis?

As an alternative, the state could choose a water tax base of gross water withdrawals. Metering would be required, but would more accurately measure the volume of water use for a specific water user. However, a tax on gross water withdrawals would set up incentives to reclaim, recycle, and reuse water within a public water supply system or on an individual farm in order to minimize the water tax paid. This would affect the traditional patterns of return flow within the river system and would affect downstream water users. Also, the ratio of water consumed to gross withdrawals varies by water users so that in the end, with a gross water withdrawal tax base, some water users would pay a higher tax rate per water consumed than others.

Finally, for instances of groundwater mining within the MRG region, the state should set a higher tax rate on such water consumption in order to provide economic signals to users of mined groundwater so that the "in-situ" services of groundwater are recognized.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

This alternative would require new state legislation authorizing such a new water tax. Such legislation should also address who collects the tax and to whom it is distributed. The proposed tax is straightforward and all technical issues are well understood by tax professionals. Determining taxable groundwater depletions would require technical studies.

Infrastructure Development Requirements

The alternative would require setting up the taxation and assessment entity and would require metering of all water uses.

Total Time to Implement

It would take one to two years to enable state legislation and appropriate funds to set up the administrative entity or incorporate new division or staff into an existing entity.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

A water tax could reduce water demand, since the after-tax price of water would increase for all users. However, the demand for urban water is price inelastic so that a 10 percent increase in the after-tax price would cause only a 1 percent decrease in water demand. The price responsiveness of water demand in agriculture is unknown, since current agricultural water use is not metered and farmers face a $0 marginal price. Indirectly, the water tax could fund other water planning projects, such as conservation measures, which would reduce water demand, ultimately reducing tax revenues

Effect on Water Supply (surface and groundwater)

There would be no direct effect; however, a water tax would provide funding for water projects, which could expand the regional water supply.

Water Saved/Lost (consumption and depletions)

Water savings would come through the reduction in water demand. The actual amount of water saved would depend upon the level of the new water tax. Indirectly, the water tax would lead to water savings via water plan projects that reduce demand or increase supply.

Impacts to Water Quality (and mitigations)

No direct impacts.

Watershed/Geologic Impacts

No direct impacts.

3.1.2 Environmental Impacts

Impact to Ecosystems

Water savings could be used to maintain riparian habitat. Funds generated by the water tax could be used to purchase water rights dedicated to ecosystem protection (in-stream flow). Alternately, funds generated could be used to fund ecosystem protection and enhancement projects.

Implications to Endangered Species

Funds generated by the water tax could be used to purchase water rights dedicated to maintaining flows for endangered species. Funds generated could be used to fund projects to improve, enhance or protect endangered species habitat.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

There would be an administrative cost for changing state legislation and for setting up tax administration agency or division within an existing program. Assuming that the administration of the water tax would require approximately 20 to 25 full-time employees, the annual budget for tax administration would amount to approximately $1.2 to $1.5 million.[2] Assuming a 10 percent increase in the average price of urban water ($0.00193 per gallon including surcharges; City of Albuquerque, 2002) in addition to the cost presented above, the cost to save 848 acre-feet (1 percent of total urban consumptive use in the three counties in the region) is approximately $8,000 per acre-foot.

3.2.2 Potential Funding Source

State and local governments.

3.2.3 Ongoing Cost for Operation and Maintenance

Ongoing tax administration cost, similar to current property tax administration in New Mexico. (See Section 3.2.1).

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[1] Wilson 1997 was used to determine total depletions in the region. Although 1999 depletions for agriculture and 2000 are available, a report with this information has not been published. Generally, the total depletions in the planning area decreased in 2000. However, the calculations of water tax revenues in this fact sheet are made only to illustrate potential revenue. Over time, total depletions can fluctuate due to climate conditions and implementation of conservation measures in certain sectors, and will cause tax revenues to fluctuate as well.

[2] This estimate is based generally on the annual operating budgets of existing property tax assessor departments within the planning region. However, these ranges are provided only to illustrate possible costs.

Technical and Physical Feasibility Fact Sheet
Alternative 63: Instream Flow

Acknowledgements: This fact sheet was written by Susan C. Kery, Esq. of Sheehan Sheehan & Stelzner, P.A. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-63: Change state water law to include instream flow as a beneficial use.

2. Summary of the Alternative Analysis

Alternative A-63 calls for a change in state law to include instream flow as a beneficial use. "Instream flow" and "instream use" refer to the concept of leaving water in a streambed where it is used by way of providing aquatic and riparian environments for fish and wildlife, and providing for recreational and aesthetic uses.[1] Of necessity, instream use involves free-flowing water in a natural channel rather than diversion of water out of the streambed or impoundment of water behind a dam or dike.[2]

By statute, New Mexico does not currently specifically authorize appropriations for instream flow. However, even in the absence of a statute, New Mexico law nevertheless recognizes instream flow as a beneficial use of water. Thus, New Mexico law currently offers adequate protection for instream flow. Nonetheless, a change in state law to specifically recognize instream flow, as done in other western states, would further strengthen the protection of instream flow in New Mexico. Finally, even specific instream flow protections offer no guarantee of water remaining in the Rio Grande, especially during times of drought.

2.1 New Mexico Law on Instream Flow

In 1998, the Attorney General issued an opinion (AG opinion) on instream flow rights.[3] The AG opinion legitimized instream flow use in New Mexico by recognizing a reasonable instream flow for recreational, fish and wildlife and ecological values as a beneficial use of water in New

Mexico.[4] The Attorney General found no legal impediment to prevent the State Engineer from approving an application to transfer an existing water right to an instream purpose and conditioning the approval on the installation of gaging devices to measure the instream flow beneficially used.[5] Thus, any transfer to instream flow would have the priority date of the existing water right that was transferred. The AG opinion was limited to consideration of applications for changes from traditional diversionary uses to instream flows, because it is unlikely that applications for new appropriations of surface waters for instream flows would be submitted and acted upon since the State's surface waters are fully appropriated.[6]

The AG opinion addressed two issues: (1) whether the state constitution, statutes and case law require a diversion or impoundment in order to obtain a valid water right and (2) whether recreational, fish and wildlife, or ecological uses constitute beneficial uses of water. The Attorney General concluded that New Mexico law has no diversion requirement.[7] Moreover, the Attorney General found that recreational, fish or wildlife, and ecological uses are beneficial uses.

> New Mexico accords a high value to recreation, fish and wildlife, and ecological values associated with riparian aquatic systems. Not only is this confirmed by numerous statutes designed to protect these values but as recently as the 1997 legislative session, the New Mexico legislature passed a memorial confirming its desire to preserve river ecosystems and promote the ecological, recreational and other instream values associated with those ecosystems. In light of all of these factors, we believe that a court would find these uses to be beneficial uses under the constitution, as long as the uses of water were reasonable and not wasteful.[8]

While the Attorney General debunked the belief that appropriations require an actual diversion, the state statute governing applications for new appropriations nevertheless contemplates the construction of dams, ditches or other "works" to effectuate an appropriation.[9] In his opinion, the Attorney General found that this requirement would be satisfied by the imposition of the State Engineer's recommendation of "accurate and continuous gaging" of instream flows throughout the permitted stream reach.[10] Thus, instream flows must be measured in order to be recognized.

New Mexico case law also lends support to instream flow as a beneficial use. While there is no statutory definition for beneficial use, determining whether a specific use is a beneficial one has become a common law inquiry based on fact.[11] Over time, New Mexico state courts have established a body of common law beneficial uses, albeit not a comprehensive one. For instance, domestic water use and stock watering are recognized beneficial uses in the state.[12] Moreover, the attainment of state conservation purposes by the state game commission constitutes a beneficial application of water.[13] The leasing or renting of water by an irrigation district together with the use of water by the lessee is also considered a beneficial use.[14]

As early as 1945, the New Mexico Supreme Court recognized a beneficial use traditionally associated with an instream flow right. In *State ex rel State Game Commission v. Red River Valley Co.,* the Court found that a "beneficial use" to which public waters may be placed includes fishing and recreation.[15] This holding is consistent with statutory instream flow allowances of both Arizona and Utah.[16]

2.2 Instream Flow Programs in New Mexico

In the absence of a statute recognizing the validity of instream flow rights in New Mexico, several surface water programs currently underway in the State legitimize instream flow as a beneficial use. Perhaps the most notable is the effort being undertaken on behalf of the Rio Grande silvery minnow (silvery minnow). In 1994, the U.S. Fish and Wildlife Service listed the silvery minnow as an endangered species under the Endangered Species Act (ESA).[17] Since then, multiple lawsuits have been filed. In September 2002, the federal court ordered the Bureau of Reclamation (Reclamation) to release approximately 40,000 acre-feet of San Juan-Chama Project and Middle Rio Grande Project water in storage in Heron Reservoir to keep the Rio Grande flowing for the benefit of the silvery minnow.[18]

Prior to this mandate, a conservation water agreement (Agreement) was brokered between the State of New Mexico and the United States to release native Rio Grande water into the river from a conservation pool above Elephant Butte Reservoir.[19] Under the Agreement, New Mexico is required to store 100, 000 acre-feet of water over a period of three years and make available to the United States for release an amount up to 30,000 acre-feet per year to benefit the silvery minnow.[20] The initiatives and mandates to release water into the Rio Grande on behalf of the silvery minnow demonstrate a recognition by state and federal agencies, and the federal court, that releasing flow into reaches of the Rio Grande for the continued existence and propagation of the silvery minnow as required by the ESA is a beneficial use of water.

Instream flow rights also have been recognized on the Pecos River in response to a lawsuit filed against Reclamation for alleged noncompliance with key provisions of the ESA. Specifically, environmental groups claimed that Reclamation's water management activities on the Pecos River threatened the habitat of the Pecos bluntnose shiner, listed as a threatened species under the ESA.[21]

By virtue of a repayment contract between Reclamation and the Fort Sumner Irrigation District (FSID), both entities have an ongoing relationship until 2033.[22] When Reclamation was notified of the ESA lawsuit, it ordered the FSID to reduce its diversion amount by 30 percent for the remainder of the irrigation season in order to keep the river wet and secure compliance with the ESA.[23] Reclamation and the FSID formalized this arrangement by entering into a forbearance contract whereby Reclamation paid individual irrigators to forego irrigation of their crops for approximately six weeks in order to maintain flow for the bluntnose shiner.[24]

The FSID, however, was concerned that the six-week period of nonuse might result in the forfeiture of individual irrigators' water rights under state statute. As a preventative measure, the FSID entered into a agreement with the New Mexico Interstate Stream Commission Water Resource Conservation Project (Project).[25] The Project provided that the FSID would suspend use of its waters to comply with Reclamation forbearance contract, and would place the subject water in a Project "conservation pool."[26] The Project, in turn, would use the water to increase the flows of the Pecos River so New Mexico could meet its compact delivery obligations under the Pecos River Compact.

Because the Project water was allowed to remain in the Pecos River for the express purpose of increasing the flow of the river (initiated by the need for compliance with the forbearance contract) and satisfying ESA requirements, the subject water has been considered an instream flow recognized by both the State of New Mexico and the United States.

Finally, to guarantee its water delivery obligations to Texas under the Pecos River Compact, New Mexico purchases water rights from appropriators on the Pecos River.[27] Rather than being used for irrigation, these purchased instream flow rights remain in the river for delivery to Texas to satisfy New Mexico's Compact requirements.

2.3 Instream Flow in Other Western States

Eleven of the eighteen states that apply the prior appropriation doctrine to surface water have explicit statutes providing for instream flow protection.[28] Of these, Colorado, Arizona, Montana and Utah are instructive due to their proximity to New Mexico, relative scarcity of water, and arid climates.

2.3.1 Colorado

In 1973, Colorado enacted legislation to create an instream flow protection program.[29] The statute recognizes the appropriation of waters in natural streams and lakes "required for minimum stream flows or for natural surface water levels or volumes for natural lakes."[30] Among the key components of the statute is the recognition of instream flows "to preserve the natural environment to a reasonable degree" as a beneficial use of water, and the removal of the diversion requirement for the appropriation of a water right.[31]

The appropriation and protection of instream flow rights is placed in the Colorado Water Conservation Board ("CWCB").[32] The CWCB has the exclusive authority to appropriate and acquire water for minimum instream flows.[33]

Colorado's instream flow program operates within the same prior appropriation system in which all other water rights are obtained and administered.[34] Water users with priorities senior to those of instream flow rights will not be affected by a CWCB instream flow right, and senior users may continue to divert water even if they reduce the flow below the specified instream flow level.[35] However, enforcement efforts are pursued against junior diverters or against proposed transfers of senior rights to new places of use, different purposes, or new points of diversion.[36]

2.3.2 Arizona

Arizona's statute allows surface water appropriations for instream flow for "recreation, wildlife, including fish,"[37] in accordance with the law of prior appropriation.[38] The statute was amended to recognize instream flow using dictum from a previous Arizona Court of Appeals case. In the AG opinion, the court upheld an agency determination granting an instream flow use for recreational purposes.[39] The court stated that water could be appropriated for *in situ* use—without a diversion—for recreation and fishing purposes.[40]

2.3.3 Utah

Utah also has a statute that explicitly provides for instream flow. Utah's statute allows applications for permanent or temporary changes for the purpose of providing water for instream flows within a designated section of a natural stream channel or altered natural stream channel for the propagation of fish, public recreation, or the reasonable preservation or enhancement of the natural stream environment.[41] The statute gives exclusive authority to its Division of Wildlife Resources and its Division of Parks and Recreation to file applications for instream flow.[42]

These two divisions my file applications for (1) changes to perfected water rights presently owned by the respective division, (2) perfected water rights purchased by the respective division for the purpose of providing water for instream flows[43] , or (3) water rights appurtenant to land acquired or owned by the respective division.[44] Utah does not require a physical structure or physical diversion to implement a change for instream flow use.[45]

2.3.4 Montana

In 1973, Montana enacted the Montana Water Use Act which sets forth a comprehensive mechanism for the protection of instream values.[46] This Act provides that the state, any political subdivision or agency of the state, or the United States may apply to acquire a state water reservation to maintain a minimum flow, level, or quality of water.[47] The applicant may apply for an instream flow reservation for periods of time throughout the year, or for a length of time designated by the state Department of Natural Resources and Conservation (Department).[48]

All water reservations, including instream flow reservations, must be reviewed at least once every ten years and if the objectives of the water reservation are not being met, the Department may extend, revoke, or modify the reservation.[49] Any undeveloped water made available as a result of a revocation or modification is available for reallocation to another qualified appropriator.[50]

Despite the absence of a statute authorizing instream flow, New Mexico nevertheless recognizes instream flow as a beneficial use of water. This is apparent in unpublished legal opinions, case law on beneficial use, and various ongoing and completed state and federal surface water programs occurring in the state. While the enactment of a state instream flow statute similar to that of Colorado, Arizona, Montana, or Utah would provide statutory recognition of such a right, instream flow legislation is unnecessary in light of the protections already afforded it under New Mexico law.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

As discussed above, instream flow is recognized and protected under New Mexico law. While the enactment of a state instream flow statute similar to that of other western states would provide statutory recognition of such a right, such a statute would not be considered a novel legal concept.

Infrastructure Development Requirements

The infrastructure development necessary to implement this alternative would be surface water gages to measure instream flow.

Total Time to Implement

The time to implement this alternative can be measured in the time necessary to complete the process of transferring a water right to a new use as instream flow. If unprotested, the process could be completed within six months of submitting a transfer application. If protested, the process could take two years to complete the administrative process, with additional time needed if appeals are taken to the New Mexico District Court, the New Mexico Court of Appeals, and the New Mexico Supreme Court.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

None.

Effect on Water Supply (surface and groundwater)

None.

Water Saved/Lost (consumption and depletions)

There will be no water saved or lost if this alternative is implemented. Only the consumptive portion of any water right would be available to transfer for instream flow purposes.

Impacts to Water Quality (and mitigations)

Generally speaking, implementing this alternative would not impact water quality, unless significant instream flows were transferred to the surface water system at such locations to improve water quality through the effects of dilution.

Watershed/Geologic Impacts

None.

3.1.2 Environmental Impacts

Impact to Ecosystems

If significant instream flows were transferred to the surface water system, the ecosystem will be impacted by an increase in surface flows.

Implications to Endangered Species

If significant instream flows were transferred to the surface water system, there could potentially be a positive impact on the silvery minnow, since increases in instream flow could augment surface flows to support the silvery minnow.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

Since the Rio Grande Stream System is fully appropriated, any costs associated with allowing instream flow as a beneficial use relates to the costs associated with transferring an existing water right to the new instream use. These costs relate to the transfer process (application, notice, and hearing) and include attorney and technical studies or model costs, as well as the cost of the water right. The current cost of a pre-1907 surface water right is $5,000 per acre-foot (consumptive) which represents a one-time purchase price.

3.2.2 Potential Funding Source

Transfers of instream flow rights would be privately and publicly funded. Private funding would be used in transactions that concern private parties, while public funding would be used if the State of New Mexico purchases water rights to meet compact delivery requirements.

3.2.3 Ongoing Cost for Operation and Maintenance

- The costs for operation and maintenance would be the incidental costs related to measurement and reporting, and would be paid by the water right holder.

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[1] 1998 Op. Att'y Gen. No. 98-01, at 9.

[2] Id.

[3] Although the Attorney General's Opinion legitimized instream flow protection in New Mexico, the New Mexico Supreme Court (and arguably other courts) are not bound by the Opinion, and will give it only such weight as it deems the Opinion merits. *City of Santa Rosa v. Jaramillo*, 85 N.M. 747, 750, 517 P.2d 69, 72 (1973). Yet, attorney general opinions are entitled to great weight. *Hanagan v. Board of County Comm'rs*, 64 N.M. 103, 106, 325 P.2d 282, 285 (1958).

[4] 1998 Op. Att'y Gen. No. 98-01, at 4.

[5] 1998 Op. Att'y Gen. No. 98-01, at 1.

[6] Id.

[7] 1998 Op. Att'y Gen. No. 98-01, at 2,4.

[8] 1998 Op. Att'y Gen. No. 98-01, at 3 (citations omitted).

[9] §§ 72-5-6, 72-5-8, 72-5-9, 72-5-10, 72-5-13 NMSA 1978 (1997 Repl.).

[10] 1998 Op. Att'y Gen. No. 98-01, at 1,8.

[11] *Jicarilla Apache Tribe v. United States*, 657 F.2d 1126, 1133 (10th Cir. 1981), *superseded by statute as stated in Rio Grande Silvery Minnow et. al. v. John Keys et. al.*, CV 99-1320 JP/RLP-ACE (D. N.M. April 19, 2002). Of special relevance to instream flow, the Jicarilla decision was subsequently superseded when Congress reversed that part of the decision that disallowed use of San Juan-Chama Project water solely for recreational purposes. Pub.L. 97-140, Act of Dec. 29, 1981, §5; 95 Stat. 1917 n. 15 (cited by *Rio Grande Silvery Minnow et. al. v. John Keys et. al.*, CV 99-1320 JP/RLP-ACE, at 64 (D. N.M. April 19, 2002)).

[12]*First State Bank v. McNew*, 33 N.M. 414, 422-423, 269 P.56 (1928).

[13]*United States v. Ballard*, 184 F.Supp.1, 12 (D.N.M. 1960).

[14]1963-1964 Op. Att'y Gen. No. 64-1.

[15]*State ex rel State Game Commission v. Red River Valley Co.*, 51 N.M. 207, 218, 182 P.2d 421, 428 (1945).

[16] See discussion *infra.*

[17] Memorandum Opinion and Order, *Rio Grande Silvery Minnow et. al. v. John Keys et. al.*, CV 99-1320 JP/RLP-ACE, April 19, 2002, at 6.

[18] Order and Partial Final Judgment, *Rio Grande Silvery Minnow et. al. v. John W. Keys et. al.*, CV 99-1320 JP/RLP-ACE, September 23, 2002.

[19] April 19, 2002 Memorandum Opinion and Order, at 19.

[20] Id. While the Agreement is in effect until December 2003, it is not likely that it will be acted on before it expires due to lack of water in the conservation pool. December 16, 2002, conversation with Karen Fisher, New Mexico Interstate Stream Commission.

[21] Complaint for Declaratory, Injunctive and Mandatory Relief, May 21, 2000, CIV No. 00-746 JP/RLP (Forest Guardians, Plaintiffs v. United States Army Corps of Engineers and the Bureau of Reclamation, Defendants).

[22] Presentation to the New Mexico Water and Natural Resources Committee, November 28, 2000, by John W. Utton, Attorney, Sheehan, Sheehan & Stelzner, P.A., Albuquerque, New Mexico.

[23] Id.

[24] Contract Between the United States Department of the Interior Bureau of Reclamation and the Fort Sumner Irrigation District of New Mexico to Forego Delivery of Water for the Remainder of the 2000 Irrigation Season ("forbearance contract"), Contract No. 00-WC-40-6750, September 15, 2000.

[25] Under statute, project water is immune from forfeiture. §72-5-28 (G) NMSA 1978 (2000 Cum Supp).

[26] New Mexico Interstate Stream Commission Water Resource Conservation Project: Pecos River Portion Supplemental Placement Agreement Between the New Mexico Interstate Stream Commission and the Fort Sumner Irrigation District, October 2000.

[27] § 72-1-2.4 NMSA 1978 (2002 Cum. Supp.); §72-14-3 NMSA 1978 (1997 Repl.).

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[28] ROBERT E. BECK ET. AL., WATERS AND WATER RIGHTS §13.05(a) (2000).

[29] COLO. REV. STAT. 37-92-102(3)(Supp. 2000).

[30] Id.

[31] Id.

[32] Id.

[33] Id.; See also *City of Thornton v. Fort Collins*, 830 P.2d 915 (Colo. 1992) (under Colorado law, a claim for a minimum instream flow can be made only by the CWCB).

[34] COLO. REV. STAT. 37-92-102 (1)(a).

[35] COLO. REV. STAT. 37-92-102 (1)(b).

[36] Id.

[37] ARIZ REV. STAT. ANN. §45-151(A)(2001).

[38] "The person [appropriator], the state of Arizona or a political subdivision thereof first appropriating the water shall have the better right." ARIZ REV. STAT. ANN. §45-151(A).

[39] *McClellan v. Jantzen*, 26 Ariz. App. 223, 547 P.2d 494 (1976).

[40] Id. at 225, 496.

[41] UTAH CODE ANNOT. § 73-3-3(11)(a) (2002).

[42] Id.

[43] Funding may be provided for this purpose by legislative appropriation or acquired by lease, agreement, gift, exchange, or contribution.

[44] Id. at § 73-3-3(11)(b).

[45] Id. at § 73-3-3(11)(c).

[46] MONT. CODE ANNOT, §85-2-316 (2002).

[47] MONT. CODE ANNOT. § 85-2-316 (1) (2002).

[48] Id.

[49] Id. at § 85-2-316 (10).

[50] Id.

Technical and Physical Feasibility Fact Sheet

Alternative 66: Watershed Plans

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1. Definition of Alternative

A-66: Implement local and regional watershed management plans through all land and water agencies in the planning area.

The Water Assembly further clarified this definition with the following text: "once a water plan is agreed upon, coordinate the implementation among the numerous agencies at the local, state, Tribal, and federal level that have some jurisdiction in the matter."

2. Summary of the Alternative Analysis

Watershed management consists of a variety of activities that can contribute to the health of a watershed, including those that protect or improve water quality, enhance water supply, and/or enhance the ecosystems of the area. Another important benefit of watershed management can be reduction of fuel loads, which in turn minimizes the potential for catastrophic forest fires. Ideally, watershed management proceeds in a manner that will optimize the benefits in all of these areas.

Because one of the primary purposes of these fact sheets is to develop an understanding of how various alternatives could affect the water supply and demand in the Middle Rio Grande (MRG) planning region, much of the following discussion focuses on the potential for watershed management activities to affect the regional water supply. However, water quality protection, ecosystem restoration, and/or forest fire protection are equally valid reasons for proceeding with watershed management planning and implementation, and lack of watershed restoration could result in negative effects such as fire risk and ecosystem deterioration.

Two other alternatives defined by the Water Assembly—A-1, Bosque Management, and A-33, Erosion Prevention (A-33 was not analyzed as part of the DBS&A contract)—should be linked to this alternative during the implementation stage so that all aspects of watershed management can be addressed with a comprehensive plan. However, to prevent duplication, this fact sheet does not discuss watershed issues relevant to A-1 and A-33.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

The first step in developing watershed management plans is to bring together entities and individuals with interests in the watershed, including local, state, Tribal, and federal agencies that have some jurisdiction in the watershed, along with private landowners. Many groups of this type have been formed throughout the western U.S., including a group that is currently considering watershed management activities in the Rio Puerco Watershed. The key to maintaining this type of group is to make sure it is well coordinated and facilitated, which can be accomplished by hiring professionals who specialize in facilitation or involving employees of land management agencies, if they are available. Numerous resources for watershed groups are available from the U.S. Environmental Protection Agency (EPA) and through the Internet.

Once a watershed group has been formed and plans have been developed, strategies that benefit the watershed can be implemented. Examples of such strategies include:

- Management practices for roads, culverts, or other construction projects that minimize erosion and protect water quality from increased sedimentation

- Projects that address water quality issues such as elevated stream temperatures, suspended sediment loads, and impacts from septic systems, mining, or potential contaminant sources

- Grazing practices that minimize water quality degradation, riparian impacts, and impacts to upland watersheds

- Thinning and/or prescribed burns to reduce the risk of catastrophic forest fire and to potentially increase water supplies at higher elevations

In general, the technology for these types of watershed projects is available and well understood, and watershed management activities are already being implemented in the planning region. In particular, the national forests in the area routinely conduct watershed projects, including erosion control, thinning, and prescribed burns (Santa Fe National Forest, 2002b, 2002c; USFS, 1985, 2002). To proceed with watershed management at a regional level, these efforts may need to be updated to incorporate current understandings of fuel loads, fire risks, grazing practices, and ecosystem management, and U.S. Forest Service planning would need to be coordinated with other state, federal, Tribal, and private interests in the region. In addition, the Rio Puerco Watershed group, with participation from state, federal, and Tribal agencies, has been evaluating and seeking funding to address water quality issues along the Rio Puerco.

An important consideration of this alternative is to estimate the potential impacts of watershed management on water supply. Since increased infiltration from watershed projects is more relevant to Alternative 33 (Erosion Prevention), the key focus of this fact sheet is the potential increase in supply due to forest thinning activities. Although the technology for thinning is well developed, most of the research on the impacts of thinning has been conducted outside New Mexico. Additional monitoring programs to evaluate the effect of thinning projects on water supply within the state or the region would be valuable. To optimize the thinning program, reseeding of thinned areas may be considered. Such reseeding may prevent or curtail regrowth of understory and restore forests to a more natural condition for mature ponderosa and piñon forests and may also reduce the risk of wildfires. However, reseeding is expensive and would only be useful if land is managed in a manner that prevents grazing on re-established grasses.

Infrastructure Development Requirements

Specific infrastructure required for this alternative would be identified through the watershed planning process with participation of landowners and land managers within the watershed. Those involved in the watershed planning process should consider specific water quality, ecosystem, and fire prevention concerns within each watershed and should seek funding to implement projects to address those concerns. Typical infrastructure development requirements related to this alternative include:

- *Road construction to create access for forest thinning activities*. Ideally, existing roads would be used, as building of new roads can have environmental, water quality, and fiscal impacts. However, some new roads may be required for watershed thinning.

- *Removal of septic tanks and replacement with centralized wastewater treatment* is sometimes addressed through watershed management, because septic tanks represent nonpoint sources that can be addressed through the Clean Water Act, Section 319, which supports many watershed efforts. Infrastructure issues for wastewater treatment are discussed in Alternative 26, Domestic Wastewater.

- *Small scale infrastructure projects* such as replacement of culverts or construction of check dams or fencing (to restrict grazing) may be beneficial watershed improvements.

Total Time to Implement

As mentioned above, some watershed efforts within the region are already underway. Once funding and/or the commitment of an organizer is secured, the formation of new watershed groups can proceed relatively quickly, generally within a few months. Though completion of specific watershed projects would be an ongoing process and timing is dependent on acquisition of funding, the development of watershed plans and initiation of watershed projects would normally be accomplished in a one- to three-year timeframe. In particular, thinning projects could be initiated in priority areas and proceed to other areas over time. Due to regrowth issues, periodic (20- to 50-year) thinning will be required in all targeted areas.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

This alternative will not affect water demand.

Effect on Water Supply (surface and groundwater)

The key consideration in this alternative is potential increases in water supply, or yield, due to forest thinning activities. An important aspect in considering potential yield increases, however, is that the entity conducting the watershed activity does not necessarily have the right to use the water. Any additional water contributed to the stream system would augment streamflows that are legally apportioned based on water rights priority dates. This limitation is further discussed in the legal feasibility fact sheet (*Evaluation of Alternative Actions for Legal Implications, Issues and Solutions).*

In general, water yield increases are proportional to annual precipitation and the amount of vegetation that is removed (MacDonald, 2002a, 2002b; Bosch and Hewlett, 1982; Troendle and Kaufmann, 1987). Small or no water yield increases can be expected in areas where annual precipitation is less than 18 to 20 inches (MacDonald 2002a, 2002b; Ffolliott and Thorud, 1975; Bosch and Hewlett, 1982; Stednick, 1996).

As water yield increases are directly proportional to precipitation and precipitation within the region varies significantly over time, the annual yield increases achieved through forest thinning in the region are expected to be highly variable. Data from the Fool Creek study in central Colorado show that water yield increases in dry years, when they are most needed, were only about one-quarter of the increases in wet years, when they are least needed (MacDonald 2002a, 2002b). The availability 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 supply long-term.

In addition, in snow-dominated areas, most of the increase in water yield comes during months with the highest level of snowmelt. At Fool Creek in Colorado, for instance, May was the only month with a statistically significant increase in monthly water yields (MacDonald, 2002a, 2002b). Paired watershed experiments in areas with more substantial amounts of summer rainfall have sometimes yielded large percentage increases in summer runoff, but the absolute amounts are very small (e.g., less than 0.1 cubic foot per second [cfs] per square mile) (MacDonald 2002a, 2002b). 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.

Areas with precipitation of 20 inches per year or greater, which cover approximately 300,000 acres of the region, were used to estimate the potential yield increases in the MRG planning region. Maps of contoured precipitation showing this area are provided in Exhibit 66A. The estimated potential yield increases are based on two primary assumptions:

- Based on previous studies in the Rocky Mountains (MacDonald, 2002a), it was assumed that yield increases from thinning would be on the order of 0.7 to 0.9 inch over the land treated.

- Because it is probably not realistic to assume that the entire area could be thinned, it was assumed that 30 to 70 percent of the area with precipitation above 20 inches would be thinned.

Table 66-1 illustrates the potential water supply increases in the region. As shown in this table, for the assumed 30 to 70 percent of the high-precipitation area that would be thinned, yield would increase by approximately 5,000 to 15,000 acre-feet per year. However, as discussed above, this amount would vary from year to year, with lesser yield increases occurring in the dry years.

Table 66-1. Potential Water Supply Increases in Middle Rio Grande Planning Region

Fraction of Total Area Thinned [a]	Area Thinned [b] (acres)	Low-End Water Yield Increase [c] (acre-feet)	High-End Water Yield Increase [d] (acre-feet)
0.00	0	0	0
0.10	30,800	1,800	2,300
0.20	61,700	3,600	4,600
0.30	92,500	5,400	6,900
0.40	123,400	7,200	9,300
0.50	154,200	9,000	11,600
0.60	185,000	10,800	13,900
0.70	215,900	12,600	16,200
0.80	246,700	14,400	18,500
0.90	277,600	16,200	20,800
1.00	308,400	18,000	23,100

[a] Within each incremental fraction, at least 25 percent of the basal area (i.e., 25 percent of the vegetation) must be removed to achieve indicated yield
[b] Total area where precipitation is above 20 inches per year = 308,398 acres
[c] Calculations assume that thinning results in 0.7 inch of additional water yield over area thinned
[d] Calculations assume that thinning results in 0.9 inch of additional water yield over area thinned

Although much of the research on this topic has been conducted outside of New Mexico, the Mescalero Apache Tribe has been conducting extensive forest management, including thinning projects. At this time anecdotal evidence indicates increases in streamflows due to the forestry projects; however, data reflecting these changes have not yet been collected in the streamflow monitoring program currently being implemented (Hornsby, 2002; Walsh-Padilla, 2003). Additional research on the effects of thinning programs within New Mexico could help to improve confidence in the estimates of potential yield increases.

Water supply impacts in piñon-juniper woodlands. Piñon-pine and juniper woodlands are widespread on the Colorado Plateau, including the MRG planning region, between about 5,000 and 7,000 feet in elevation. Annual precipitation is typically from 10 to about 15 inches in piñon-juniper woodlands, and tree species in these communities have evolved both drought and cold resistance. Though the research discussed above indicates potential for increases only at higher elevations, potential water supply impacts in piñon-juniper woodlands is discussed here because they constitute a significant portion of the MRG planning region.

Though some improvements in the ecological health of the area and the timing of runoff events can be expected, the opportunities for management actions to affect water yields in the piñon-juniper zone are generally much more limited than in the forested areas. Research in this area has produced variable results, as indicated by the following examples:

- In 1956, research conducted in Arizona on the removal of piñon and juniper estimated a per-acre yield between 0.5 and 1.0 acre-inch, and in the next decade, a considerable number of acres were cleared using mechanical methods. Almost 20 years later, continued research and field results found that chaparral-infested lands, which had been dismissed by the first study, exhibited significantly more potential for water yield, while the piñon-juniper acres provided disappointing results (Hays, 1998).

- A summary of research into the effects of piñon-juniper management on hydrology was provided by Roundy and Vernon (1999). The results of the studies they surveyed were variable depending on watershed conditions, soil types, removal practices (i.e., whether vegetation is left on-site after cutting), and the scale of the projects, and they cannot necessarily be generalized to cover broader conditions. However, several of the investigations indicated that little usable water would result from piñon-juniper management. Conversely, studies in Oregon and Utah reported some benefits to springflow and/or increased infiltration.

- In reviewing piñon-juniper management, Gottfried and Severson (1994) indicated that many control programs failed to produce more water and better wildlife habitat, as had originally been expected.

Research conducted by Wood and Javed (2001) compared runoff from untreated piñon-juniper stands to runoff from stands where the piñon-juniper were clear-cut and the land was either cleared, burned, or covered with slash. The test plots were monitored from the time of treatment in 1989 until 1999. The findings of this study suggest that treatment of slash following thinning can be used to effect short-term changes in runoff, but that long-term changes are more difficult to achieve. The reestablishment of understory growth may be beneficial for certain land use practices (cattle grazing, fire suppression), but does not appear to achieve greater water yields.

Water Saved/Lost (consumption and depletions)

This alternative will not have an impact on consumption. The alternative could affect water supply as described above and by reducing depletions due to evapotranspiration.

Impacts to Water Quality (and mitigations)

In general, watershed management should have a positive impact on water quality. Watershed groups and public lands managers can work to identify and remediate sources of water quality degradation and to address water quality issues associated with grazing, erosion, septic tanks, or other concerns.

Conversely, thinning activities can have a negative impact on water quality if they are not conducted properly. The primary water quality concern from thinning is increased erosion and sedimentation. This type of impact can be minimized, however, by using best management practices for road installation (if needed) and logging activities.

Watershed/Geologic Impacts

The objective of this alternative is to provide positive impacts to watersheds, as described in Section 2.

3.1.2 Environmental Impacts

Impact to Ecosystems

Environmental impacts from watershed management activities are generally positive, though some environmental damage could occur if activities are not carefully planned and executed. Watershed management can help identify point and nonpoint sources of water quality degradation, secure funding, and implement best management practices that result in overall environmental improvements. Because thinning projects can have either positive or negative environmental impacts, depending on how they are executed, careful planning and execution of thinning projects is required. Best management practices for logging activities, road construction and maintenance, and timing of projects (in relation to species needs) should be used to minimize environmental disturbances. To achieve optimal ecosystem benefit, watershed management programs should integrate grazing management with efforts to reduce fire risk, such as thinning or prescribed burns (Horning, 2003).

Implications to Endangered Species

State or federal threatened or endangered species in the MRG planning region include the Jemez Mountain Salamander, Neotropic Cormorant, Bald Eagle, Whooping Crane, Mexican Spotted Owl, Bell's Vireo, Southwestern Willow Flycatcher, New Mexican Meadow Jumping Mouse, and Rio Grande Silvery Minnow (NMNHP, 2002). With the exception of the Whooping Crane, Bell's Vireo, and the Rio Grande Silvery Minnow, these species may be present in the upland watersheds where management activities would be concentrated. The potential for watershed projects to affect these species is dependent on the nature of the activity and the location of the project in relation to species habitat. Careful planning and timing of projects can help to ensure that they do not impact endangered species.

Additions to the water supply, if any, will be in late spring as snowmelt is occurring. Unless this water is stored and later released, it would not be expected to have an impact on the silvery minnow. Water quality improvements resulting from watershed management would generally have a positive impact on aquatic species, particularly if severe ash flows from catastrophic fires are prevented. It is not known whether water quality improvements would have a positive impact on the silvery minnow, specifically, but no negative impact is anticipated.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

The formation of watershed groups could be accomplished relatively inexpensively if the group is coordinated by state, Tribal or federal employees or volunteers. The cost for initiating a watershed group and designing watershed projects using professional facilitation and technical expertise on watershed planning issues could range from approximately $20,000 to $100,000.

Costs for conducting watershed projects that affect water quality are highly variable. A general approach is to identify needed projects in the planning stage, and implement those projects as funding becomes available.

Costs for conducting thinning projects are also variable depending on the ease of access, thickness of vegetation, amount of thinning to be done, treatment of slash (i.e., it can be, in order of increasing cost, scattered, piled, burned, or removed), and techniques used (in order of increasing cost, hand pruning, chainsawing, bulldozing). Example cost ranges are:

- In areas with road access, costs for non-commercial thinning are approximately $80 to $140 per acre for ponderosa forest vegetation.

- The piñon-juniper forest is more expensive because there are more small branches and more slash; costs vary from $160 to $280 per acre (Alter, 2003).

- Costs for steeper or more inaccessible terrain could be considerable higher. For example, recent costs for thinning relatively steep terrain within the Santa Fe watershed were approximately $1,000 per acre (MacDonald, 2002a).

- Reseeding is generally not performed as part of forest thinning programs (Alter, 2003). Costs for areal reseeding can be in the range of $600 to $2,000 per acre (Lewis, 2000).

These costs do not include expenses for necessary planning or environmental studies, which may be significant.

Assuming a cost of $200 per acre, and assuming that 50 percent of the area with precipitation above 20 inches is thinned, resulting in a yield increase of 10,000 acre-feet per year (Table

66-1) that recurs every year for 20 years, the cost for this option, spread over the 20-year time frame, is approximately $150 per acre-foot of increased water supply. The actual period of increased yields (and therefore the annual cost) is dependent on the rate of regrowth.

3.2.2 Potential Funding Sources

Funding for watershed activities can be derived from a variety of sources. U.S. EPA Section 319 nonpoint source grants can potentially be used to form watershed groups, to identify nonpoint source issues, and to implement projects that use best management practices. The focus of these grants is to improve water quality conditions.

In 2002, the New Mexico Water Trust Fund issued a request for funding applications in four categories, one of which was watershed management. Depending on legislative appropriations, this may be a continuing source of funding. Other potential funding sources include Natural Resources Conservation Service (NRCS) grants (e.g., Conservation Technical Assistance, Small Watershed Program, Environmental Quality Incentives Program, Conservation Reserve Program, Emergency Watershed Protection).

Costs for watershed improvements as a result of improved grazing practices could potentially be covered by ranchers. Changes in stocking rates and rotation schedules may provide a benefit to the rancher as well as to the watershed, providing the rancher with an incentive to make these changes (Quivira Coalition, 2000; Goodloe, 2002).

3.2.3 Ongoing Cost for Operation and Maintenance

The primary ongoing cost of forest thinning projects is the need to address regrowth through periodic thinning. In general, a ponderosa forest must be thinned at least every 30 to 40 years to prevent fires and to maintain increased water yield. Costs for repeat thinning would be similar to the initial costs (excluding inflation).

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Alternative 66

Exhibit A
Maps

Technical and Physical Feasibility Fact Sheet

Alternative 66: Watershed Plans

Acknowledgements: This fact sheet was written by Joanne Hilton of Daniel B. Stephens & Associates, Inc. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-66: Implement local and regional watershed management plans through all land and water agencies in the planning area.

The Water Assembly further clarified this definition with the following text: "once a water plan is agreed upon, coordinate the implementation among the numerous agencies at the local, state, Tribal, and federal level that have some jurisdiction in the matter."

2. Summary of the Alternative Analysis

Watershed management consists of a variety of activities that can contribute to the health of a watershed, including those that protect or improve water quality, enhance water supply, and/or enhance the ecosystems of the area. Another important benefit of watershed management can be reduction of fuel loads, which in turn minimizes the potential for catastrophic forest fires. Ideally, watershed management proceeds in a manner that will optimize the benefits in all of these areas.

Because one of the primary purposes of these fact sheets is to develop an understanding of how various alternatives could affect the water supply and demand in the Middle Rio Grande (MRG) planning region, much of the following discussion focuses on the potential for watershed management activities to affect the regional water supply. However, water quality protection, ecosystem restoration, and/or forest fire protection are equally valid reasons for proceeding with watershed management planning and implementation, and lack of watershed restoration could result in negative effects such as fire risk and ecosystem deterioration.

Two other alternatives defined by the Water Assembly—A-1, Bosque Management, and A-33, Erosion Prevention (A-33 was not analyzed as part of the DBS&A contract)—should be linked to this alternative during the implementation stage so that all aspects of watershed management can be addressed with a comprehensive plan. However, to prevent duplication, this fact sheet does not discuss watershed issues relevant to A-1 and A-33.

3. Alternative Evaluation

3.1 Technical Feasibility

Enabling New Technologies and Status

The first step in developing watershed management plans is to bring together entities and individuals with interests in the watershed, including local, state, Tribal, and federal agencies that have some jurisdiction in the watershed, along with private landowners. Many groups of this type have been formed throughout the western U.S., including a group that is currently considering watershed management activities in the Rio Puerco Watershed. The key to maintaining this type of group is to make sure it is well coordinated and facilitated, which can be accomplished by hiring professionals who specialize in facilitation or involving employees of land management agencies, if they are available. Numerous resources for watershed groups are available from the U.S. Environmental Protection Agency (EPA) and through the Internet.

Once a watershed group has been formed and plans have been developed, strategies that benefit the watershed can be implemented. Examples of such strategies include:

- Management practices for roads, culverts, or other construction projects that minimize erosion and protect water quality from increased sedimentation
- Projects that address water quality issues such as elevated stream temperatures, suspended sediment loads, and impacts from septic systems, mining, or potential contaminant sources
- Grazing practices that minimize water quality degradation, riparian impacts, and impacts to upland watersheds

- Thinning and/or prescribed burns to reduce the risk of catastrophic forest fire and to potentially increase water supplies at higher elevations

In general, the technology for these types of watershed projects is available and well understood, and watershed management activities are already being implemented in the planning region. In particular, the national forests in the area routinely conduct watershed projects, including erosion control, thinning, and prescribed burns (Santa Fe National Forest, 2002b, 2002c; USFS, 1985, 2002). To proceed with watershed management at a regional level, these efforts may need to be updated to incorporate current understandings of fuel loads, fire risks, grazing practices, and ecosystem management, and U.S. Forest Service planning would need to be coordinated with other state, federal, Tribal, and private interests in the region. In addition, the Rio Puerco Watershed group, with participation from state, federal, and Tribal agencies, has been evaluating and seeking funding to address water quality issues along the Rio Puerco.

An important consideration of this alternative is to estimate the potential impacts of watershed management on water supply. Since increased infiltration from watershed projects is more relevant to Alternative 33 (Erosion Prevention), the key focus of this fact sheet is the potential increase in supply due to forest thinning activities. Although the technology for thinning is well developed, most of the research on the impacts of thinning has been conducted outside New Mexico. Additional monitoring programs to evaluate the effect of thinning projects on water supply within the state or the region would be valuable. To optimize the thinning program, reseeding of thinned areas may be considered. Such reseeding may prevent or curtail regrowth of understory and restore forests to a more natural condition for mature ponderosa and piñon forests and may also reduce the risk of wildfires. However, reseeding is expensive and would only be useful if land is managed in a manner that prevents grazing on re-established grasses.

Infrastructure Development Requirements

Specific infrastructure required for this alternative would be identified through the watershed planning process with participation of landowners and land managers within the watershed. Those involved in the watershed planning process should consider specific water quality, ecosystem, and fire prevention concerns within each watershed and should seek funding to implement projects to address those concerns. Typical infrastructure development requirements related to this alternative include:

- *Road construction to create access for forest thinning activities*. Ideally, existing roads would be used, as building of new roads can have environmental, water quality, and fiscal impacts. However, some new roads may be required for watershed thinning.

- *Removal of septic tanks and replacement with centralized wastewater treatment* is sometimes addressed through watershed management, because septic tanks represent nonpoint sources that can be addressed through the Clean Water Act, Section 319, which supports many watershed efforts. Infrastructure issues for wastewater treatment are discussed in Alternative 26, Domestic Wastewater.

- *Small scale infrastructure projects* such as replacement of culverts or construction of check dams or fencing (to restrict grazing) may be beneficial watershed improvements.

Total Time to Implement

As mentioned above, some watershed efforts within the region are already underway. Once funding and/or the commitment of an organizer is secured, the formation of new watershed groups can proceed relatively quickly, generally within a few months. Though completion of specific watershed projects would be an ongoing process and timing is dependent on acquisition of funding, the development of watershed plans and initiation of watershed projects would normally be accomplished in a one- to three-year timeframe. In particular, thinning projects could be initiated in priority areas and proceed to other areas over time. Due to regrowth issues, periodic (20- to 50-year) thinning will be required in all targeted areas.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

This alternative will not affect water demand.

Effect on Water Supply (surface and groundwater)

The key consideration in this alternative is potential increases in water supply, or yield, due to forest thinning activities. An important aspect in considering potential yield increases, however, is that the entity conducting the watershed activity does not necessarily have the right to use the water. Any additional water contributed to the stream system would augment streamflows that are legally apportioned based on water rights priority dates. This limitation is further discussed in the legal feasibility fact sheet (*Evaluation of Alternative Actions for Legal Implications, Issues and Solutions).*

In general, water yield increases are proportional to annual precipitation and the amount of vegetation that is removed (MacDonald, 2002a, 2002b; Bosch and Hewlett, 1982; Troendle and Kaufmann, 1987). Small or no water yield increases can be expected in areas where annual precipitation is less than 18 to 20 inches (MacDonald 2002a, 2002b; Ffolliott and Thorud, 1975; Bosch and Hewlett, 1982; Stednick, 1996).

As water yield increases are directly proportional to precipitation and precipitation within the region varies significantly over time, the annual yield increases achieved through forest thinning in the region are expected to be highly variable. Data from the Fool Creek study in central Colorado show that water yield increases in dry years, when they are most needed, were only about one-quarter of the increases in wet years, when they are least needed (MacDonald 2002a, 2002b). The availability 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 supply long-term.

In addition, in snow-dominated areas, most of the increase in water yield comes during months with the highest level of snowmelt. At Fool Creek in Colorado, for instance, May was the only month with a statistically significant increase in monthly water yields (MacDonald, 2002a, 2002b). Paired watershed experiments in areas with more substantial amounts of summer rainfall have sometimes yielded large percentage increases in summer runoff, but the absolute amounts are very small (e.g., less than 0.1 cubic foot per second [cfs] per square mile) (MacDonald 2002a, 2002b). 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.

Areas with precipitation of 20 inches per year or greater, which cover approximately 300,000 acres of the region, were used to estimate the potential yield increases in the MRG planning region. Maps of contoured precipitation showing this area are provided in Exhibit 66A. The estimated potential yield increases are based on two primary assumptions:

- Based on previous studies in the Rocky Mountains (MacDonald, 2002a), it was assumed that yield increases from thinning would be on the order of 0.7 to 0.9 inch over the land treated.

- Because it is probably not realistic to assume that the entire area could be thinned, it was assumed that 30 to 70 percent of the area with precipitation above 20 inches would be thinned.

Table 66-1 illustrates the potential water supply increases in the region. As shown in this table, for the assumed 30 to 70 percent of the high-precipitation area that would be thinned, yield would increase by approximately 5,000 to 15,000 acre-feet per year. However, as discussed above, this amount would vary from year to year, with lesser yield increases occurring in the dry years.

Table 66-1. Potential Water Supply Increases in Middle Rio Grande Planning Region

Fraction of Total Area Thinned [a]	Area Thinned [b] (acres)	Low-End Water Yield Increase [c] (acre-feet)	High-End Water Yield Increase [d] (acre-feet)
0.00	0	0	0
0.10	30,800	1,800	2,300
0.20	61,700	3,600	4,600
0.30	92,500	5,400	6,900
0.40	123,400	7,200	9,300
0.50	154,200	9,000	11,600
0.60	185,000	10,800	13,900
0.70	215,900	12,600	16,200
0.80	246,700	14,400	18,500
0.90	277,600	16,200	20,800
1.00	308,400	18,000	23,100

[a] Within each incremental fraction, at least 25 percent of the basal area (i.e., 25 percent of the vegetation) must be removed to achieve indicated yield
[b] Total area where precipitation is above 20 inches per year = 308,398 acres
[c] Calculations assume that thinning results in 0.7 inch of additional water yield over area thinned
[d] Calculations assume that thinning results in 0.9 inch of additional water yield over area thinned

Although much of the research on this topic has been conducted outside of New Mexico, the Mescalero Apache Tribe has been conducting extensive forest management, including thinning projects. At this time anecdotal evidence indicates increases in streamflows due to the forestry projects; however, data reflecting these changes have not yet been collected in the streamflow monitoring program currently being implemented (Hornsby, 2002; Walsh-Padilla, 2003). Additional research on the effects of thinning programs within New Mexico could help to improve confidence in the estimates of potential yield increases.

Water supply impacts in piñon-juniper woodlands. Piñon-pine and juniper woodlands are widespread on the Colorado Plateau, including the MRG planning region, between about 5,000 and 7,000 feet in elevation. Annual precipitation is typically from 10 to about 15 inches in piñon-juniper woodlands, and tree species in these communities have evolved both drought and cold resistance. Though the research discussed above indicates potential for increases only at higher elevations, potential water supply impacts in piñon-juniper woodlands is discussed here because they constitute a significant portion of the MRG planning region.

Though some improvements in the ecological health of the area and the timing of runoff events can be expected, the opportunities for management actions to affect water yields in the piñon-juniper zone are generally much more limited than in the forested areas. Research in this area has produced variable results, as indicated by the following examples:

- In 1956, research conducted in Arizona on the removal of piñon and juniper estimated a per-acre yield between 0.5 and 1.0 acre-inch, and in the next decade, a considerable number of acres were cleared using mechanical methods. Almost 20 years later, continued research and field results found that chaparral-infested lands, which had been dismissed by the first study, exhibited significantly more potential for water yield, while the piñon-juniper acres provided disappointing results (Hays, 1998).

- A summary of research into the effects of piñon-juniper management on hydrology was provided by Roundy and Vernon (1999). The results of the studies they surveyed were variable depending on watershed conditions, soil types, removal practices (i.e., whether vegetation is left on-site after cutting), and the scale of the projects, and they cannot necessarily be generalized to cover broader conditions. However, several of the investigations indicated that little usable water would result from piñon-juniper management. Conversely, studies in Oregon and Utah reported some benefits to springflow and/or increased infiltration.

- In reviewing piñon-juniper management, Gottfried and Severson (1994) indicated that many control programs failed to produce more water and better wildlife habitat, as had originally been expected.

Research conducted by Wood and Javed (2001) compared runoff from untreated piñon-juniper stands to runoff from stands where the piñon-juniper were clear-cut and the land was either cleared, burned, or covered with slash. The test plots were monitored from the time of treatment in 1989 until 1999. The findings of this study suggest that treatment of slash following thinning can be used to effect short-term changes in runoff, but that long-term changes are more difficult to achieve. The reestablishment of understory growth may be beneficial for certain land use practices (cattle grazing, fire suppression), but does not appear to achieve greater water yields.

Water Saved/Lost (consumption and depletions)

This alternative will not have an impact on consumption. The alternative could affect water supply as described above and by reducing depletions due to evapotranspiration.

Impacts to Water Quality (and mitigations)

In general, watershed management should have a positive impact on water quality. Watershed groups and public lands managers can work to identify and remediate sources of water quality degradation and to address water quality issues associated with grazing, erosion, septic tanks, or other concerns.

Conversely, thinning activities can have a negative impact on water quality if they are not conducted properly. The primary water quality concern from thinning is increased erosion and sedimentation. This type of impact can be minimized, however, by using best management practices for road installation (if needed) and logging activities.

Watershed/Geologic Impacts

The objective of this alternative is to provide positive impacts to watersheds, as described in Section 2.

3.1.2 Environmental Impacts

Impact to Ecosystems

Environmental impacts from watershed management activities are generally positive, though some environmental damage could occur if activities are not carefully planned and executed. Watershed management can help identify point and nonpoint sources of water quality degradation, secure funding, and implement best management practices that result in overall environmental improvements. Because thinning projects can have either positive or negative environmental impacts, depending on how they are executed, careful planning and execution of thinning projects is required. Best management practices for logging activities, road construction and maintenance, and timing of projects (in relation to species needs) should be used to minimize environmental disturbances. To achieve optimal ecosystem benefit, watershed management programs should integrate grazing management with efforts to reduce fire risk, such as thinning or prescribed burns (Horning, 2003).

Implications to Endangered Species

State or federal threatened or endangered species in the MRG planning region include the Jemez Mountain Salamander, Neotropic Cormorant, Bald Eagle, Whooping Crane, Mexican Spotted Owl, Bell's Vireo, Southwestern Willow Flycatcher, New Mexican Meadow Jumping Mouse, and Rio Grande Silvery Minnow (NMNHP, 2002). With the exception of the Whooping Crane, Bell's Vireo, and the Rio Grande Silvery Minnow, these species may be present in the upland watersheds where management activities would be concentrated. The potential for watershed projects to affect these species is dependent on the nature of the activity and the location of the project in relation to species habitat. Careful planning and timing of projects can help to ensure that they do not impact endangered species.

Additions to the water supply, if any, will be in late spring as snowmelt is occurring. Unless this water is stored and later released, it would not be expected to have an impact on the silvery minnow. Water quality improvements resulting from watershed management would generally have a positive impact on aquatic species, particularly if severe ash flows from catastrophic fires are prevented. It is not known whether water quality improvements would have a positive impact on the silvery minnow, specifically, but no negative impact is anticipated.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

The formation of watershed groups could be accomplished relatively inexpensively if the group is coordinated by state, Tribal or federal employees or volunteers. The cost for initiating a watershed group and designing watershed projects using professional facilitation and technical expertise on watershed planning issues could range from approximately $20,000 to $100,000.

Costs for conducting watershed projects that affect water quality are highly variable. A general approach is to identify needed projects in the planning stage, and implement those projects as funding becomes available.

Costs for conducting thinning projects are also variable depending on the ease of access, thickness of vegetation, amount of thinning to be done, treatment of slash (i.e., it can be, in order of increasing cost, scattered, piled, burned, or removed), and techniques used (in order of increasing cost, hand pruning, chainsawing, bulldozing). Example cost ranges are:

- In areas with road access, costs for non-commercial thinning are approximately $80 to $140 per acre for ponderosa forest vegetation.

- The piñon-juniper forest is more expensive because there are more small branches and more slash; costs vary from $160 to $280 per acre (Alter, 2003).

- Costs for steeper or more inaccessible terrain could be considerable higher. For example, recent costs for thinning relatively steep terrain within the Santa Fe watershed were approximately $1,000 per acre (MacDonald, 2002a).

- Reseeding is generally not performed as part of forest thinning programs (Alter, 2003). Costs for areal reseeding can be in the range of $600 to $2,000 per acre (Lewis, 2000).

These costs do not include expenses for necessary planning or environmental studies, which may be significant.

Assuming a cost of $200 per acre, and assuming that 50 percent of the area with precipitation above 20 inches is thinned, resulting in a yield increase of 10,000 acre-feet per year (Table

66-1) that recurs every year for 20 years, the cost for this option, spread over the 20-year time frame, is approximately $150 per acre-foot of increased water supply. The actual period of increased yields (and therefore the annual cost) is dependent on the rate of regrowth.

3.2.2 Potential Funding Sources

Funding for watershed activities can be derived from a variety of sources. U.S. EPA Section 319 nonpoint source grants can potentially be used to form watershed groups, to identify nonpoint source issues, and to implement projects that use best management practices. The focus of these grants is to improve water quality conditions.

In 2002, the New Mexico Water Trust Fund issued a request for funding applications in four categories, one of which was watershed management. Depending on legislative appropriations, this may be a continuing source of funding. Other potential funding sources include Natural Resources Conservation Service (NRCS) grants (e.g., Conservation Technical Assistance, Small Watershed Program, Environmental Quality Incentives Program, Conservation Reserve Program, Emergency Watershed Protection).

Costs for watershed improvements as a result of improved grazing practices could potentially be covered by ranchers. Changes in stocking rates and rotation schedules may provide a benefit to the rancher as well as to the watershed, providing the rancher with an incentive to make these changes (Quivira Coalition, 2000; Goodloe, 2002).

3.2.3 Ongoing Cost for Operation and Maintenance

The primary ongoing cost of forest thinning projects is the need to address regrowth through periodic thinning. In general, a ponderosa forest must be thinned at least every 30 to 40 years to prevent fires and to maintain increased water yield. Costs for repeat thinning would be similar to the initial costs (excluding inflation).

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Alternative 66

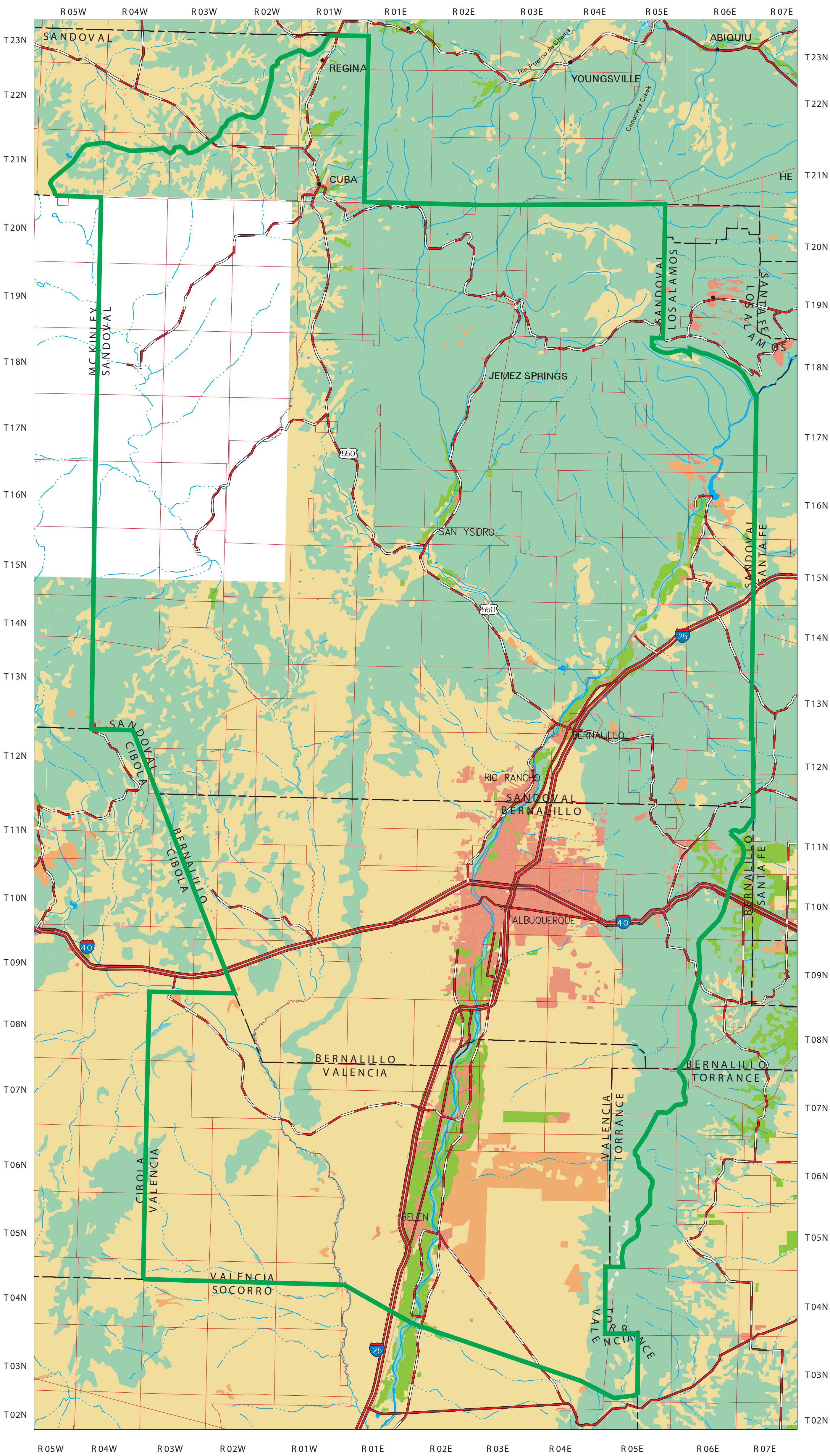
Exhibit A
Maps

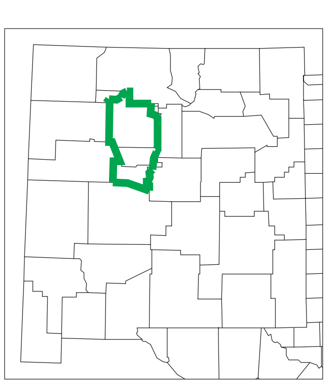
Middle Rio Grande Regional Water Plan

Landuse in Region

Explanation

- State Line
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State/Other Highway
- Township/Range
- Planning Region
- No Data
- Urban
- Agricultural Land
- Rangeland
- Forest Land
- Water
- Wetland
- Barren Land
- Tundra





Produced by New Mexico Water Resources Research Institute, December 2002

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. Landuse coverage developed by USGS/EPA at 1:250,000 scale. Boundary of the Middle Rio Grande Water Planning Region is based on county lines and surface drainage divides.

SCALE 1: 650 000

10 0 10 20 30 40 50 MILES

10 0 10 20 30 40 50 KILOMETERS

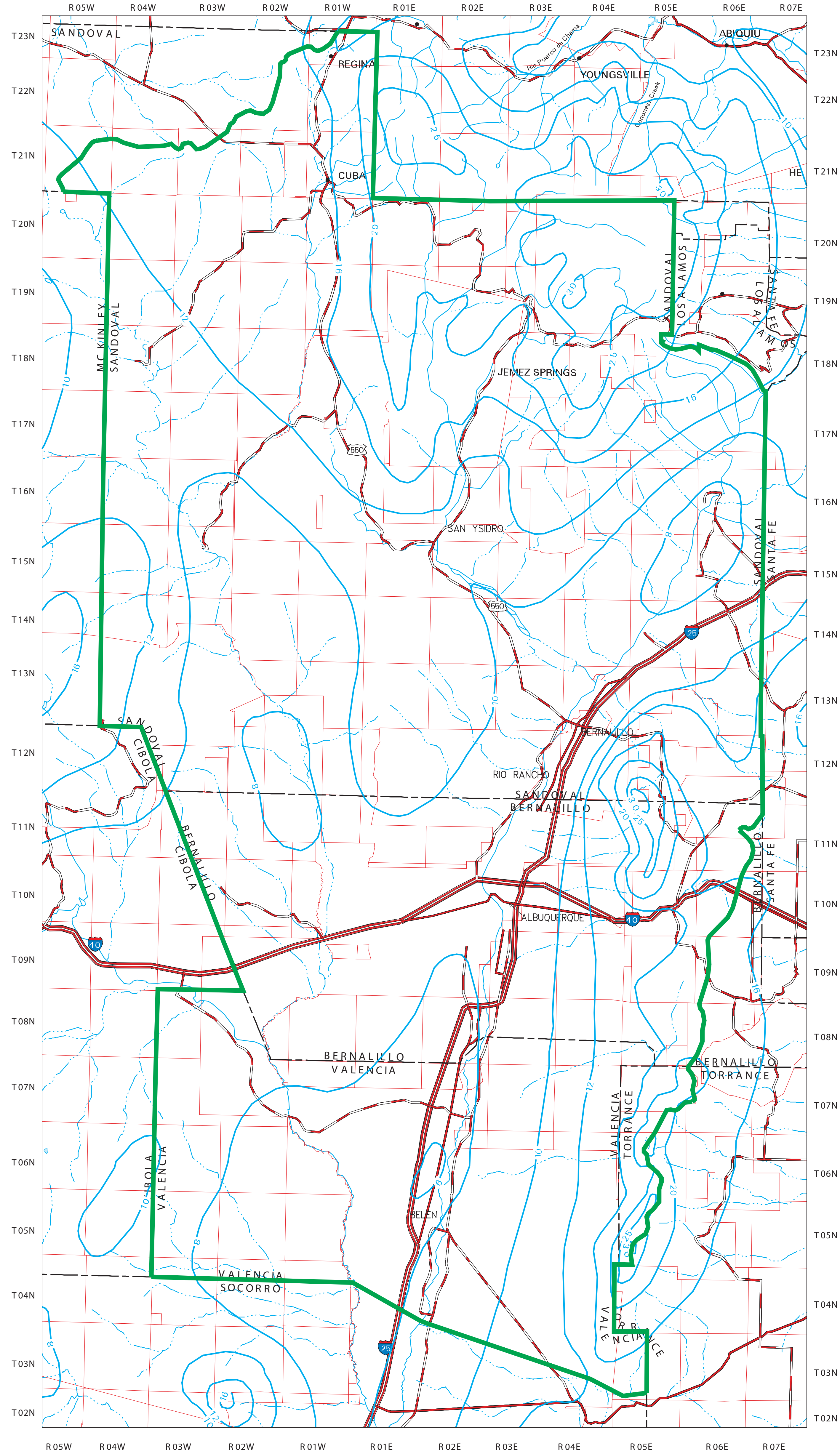
Horizontal accuracy: At the scale of 1:650,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 547 ground meters, of their true location.

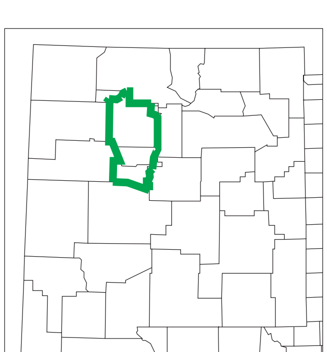
Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.

Middle Rio Grande Regional Water Plan
Average Annual Precipitation from 1931 to 1960

Explanation

- State Line
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State/Other Highway
- Township/Range
- Planning Region
- Average Precipitation in Inches





SCALE 1: 650 000

10 0 10 20 30 40 50 MILES

10 0 10 20 30 40 50 KILOMETERS

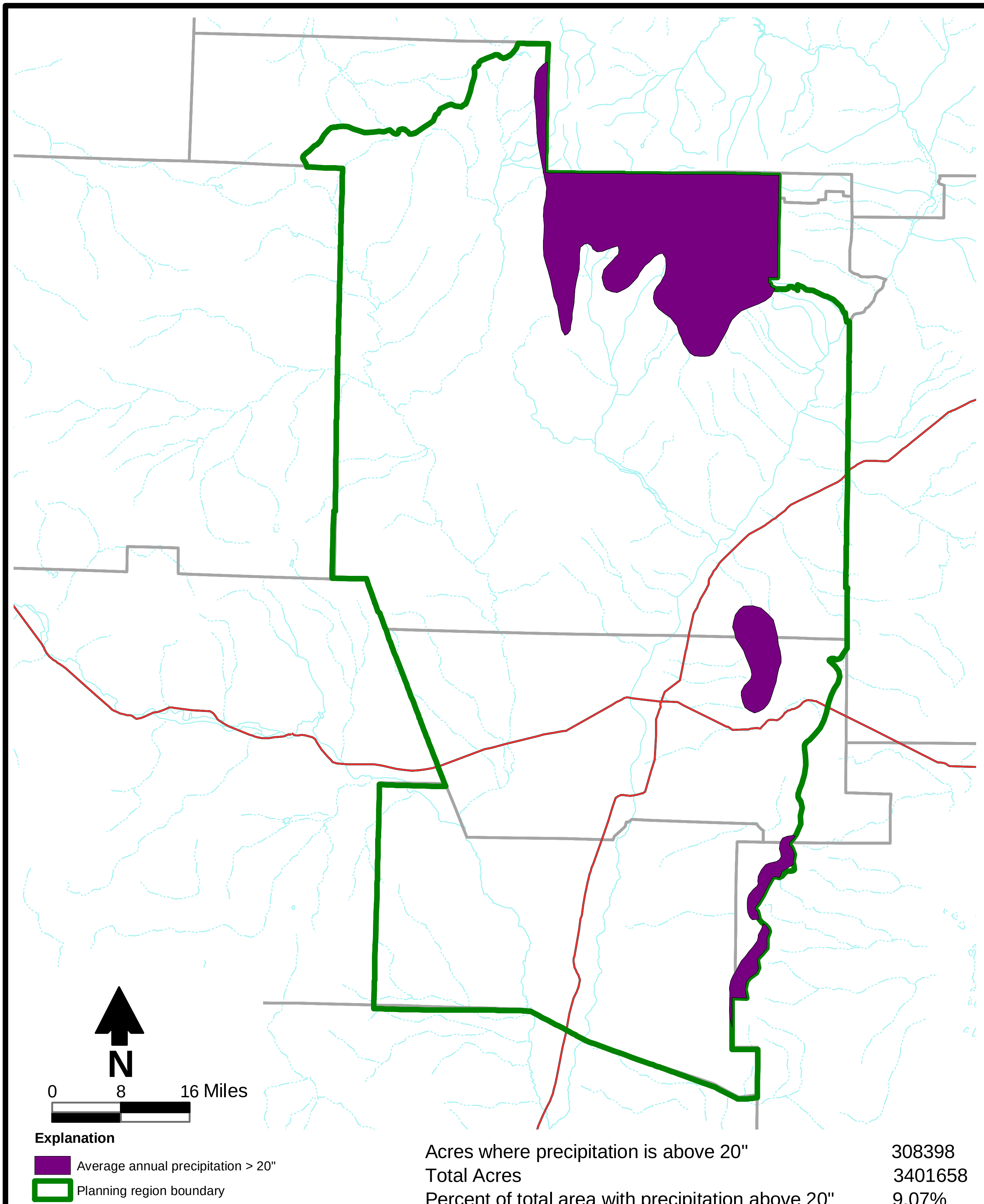
Produced by New Mexico Water Resources Research Institute, December 2002

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. This dataset contains the precipitation isopleths of the state of New Mexico. The data set was created to digitally represent the average precipitation of the state of New Mexico between the years of 1931 and 1960. The original source of the data set came from National Oceanic and Atmospheric Administration (NOAA). Earth Data Analysis Center manually digitized from the NOAA 1:500,000 scale map of the state of New Mexico. Boundary of the Middle Rio Grande Water Planning Region is based on county lines and surface drainage divides.

Horizontal accuracy: At the scale of 1:650,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 547 ground meters, of their true location.

Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.



MIDDLE RIO GRANDE PLANNING REGION

Areas with Average Annual Precipitation Above 20 Inches

Daniel B. Stephens & Associates, Inc.
2-11-03

JN WR02.0002

S:/PROJECTS/WR02.002/GIS/MXD/PRECIPITATION.MXD

Technical and Physical Feasibility Fact Sheet
Alternative 67: Water Authority/Banking

Acknowledgements: This fact sheet was written by John Utton, Esq. of Sheehan Sheehan & Stelzner as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-67: Establish a regional water management authority to provide professional water resource management and to administer or assist in a water banking program.

2. Summary of Alternative Analysis

This alternative encompasses the general question of the powers, duties and functioning of regional management entity and specifically within such an entity the creation and operation of a regional water bank.

The key issue is the scope of a regional water authority's operations and powers. Some of the competing models are: (1) a regional planning and coordination organization that does not itself assert jurisdiction over water use, but works with and for the existing local governments; (2) a regional water utility that would supply water and would assert jurisdiction and regulation over municipal, industrial and domestic water use, including imposing water conservation requirements; (3) a regional land use authority; and (4) a regional water management and regulatory authority that engages in some level of water rights administration, at least in part currently performed by the State Engineer, and whose water administration function could include water banking.

All four models are legally feasible to varying decrees. A regional coordinator and planner exists already in the form of the Mid-Region Council of Governments. Either a regional utility or land use authority could be created under existing law by agreement among local governments, most likely in the form of a Joint Powers Agreement. Alternatively, although state law authorizes a number of multi-jurisdictional water suppliers, a change in state law could be required to address the diverse and complex interests of the Middle Rio Grande. Finally, formation of a regional water rights manager and administrator would likely require a change in state law, defining the role and functioning of such an entity vis-a-vis the Office of the State Engineer. Such authority could be limited to overseeing and reporting to the State Engineer on the operations of a regional water bank.

2.1 Regional Entities

Planner and Coordinator. A less ambitious form of regional organization is found in the regional coordinator and planner. Such an entity works for and between existing local governments. It serves to coordinate and plan policies affecting its member governments and institutions, to facilitate inter-jurisdictional cooperation and to provide information and services to members. Such services may include not only water planning but also preparation of integrated land use polices that link land development to water supply, as discussed in the fact sheet for A-30, *Land Use*. The Mid-Region Council of Governments (MRCOG) currently serves that role. Although MRCOG is facilitating regional water planning, it does not have the authority or resources to become a regional water utility or a regional water rights administrator.

Regional water utility. Current state law provides three or four mechanisms for formation of a multi-jurisdictional water supplier. First, water and sanitation districts may be created to supply water to the public within the district for domestic, commercial and industrial uses, and to provide sanitary sewers or sewage disposal systems.[1] A district may be created within or partly within one or more counties, providing that the areas of the district lying in two or more counties are contiguous with one another.[2] Districts have the power to purchase, acquire, establish or construct waterworks necessary to the provision of water, including the power to extend water lines outside of the district to secure water for the state, Indian reservations or federal lands.[3] Moreover, water and sanitation districts have the power of eminent domain.[4]

Second, New Mexico counties and municipalities may jointly create metropolitan water boards to supply water. Metropolitan water boards are regulated like municipal water utilities.[5] They have the power to contract for, lease or sublease any supply of water for municipal, domestic or industrial purposes which the municipality and the county in combination with any other public or private entity may receive from the U.S. Bureau of Reclamation.[6] Boards have the same power of condemnation to acquire and operate water facilities as municipalities.[7] Until 1995, the City and County of Santa Fe operated a metropolitan water board but then disbanded it.

Third, the Joint Powers Agreements Act (JPA Act)[8] authorizes public agencies to enter into agreements with other public agencies.[9] "Public agencies" include the federal government or any federal department, agency or instrumentality; the state, an adjoining state or any state department, agency or instrumentality; an Indian Nation, Tribe or Pueblo; a subdivision of an Indian Nation, Tribe or Pueblo that has authority pursuant to the law of that Indian Nation, Tribe or Pueblo to enter into joint powers agreements directly with the state; a county, municipality, public corporation or public district of this state or an adjoining state; a New Mexico educational institution and a New Mexico school district. Under the Act, two or more public agencies, by agreement, may jointly exercise any power that the agencies have in common.[10]

The only example in the Middle Rio Grande of a regional utility is the Albuquerque Metropolitan Water and Wastewater Authority created in 2000 by JPA by the City of Albuquerque, Bernalillo County and the Village of Los Ranchos to provide domestic water and waste water services to the developed areas of unincorporated Bernalillo County, to the city and to the Village, and to allow the three participants to jointly exercise their powers to operate and set rates for water and waste water utilities.

The last potential vehicle under state law for supplying regional municipal, industrial and domestic water is found in the Conservancy Act. Although historically devoted to irrigation, the purposes of a conservancy district can be broad, consistent with the "public health, safety, convenience, and welfare."[11] "Public welfare" includes acts or things that tend to improve or benefit the general public or the inhabitants of the district.[12] In particular, the Conservancy Act requires conservancy districts to give first preference to domestic and municipal water supplies. Second in preference is water for irrigation, manufacturing, for the production of steam, for refrigerating, cooling, condensing, and for maintaining sanitary conditions of stream flow. Third in preference is water for power development, recreation, fisheries, and other uses.

Finally, federal law can provide the authority for formation of regional water suppliers. Many of the planned and operational regional water supply projects in New Mexico are sponsored and authorized by the federal government, including the San Juan-Chama Project. This sponsorship can take a variety of forms, including the financing of a project, project planning and feasibility studies, and creation of environmental impact statements. Most projects involve collaboration with state and local entities. This collaboration may include the establishment of joint powers agreements between the non-federal agencies, and may encompass various state and local regional water supply entities. Usually, water under such a project is supplied pursuant to a water supply or repayment contract between the government and the local user or users group. Especially where Indian Tribes are part of a regional authority, a federally approved supply entity may be necessary.

A regional utility could be created under existing law by agreement among local governments, most likely in the form of a Joint Powers Agreement.

Regional land use authority. A regional organization could also be established with the charge of assuring that land development and use are backed by a reliable water supply. A Joint Powers Agreement among local governments would be the most likely vehicle for creating such an authority. It could adopt policies, or perhaps even binding rules: (1) requiring linkages between water management and land use plans, such as policies requiring higher densities, conservation, xeriscaping, storm water management, and reuse; (2) imposing development fees that reflect the cost of water; (3) requiring proponents of land uses requiring additional water to acquire the commensurate water rights; and (4) using transfer of development rights to protect hydrogeologically sensitive areas.

Regional water authority. Finally, formation of a regional water rights manager and administrator would likely require a change in state law, defining the role and functioning of such an entity vis-a-vis the Office of the State Engineer. Such authority could be limited to overseeing and reporting to the State Engineer on the operations of a regional water bank.

Under New Mexico law the State Engineer is charged with "the supervision of waters of the State and of the measurement, appropriation, distribution thereof[13] . . . [a]ccording to the licenses issued by him and the adjudications of the courts."[14] He can "adopt regulations and codes to implement and enforce any provision of any law administered by him . . . to aid him in the accomplishment of his duties . . ..."[15] The State Engineer must approve all new appropriations of water as well as changes in the point of diversion and/or changes in the place and/or purpose of use of an existing water right, commonly referred to as a "transfer."[16] The State Engineer also has statutory enforcement powers.[17]

Given the State Engineer's plenary powers, a region might desire to further regulate water use where a specific regional goal is identified that is not met by existing State Engineer administration. One current example is the regulation of domestic wells, where the State

Engineer explicitly allows local governments to impose tighter restrictions on new domestic well permits. A potential example is the creation of regional water banks that would allow for speedier reallocation of water than occurs under the current transfer process. Such a bank could be operated and administered by a regional water authority. As discussed below, a change in state law is necessary to clearly define and authorize regional water banking.

2.2 Water Banking

Description of water banking. 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, by the State Engineer or by some other stated-created entity). 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. A great advantage of the California water bank is the ease with which water can be withdrawn, especially in times of drought.

Legal status of water banking. Currently there is no specific water banking law that allows for creation of regional water banks in the Middle Valley. In the 2002 legislative session, the Legislature enacted water banking legislation for the Lower Pecos River and undoubtedly will consider extending the authorization for water banking to the rest of the state. At the last meeting of the Interim Water and Natural Resources Committee on November 7, 2002, Senator

Sue Wilson presented a one-page conceptual outline of proposed legislation and has indicated she may introduce water banking legislation.

Under current law, water reallocation will be administered by the State Engineer and managed by water distributing entities, such as acéquias and conservancy districts. Under Chapter 72, the State Engineer will continue to permit changes in point of diversion and place and purpose of use pursuant to the transfer statutes, NMSA 1978 §§ 72-5-23 and 72-12-7, and under the leasing statute, Chapter 72, Article 6.

One statutory provision that 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, acéquia 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 statute, however, does not provide for expedited reallocation procedures.

In addition, conservancy districts may reallocate water within their boundaries consistent with the Conservancy Act, NMSA 1978, Chapter 73, Articles 14-17. The Conservancy Act allows conservancy districts to provide water that is not needed for irrigation to other users by contract or other agreement for compensation.[18] The Act provides that "persons, public corporations, or others" who wish to use district water may apply to the Board for permission to lease or purchase water.[19]

At this time, the only existing "water bank" to speak of in the Middle Valley was established by the Middle Rio Grande Conservancy District in 1995, when the MRGCD Board adopted Rule 23, the Water Bank Rule. The Water Bank is essentially a water management system and a method by which the MRGCD manages the distribution of water within its boundaries by moving water from areas where it is not being used to areas of need. In this way, the MRGCD can maximize the beneficial use of water. The bank is limited in that to date the State Engineer has taken the position that water reallocated by change in point of diversion or to a place of use outside of the District boundaries is not authorized by the Conservancy Act and requires a State Engineer permit. The State Engineer has also taken the position that the quantity of vested water rights in the bank cannot be calculated until the State Engineer determines total beneficial use of MRGCD water.

In general, because no rights in the Middle Valley are adjudicated, the key issue will be establishing an expedited process for approving deposits into the water bank. Before delegating any authority to the bank, the State Engineer will insist on a process that protects existing rights and does not reduce New Mexico's deliveries under the Rio Grande Compact.

3. Alternative Evaluation

3.1 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. 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.

Enabling New Technologies and Status

Regional water authority. A regional water authority, which could include a water banking function, would require the establishment of a new administrative agency with the various functions discussed in this alternative. Changes in state law would be required as well as the drafting of regulations for the new agency. Technical issues associated with water banking are discussed above.

Water banking. Technical considerations associated with this alternative center on 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 acéquia 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.

Infrastructure Development Requirements

Water banking. 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.

Total Time to Implement

Given the numerous legal changes required, it may take several years to draft authorizing legislation to implement this alternative. For example, water banking legislation already has been introduced in several legislative sessions with no or marginal success. Once the state law is enacted and necessary funds appropriated, it could take up to a year to set up the agency, train staff and fully implement all agency programs.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

As proposed in this analysis, a regional water authority would have broad legal authority over water or matters that can affect water demand (land use planning). The purpose of the authority is to improve water management, which would include development and implementation of measures or programs designed to reduce water demand and improve water supply operation flexibility and management.

Effect on Water Supply (surface and groundwater)

See above.

Water Saved/Lost (consumption and depletions)

Reductions in demand due to elimination of a percentage of high water use landscaping would reduce depletions in the region. Other measures described in other fact sheets could diminish depletions through reduction of incidental losses or evaporation or evapotranspiration (see fact sheets for A-18, A-28, A-1, A-66, A-7, A-9, & A-10.)

Impacts to Water Quality (and mitigations)

Land use policies could be designed to protect aquifer recharge zones and sensitive areas and to establish wellhead protection areas.

Watershed/Geologic Impacts

None.

3.1.2 Environmental Impacts

Impact to Ecosystems

Depending on legal and administrative limitations, a reduction in depletions could make more water available for other uses. Such water, if legally available, could be used for measures to improve ecosystem health.

Implications to Endangered Species

Depending on legal and administrative limitations, a reduction in depletions could make more water available for other uses. Such water, if legally available, could be used for measures to improve endangered species habitat.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

A cost per acre foot of water saved cannot be determined for this alternative without further hydrologic studies to determine an actual amount of water that could be saved or cost studies.

Regional water authority. Cost associated with changes in state law are difficult to quantify. It would depend on the number of individuals involved in drafting new legislation, lobbying for such legislation and the numerous activities associated with the legislative process.

Once a state agency were created, then the costs associated with this alternative would be the up front costs (purchase or lease of facilities, equipment, software, as well as time to hire and train staff).

Water bank. 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. Startup costs also 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.

3.2.2 Potential Funding Source

Regional water authority. Funding sources for a regional organization, whether serving as planner/coordinator, regional utility, land use authority or water manager are readily identifiable. If authorized by law, the entity may derive its revenues from customers or user fees or by local taxation or issuance of bonds. Otherwise, it must look to the local member governments it represents to pay an allocated shared of its costs of operation. Under the JPA Act, a JPA may include provisions for the contribution of funds from the participating public agencies, the payment of public funds to defray the cost of the agreement, and advances of funds and repayment of advances from participating agencies.[20] The agreement may also provide that funds be paid to and disbursed by the agency agreed upon by the public agencies under the terms of the agreement.[21] The agreement must provide for strict accountability of all receipts and disbursements,[22] as well as provide for the disposition, division or distribution of any property acquired as the result of the joint exercise of powers.[23]

Water bank. Given the high price for water in the region (currently estimated at a one-time purchase price of $5,000), 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.

3.2.3 Ongoing Cost for Operation and Maintenance

Regional water authority. Ongoing operations and maintenance costs would be included in the annual budget for the authority. One factor that greatly influences the cost of an administrative agency is the number of employees and employee salaries. Assuming the regional water authority employed 100 people, the annual budget could range from $4 to $6 million per year.[24]

Water bank. If the water bank were not incorporated into the regional water authority, it would require approximately 10 to 15 employees to operate. An agency with this number of employees could have an annual budget of $600,000 to $900,000.

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.

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[1] NMSA 1978 §73-21-3.

[2] NMSA 1978 §73-21-4(B).

[3] NMSA 1978 §73-21-3.

[4] NMSA 1978 §73-21-16(J).

[5] *See* Suedeen Kelly, "Water Entities in New Mexico" presentation paper, CLE International New Mexico Water Law Conference, August 1995 at 14 (on file with author); *see also* "Municipally-owned utilities" section *supra.*

[6] NMSA 1978 §3-61-1 (A).

[7] NMSA 1978 §3-61-3.1.

[8] NMSA 1978 §§ 11-1-1 to -7.

[9] *Id*.

[10] NMSA 1978 §11-1-3.

[11] NMSA 1978 § 73-14- 2.

[12] NMSA 1978 § 73-14-3(P).

[13] NMSA 1978 § 72-2-1 (1907).

[14] NMSA 1978 §72-2-9 (1907).

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[15] NMSA 1978 § 72-2-8(A) (1953); State Engineer regulations may be for the purpose of "prescribing procedures and interpreting and exemplifying the statutes to which they relate." NMSA 1978 §72-2-8(B)(1) (1953).

[16] NMSA 1978 §§ 72-2-9 (1907), 72-5-1 (1907) - 72-5-39 (1965) and 72-12-7 (1931).

[17] NMSA 1978 § 72-2-18 (2001).

[18] § 73-14-47 (H).

[19] § 73-14-47(I).

[20] §11-1-4(B).

[21] §11-1-4(C).

[22] §11-1-4(D).

[23] §11-1-4(F).

[24] This estimate is based generally on the annual operating budgets of existing property tax assessor departments in the region. The assumed baseline cost is an agency with 25 employees has an annual budget of $1.5M per year. This number can vary depending on the salaries of the employees and the nature of the work conducted. Therefore, the costs are provided as a range for illustration purposes.

Technical and Physical Feasibility Fact Sheet
Alternative 144: Conjunctive Management

Acknowledgements: This fact sheet was written by Susan C. Kery, Esq. of Sheehan Sheehan & Stelzner, P.A. as part of the "Evaluation of Alternative Actions for Technical, Physical, Hydrological, Environmental, Economic, Social, Cultural, and Legal Feasibility and Water Quality Issues and Legal Overview" contracted to Daniel B. Stephens & Associates, Inc. The format and organization of the fact sheet and the definition of the alternative were developed by the Water Assembly.

1. Definition of Alternative

A-144: Address groundwater/surface water interactions in the statutes for administering water rights.

2. Summary of Alternative Analysis

This alternative was more fully described by the Water Assembly as follows:

> There is a connection between surface water and shallow groundwater. That is, by extracting groundwater, surface water will percolate down to the shallow groundwater and "fill in" the volume of water that has been pumped. This interaction has a time lag, and will not be immediately observable. For groundwater wells near the river, the effect may take days or weeks depending on the separation distance. For groundwater wells further away, the effect could take weeks or years. One example of the need for this accounting of the interaction of surface water and groundwater is that a junior water rights holder who has pumped groundwater, could later "infringe' on the water supply to senior surface rights holders, particularly during a time of drought.

Thus, the primary focus of this alternative is to take full benefit of the priority administration of water, as mandated by the law of New Mexico.

3. Alternative Evaluation

Conjunctive management and priority administration are recognized in both the constitutional (priority administration) and statutory (conjunctive management and priority administration) law of New Mexico. As such, this alternative is legally feasible. Nonetheless, conjunctive management could be strengthened through the passage of legislation which would allow for the augmentation of surface waters depleted by groundwater pumping. The State of Colorado presents a model for augmentation plans.

Description of conjunctive management. Conjunctive management allows water managers to use a combination of surface water and groundwater resources to meet demand. With conjunctive management, a water right owner who holds both surface and groundwater rights may rely entirely on surface water in a wet year while allowing the aquifer to recover through natural recharge. Conversely, in a drought year, the water supply could be obtained through reliance on ground water. This would benefit the river system and downstream users by leaving additional water in the river. As analyzed below, an issue that arises in conjunctive management is whether priority administration can be maintained in a conjunctive management system.

New Mexico Law on priority administration and conjunctive management. The State of New Mexico, like most western states, uses the doctrine of prior appropriation to allocate water use. This doctrine has these essential principles: (1) the first user (appropriator) in time has the right to take and use water and (2) that right continues as against subsequent users as long as the appropriator puts the water to beneficial use. [1]

The State Engineer has the power, through permit conditions, to allow the commingling of water rights and the conjunctive use of water. A water right is generally restricted to a point of diversion (either a well or a surface water diversion). For example, a groundwater right must be diverted from a well permitted by the State Engineer and cannot be taken from a surface water diversion. Surface water can be diverted at the surface point of diversion and as such, the supply may be limited in times of drought. In order to conjunctively manage these two rights, the water holder would apply to the State Engineer requesting permission to divert the total water right held from either (1) surface water, (2) groundwater, or (3) a combination of surface and groundwater. The type of diversion used would depend upon certain conditions, which would be described in the permit allowing conjunctive management. Prior to the State Engineer approving any application for conjunctive management, notice of the application would have to be published, and the applicant would have to show that the management tools requested would not impair existing water right users, be contrary to the conservation of water in New

Mexico, or be detrimental to public welfare.[2] Also, in permitting the conjunctive use of surface water and groundwater, the State Engineer may limit the amount of surface water available to such use to the historical supply of such surface water.

Conjunctive management can also be accomplished through the use of supplemental wells. By statute, surface water users may apply to supplement their use of surface water with a supplemental well. Such an application would be subject to publication and notice, and would be granted only upon a finding by the State Engineer that the drilling of a supplemental well would not impair existing water right users, be contrary to the conservation of water in New Mexico, or be detrimental to public welfare.[3]

Priority administration of conjunctively used water. One issue that may arise in the conjunctive management of water is that of priority administration of the surface and groundwater that is being conjunctively used. Although it is true that in New Mexico priority administration of water rights has not typically been enforced, the possibility exists that during times of extended drought, priority calls may occur.

In the Rio Grande Basin, groundwater is hydrologically connected to surface water. This presents a problem in priority administration because of the delayed hydrologic effects from pumping wells. When water is diverted from a well, thus depleting the aquifer that is interconnected with a stream system, the well initially draws water from underground storage and has no effect on streamflow. However, as groundwater is storage is depleted over time, the well eventually begins to draw water from the stream system, resulting in decreased surface flow. Conversely, when a groundwater appropriator stops pumping a well, there is also a delay in the impact on the hydrologically connected stream. The impact from prior pumping on the stream will continue until the depleted groundwater is replaced. The time in which the impacts of well pumping are realized on the stream system is variable, and depends upon the location of the well in relation to the stream. For example, pumping from wells adjacent to a stream may affect the river immediately.

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 makes a “priority call” in which junior water users would have to curtail their water diversions, it would be expected that well appropriators with water rights junior to those of the senior user would cease pumping. But, due to the delayed effects on the stream when groundwater pumping is stopped, such curtailment of groundwater use would not result in additional water reaching the senior user. This situation could occur often since, in the planning region, many groundwater users are junior to surface water users.[4] This set of hydrological facts brings the "futile call" doctrine into play. Since cessation of well pumping would result in no additional water for the senior user, the junior users could continue pumping. Such a result is contrary to the spirit of the prior appropriation doctrine, which requires that senior users fulfill their rights in times of shortage prior to junior users.

The Interstate Stream Commission recently proposed priority administration and water banking regulations on the lower Pecos River that would address this issue.[5] The two sets of regulations are designed to work hand in hand to assure that groundwater and surface water are diverted in priority. Under these regulations, a groundwater user depleting streamflows can continue to pump only by going to a water bank and obtaining replacement water and thereby offsetting surface depletions.

The State of Colorado has attempted to deal with the priority administration of surface and ground water through legislation regulating "tributary ground water" (water that is hydrologically connected to a surface water system) conjunctively with surface water. By statute, Colorado has attempted to balance priority administration with the maximum utilization doctrine. Colorado's 1969 Water Right Determination and Administration Act declared that "it 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 the waters of the state" (C.R.S. § 37-92-102(1)(a)(2002)).

In light of this policy, and further recognizing "that the use of underground waters as an independent source or in conjunction with surface waters is necessary to the present and future welfare of the people of this state, and that the future welfare of the state depends on a sound and flexible integrated use of all waters of the state," Colorado further declared that "the use of ground water may be considered as an alternate or supplemental source of supply" for surface water right holders (C.R.S. § 37-92-102(2)(c)(2002)). By these declarations, Colorado specifically recognizes the utility of conjunctive management, and that utilizing groundwater maximizes beneficial use because it uses stored groundwater that otherwise would not be beneficially used.

Although recognizing conjunctive use, Colorado protects senior surface users from junior groundwater users. "[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. . ." (C.R.S. § 37-92-501(1)(2002)). Yet, the same statute codifies the futile call doctrine:

> [G]round 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 by such surface right under the priority system.

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 users (C.R.S. § 37-92-305(5)(2002)). This provision is similar to New Mexico's requirement that senior water rights be retired to offset depletions to surface water caused by groundwater pumping.

Conclusion. Both conjunctive management and priority administration are recognized in New Mexico law. Nonetheless, the adoption in New Mexico of specific laws mandating that junior users replace water lost to seniors through out-of-priority groundwater pumping may ensure the orderly administration of priorities in times of shortage.

3.1 Technical Feasibility

Enabling New Technologies and Status

A change in water rights administration would be necessary to legally require junior users to replace water lost by senior users by out of priority groundwater pumping.

Infrastructure Development Requirements

If a water right holder has the right by license or permit to use both surface and groundwater points of diversion, no infrastructure development requirements would be necessary to implement this alternative. Conversely, if a surface water user applied for, and was granted permission to use, supplemental groundwater points of diversion for conjunctive management purposes, new wells would be required.

Total Time to Implement

The time to implement this alternative would include (1) the time necessary to change the water rights administration policy described above, (2) the time necessary to train Office of State Engineer staff on priority management if out-of-priority pumping occurs, and (3) the time necessary to apply for supplemental points of diversion (application, notice, and hearing) to allow an individual water owner to conjunctively manage a water right.

3.1.1 Physical and Hydrological Impacts

Effect on Water Demand

Demands on groundwater and surface water would vary from year-to-year, depending on whether surface or groundwater is being used through conjunctive management. Overall depletions would remain consistent and would be determined by the water right permit.

Effect on Water Supply (surface and groundwater)

Conjunctive management would allow for there to be more equilibrium between surface and groundwater use; therefore, there is more likelihood that senior water rights can be met in drought years.

Water Saved/Lost (consumption and depletions)

None

Impacts to Water Quality (and mitigations)

No direct impacts. Switching to groundwater pumping in a year with low surface flows could mitigate water quality concerns associated with low flows.

Watershed/Geologic Impacts

Conjunctive management will allow for increased surface flows in drought years (when water is withdrawn from the aquifer) and aquifer recharge in wet years, when water is diverted from the river.

3.1.2 Environmental Impacts

Impact to Ecosystems

Conjunctive management would for increased surface flows in drought years and aquifer recharge in wet years. Increased surface flows would benefit the riparian ecosystem.

Implications to Endangered Species

This alternative could have a positive impact on the silvery minnow, since conjunctive management will allow for increased surface flows in drought years.

3.2 Financial Feasibility

3.2.1 Initial Cost to Implement

The costs to implement this alternative include costs associated with applying for a permit for a new point of diversion in order to conjunctively manage a water resource. This includes the costs related to the transfer process (application, notice, and hearing), such as attorney and hydrology costs, as well as the cost of the water right. The current cost of a pre-1907 surface water right is $5,000 per acre-foot (consumptive), which represents a one-time purchase price.

3.2.2 Potential Funding Source

This alternative would be funded through water rights purchasers (individuals and/or public entities).

3.2.3 Ongoing Cost for Operation and Maintenance

None.

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[1] N.M. Const Art. XVI, § 2; NMSA 1978 § 72-12-1 (1907)

[2] NMSA 1978 § 72-5-25 (1971); NMSA 1978 § 72-12-7 (1931)

[3] NMSA 1978 § 72-5-25 (1971); NMSA 1978 § 72-12-24 (1959)

[4] In New Mexico, groundwater pumping based on the priority of pre-1907 surface water rights transferred as offsets could be administered by the actual priority of the offset right, not just 1907.

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[5] Two issues raised by the proposals to address the futile call doctrine are whether the proposed measures would (1) the curtail groundwater pumping down to the priority of the most senior surface water user that would have had water if there had never been pumping, or (2) the curtailment of pumping to the extent that such curtailment would lead to the immediate restoration of streamflow