APPENDIX D

Part II
Economic Benefit/Cost Analysis

ECONOMIC BENEFIT/COST ANALYSIS
NAVAJO – GALLUP WATER SUPPLY PROJECT

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A. Executive Summary

This report focuses on the economic benefits and costs associated with the proposed Navajo – Gallup Water Supply Project in northwestern New Mexico. The Project would be developed to deliver water for domestic, commercial, municipal and industrial use to the City of Gallup, to numerous Navajo Chapters and to an undeveloped section of the Jicarilla Apache Nation. Water is currently scarce in all of these areas, and the Project will ultimately deliver water to some individuals who presently drive many miles to haul water.

The economic analysis in this report is distinct from a financial analysis. While a financial analysis traces cash receipts and expenditure, the economic analysis is instead more concerned with the generation and use of societal resources. Because the U.S. Bureau of Reclamation is overseeing the planning of this Project, and because the Project participants are seeking monetary support from the Federal government, the society whose resources we are concerned about is the United States as a whole. The principal differences between this economic analysis and a financial analysis are (1) inclusion of non-cash Project costs that would affect third parties (diminished power generation and increased salinity effects), (2) exclusion of Project cash costs that do not represent use of scarce national resources (use of otherwise unemployed people for construction workforce), and (3) exclusion of Project transfer payments that do not represent use of scarce national resources (taxes paid on construction spending).

The Project will principally benefit people in the northwest corner of New Mexico by providing water to which they otherwise would not have access or could only have access at a relatively higher cost. The measure of the benefits to the City of Gallup and to the Navajo people who would be supplied by the Project is the willingness of these beneficiaries to pay for Project water. Gallup's willingness to pay was estimated from data on the current use of water by people in communities throughout the mountain states. The Navajo people's willingness to pay was estimated from data on their spending for piped water service when available and on spending to haul water when no service is available. Benefits to the Jicarilla Apache people were estimated from the cost of the next cheapest alternative source of water for the area of the Reservation to be served by the Project.

The Indian Health Service identifies the availability of a community water supply as critical for maintaining the health of Indian people. This report roughly estimates the indirect health benefits to Navajo people that would accrue from the provision of a clean water supply.

The completion of the water supply project will also provide infrastructure that is a necessary prerequisite to economic development and poverty relief on the Reservations. While it is uncertain how much economic development would be encouraged by the Project, it is clear that the lack of a reliable water supply presently poses a significant constraint to most types of economic development. Table ES-1 summarizes the economic costs and benefits associated with the Project.

Table ES-1

Summary of Navajo-Gallup Water Supply Project Economic Benefits and Costs

Millions 2007$, 4.875% Discount Rate, 50 year Project life

BENEFITS		**Direct**	**Direct Plus Other**
	Gallup Willingness to Pay	$361	$361
	Navajo Willingness to Pay	$1,488	$1,488
	Jicarilla Avoided Cost	$57	$57
	Construction Employment	$231	$231
	Indirect and Induced Employment	$0	$111
	Health Benefits	$0	$435
	Reverse Outmigration	$0	+
	Economic Development	$0	+
	Total Benefits	$2,137	$2,683
COSTS			
	Project Construction	$1,192	$1,192
	Distribution System Construction	$48	$48
	O,M&R	$368	$368
	Gallup Water Cost	$33	$33
	Navajo Water Cost	$24	$24
	Power Generating Cost	$19	$19
	Salinity Increase Cost	$20	$20
	Total Costs	$1,704	$1,704
BENEFIT/COST RATIO		**1.25**	**1.57**

The benefit/cost ratio greater than 1.0 indicates that the anticipated project benefits are greater than cost and thus, that the Project represents a beneficial use of national resources.

B. Analytical Framework

Dornbusch Associates was engaged by the Bureau of Reclamation et al. to evaluate the economic feasibility of the proposed Navajo-Gallup Water Supply Project (NGWSP). This report summarizes the Dornbusch analysis findings as well as the supporting data and technical methodologies. While a Cost Allocation Report, under separate cover, analyzes the distribution of the Project's estimated ***financial*** cost between the Project's stakeholders, this report focuses on the Project's overall ***economic*** benefits and costs and thus economic feasibility. The Project's economic benefits and costs are compared to a base case that is expected to occur if the Project is not built (a "with vs. without" comparison).

An economic as opposed to a financial analysis approach is used to evaluate projects by international and federal agencies because those agencies are concerned with using a country's resources most effectively. The economic analysis approach considers the value to the country's overall economy of the resources potentially used and produced by a project, so that the sponsoring agency can determine whether that project represents a good investment of the country's resources. In general, if a substantial source of financing for a project is to be national government funds then it is appropriate to conduct a national level economic analysis to determine whether the project contributes to the country's overall economic well-being. This economic approach is also recommended by the Water Resource Council's Principles and Guidelines [Water Resource Council, p. iv], which the Bureau of Reclamation is required to follow.

In contrast, a financial analysis focuses only on whether a project is or will be a profitable investment for a participant. If, for example, a city were able to obtain private financing to develop a water project the city would use a financial analysis to determine what the project would cost and how to pay for it. Depending on some of the factors discussed below, such as subsidies or the cost of money, financial and economic analyses may reach similar or diverse conclusions as to the feasibility of a project.

The approach in this report is to use an economic rather than a financial perspective to evaluate the potential benefits and costs from the proposed NGWSP. The primary source of funding for the NGWSP would most likely be the federal government; hence it is appropriate to assess the Project's feasibility from the perspective of the U.S. as a whole. The remainder of this section discusses the important differences between economic and financial analyses and explains several key aspects of the economic analysis methodology used to evaluate the proposed project.

The primary technical differences between an economic and a financial analysis relate to valuing commodity prices, investment subsidies, taxes, discount rates, labor and water. Each of these is explained as follows:

1. **Commodity prices**

In a financial analysis it would be appropriate to use whatever prices a project paid for materials and services or would receive for water sold. The actual prices (including any subsidies) would accurately reflect the cash flow from the perspective of the project participants. The objective of an economic analysis, however, is to price commodities at a level that indicates their value to the economy. Government subsidies are a type of transfer payment as they represent payments from the government without the government receiving any goods or services in return. Accordingly, in an economic analysis subsidies paid within the economy are removed from commodity prices. If a participating agency chooses to subsidize water sales, for example, an economic analysis would impute a price reflective of the water's value to the economy and disregard the subsidized price. In contrast, a financial analysis would use the subsidized price to reflect actual revenues realized by the direct participants from the sale of water.

2. **Investment costs**

Investment costs are treated in a similar fashion to commodity prices (as discussed above). In an economic analysis, even if a project's investment costs are subsidized by a federal program, the full costs of the resources used to build the project are counted. Costs for goods and services used to build a project are measured by their value in other uses that would be displaced by the project (opportunity cost). This concept is discussed in greater detail below, in the sections addressing labor and water costs.

3. Taxes

Most taxes are levied simply to raise general revenues and are not payments that are directly exchanged for something of value. Taxes levied to raise general revenues include, for example, income and sales taxes. Income tax payments go into a general fund and do not pay for specific goods or services that the taxpayer only receives if he pays taxes. Because taxes are not usually linked to an exchange of goods or services they are excluded from an economic analysis. Such general taxes can be thought of not as determining whether a project is feasible but as determining how the benefits from a project are split between the project participants and the government. These taxes are a type of transfer payment because they "transfer" resources from one entity (a taxpayer) to another (the government) without the direct exchange of goods or services.

A use tax is one of the few examples of a tax levied in exchange for goods or services. In the case of use taxes a government entity levies the tax as a fee for services rendered, such as payments for the use of a public facility like a park. In this case value is being received (enjoyment of a park) that is linked directly to the payment of the tax. In an economic analysis such a use tax payment would be recognized as a purchase of goods or services and would be counted as a cost or a benefit.

Both general taxes and use taxes are included in a financial analysis because both represent cash outflows that increase the cost of a project. Only the use tax would be included in an economic analysis, however, because the general tax is a transfer payment that does not represent a purchase of specific goods and services.

For the NGWSP analysis, we consider taxes on field costs to be a type of transfer payment and accordingly we exclude them from our estimates of the Project's economic cost.

4. Discount rate

A development project is considered to be economically feasible when its potential benefits are equal to or exceed its estimated costs. A problem in comparing a project's benefits with its costs is that those benefits and costs do not typically occur at the same point in time. Construction costs are incurred only during the development phase of a project, whereas replacement of equipment occurs periodically throughout a project's life, and operating costs and economic benefits occur annually throughout a project's life.

To relate the stream of benefits and costs to each other, it is necessary to recognize that money has a "time value". A dollar today has a greater value than a dollar in the future – a reality that is recognized in every loan transaction. To illustrate, if Party A loans $100 to Party B for ten years, Party A will require Party B to repay something more than $100 at the end of the ten year period. The additional amount that must be paid reflects the "time value" of the $100 loan. Or, looking at it another way, if someone is offered a choice between $100 today or $100 in ten years, he or she will certainly prefer receiving the $100 today, recognizing that the money can be invested and subsequently yield more than $100 at the end of the ten-year period.

For the purpose of discounting future benefits and costs for the NGWSP we have used the federal rate of 4.875% that is applicable during FY2007 to water resource projects [U.S. Bureau of Reclamation, 2006]. This federal rate is a constrained, lagged, nominal (includes inflation) rate computed annually from U.S. Treasury security yields. It reflects average yields on marketable securities with a term of 15 years or more, but is constrained from changing more than .25% per year. The rate is then rounded to the nearest one-eighth of one percent. Absent these constraints the 2007 rate would be 4.9351% [Ibid.]. For sensitivity analysis we have also evaluated the Project's economic feasibility applying a real (inflation removed) discount rate of 3%. This real rate is based on an average between inflation-free rates of return on long-term federal bonds and inflation-free returns that have been obtained historically by all taxpayers, including all industrial and commercial sectors, households, and institutions [Fraumeni, pp. 161-244].

A financial analysis would use an actual market rate of interest, adjusted so to be consistent with the inflation assumption built into the benefit and cost projections for the project. For example, if the project benefits were projected in inflation-free (constant) dollars, then the interest rate should be net of the expected inflation rate.

5. Labor

In an economic analysis the cost of labor is determined based on its value as a productive resource. This means that in a national economic analysis the cost of labor for the subject project depends on how much it would contribute to the national economy if that labor was not used for the project being evaluated. This cost is measured by labor's opportunity cost, which is its value in its next best use. For that portion of the labor pool that would be otherwise fully employed in another project, the labor cost is its value as reflected in the full wage rate. However, for that portion of the labor pool that would be otherwise unemployed, and for whom no alternative employment opportunities would be available in the absence of the proposed development project, the opportunity cost of that labor is assumed to be zero. The implication of a zero opportunity cost in analyzing the proposed NGWSP is that in the absence of the project the workers would be unlikely to otherwise be employed in some type of work that added to the nation's supply of goods and services.

This method of using the opportunity cost to reflect the cost of labor in an economic analysis is standard practice among international development agencies such as the World Bank and the U.S. Agency for International Development. The Principles and Guidelines recommend using this method of labor valuation in assessing the costs of a project's construction phase but not its operational phase [Water Resource Council, section 2.11.2(b)].

A financial analysis would account for all wage costs that may be incurred by a project regardless of whether the workers would otherwise be employed or not.

6. Water

In a financial analysis the water used in a project would be valued at whatever dollar cost was paid for the use of water by the project participants. In an economic analysis the water is valued at its opportunity cost, or its value in its next best use. To the extent that project participants pay market prices for the water then the two approaches (financial and economic) should converge. If a participant already owns rights to water, however, then its financial cost would be zero while its economic cost would be the value in whatever other uses were precluded by the project.

C. Project Benefits

In an economic analysis the basis for estimating benefits from a water project is the *Willingness to Pay* for the "increase in value of goods and services attributable to the [project] water supply." [see Water Resource Council, section 2.2.2(a)]. In a municipal water use setting it is impractical to measure the increase in value for each use of water (bathing, toilet flushing, cooking, drinking washing, lawn and garden watering, etc.) Instead we try to estimate what users are willing to pay for the water itself, assuming they are best placed to know the value of water's various uses. This estimated willingness to pay is the amount of money that water users would be willing to pay for project water; it reflects the economic value of the water to the users and thereby to society as a whole. In performing an economic feasibility analysis of the NGWSP, we estimated this willingness to pay separately for the three project participants: the City of Gallup, the Navajo Nation and the Jicarilla Apache Nation.

1. City of Gallup Willingness to Pay

Willingness to pay is commonly estimated in one of two ways: deducing what people are willing to pay by analyzing their actual payment patterns (revealed preference) or by asking them what they would pay in a structured hypothetical situation (stated preference). We have used a revealed preference approach to estimate a water demand function for 79 mountain states mid-sized communities, including Gallup. Towards this end, we compiled data on each communities water use during 2000, price for water, median income levels, household size and average rainfall. From this data we estimated a generalized demand curve that relates these variables to the demand for water. This approach implicitly assumes that water use patterns are substantially similar among the communities in the database, except for those differences accounted for by the explanatory variables (see also the discussion of other variables in part C.1.e, below). Equation (1) shows the estimated relationships. The data and regression results are shown in Appendices A and B.

$$(1)\quad \ln GPCD = 2.913 + .372 * \ln HHY - 1.348 * \ln HHS - .554 * \ln P$$
$$\qquad (2.258)^{**} \qquad (2.805)^{**} \qquad (-5.680)^{**} \qquad (-10.878)^{**}$$

where GPCD = water use in gallons per capita per day

HHY = median household income

HHS = average household size

P = average price for water

Numbers in parentheses are t-statistics. All coefficients are different from zero at 90% (*) or 95% (**) level of confidence.

Adjusted $R^2 = .630$

Observations = 79

Degrees of freedom = 75

Converting the logarithmic equation (1) to an exponential equation form gives equation (2), which was used to estimate the demand for water in Gallup.

$$(2)\quad GPCD = 18.405 * HHY^{.372} * HHS^{-1.348} * P^{-.554}$$

a. Household Income

Our expectation is that increasing income will lead to increasing water use, and the estimated exponent in equation (2) is consistent with that expectation. The exponent of the income term can be interpreted at the ***Income Elasticity*** of demand for water, that is, the amount by which the demand for water will increase given an increase in household income. The estimated income elasticity of .372 in equation (2) is similar to other income elasticities reported in the literature. Table 1 shows examples of reported income elasticities for water.

Table 1

Income Elasticities Reported in the Economics Literature

STUDY	INCOME ELASTICITY
Jones & Morris	0.40 to 0.55
Martin & Wilder	0.04 to 0.27
Nieswiadomy & Cobb	0.64
Nieswiadomy	0.28 to 0.44
Schneider & Whitlatch	0.207
Morgan	0.33 to 0.39

The income elasticity was used in the willingness to pay analysis to estimate how the demand for water in Gallup (willingness to pay for water) would increase in the future with increases in median household income. Median household income was assumed to continue growing at a real (adjusted for inflation) rate of slightly above 1.0% per year, which was the rate of growth in McKinley County personal income from 1969 to 1999 [US Census Bureau, 2004].

b. Household Size

Some researchers have observed that per capita water use is inversely related to household size [see eg. Brown]. This inverse relationship seems logical, as outdoor use in particular should not increase linearly with the number of people in a household. Our data analysis did find a strong inverse correlation between household size and per capita water use. The estimated exponent in equation (2) is negative 1.348, which is substantially larger than some other values reported in the literature. Nieswiadomy reports a household size water use elasticity of .69 for western cities, on a dependent variable defined as total household use. Converting the dependent variable in Niewswiadomy's estimate to per capita terms would reduce the exponent of the household size independent variable to negative .31. Jones and Morris report a household size elasticity of 0.17 (also on total household use), which converts to an elasticity estimate of negative .83 for per capita use.

This household size variable is used in the willingness to pay analysis to adjust per capita water demand in accordance with the expected future decrease in average Gallup household size. Gallup presently has an average household size of 2.85 persons per household, compared to the national average of 2.63 persons per household, and Gallup's average household size has been declining. For the analysis, we assumed that Gallup's household size would continue to decline at 0.005 persons per household per year until it converged with the 2000 national average, and then would remain at that level.

c. Price for Water

Economic theory suggests that, if all else is equal, people demand less of most goods and services the more expensive they are. Our data analysis showed a strong inverse correlation between per capita water use and the price for water. The estimate exponent of the water price term in equation (2) is negative 0.554. This estimate is generally consistent with other price elasticity results reported in the literature, examples of which are shown in Table 2.

Table 2

Price Elasticities Reported in the Economics Literature

STUDY	**PRICE ELASTICITY**
Jones & Morris	-0.34
Nieswiadomy	-0.22 to -0.60
Agthe & Billings	-0.595 to -0.624
Billings & Agthe	-0.267
Martin & Wilder	-0.49 to -0.70
Nieswiadomy & Cobb	-0.63
Schneider & Whitlatch	-0.63
Weber	-0.202
Nieswiadomy & Molina	-0.36 to -0.86
Hasson	-0.22 to -0.34
Young	-0.41 to -0.60
Foster & Beattie	-0.27 to -0.76
Brookshire et al. (summarizing other studies)	-0.11 to -1.59 (average -0.49)

The estimated price elasticity, income elasticity and household size elasticity of water consumption are used in the willingness to pay analysis to estimate the implicit price associated with various quantities of water use. These price estimates are necessary in order to calculate the total willingness to pay by Gallup residents for different quantities of water. These elasticity estimates are used in conjunction with the assumptions about future changes in income and household size levels, previously discussed. Table 3 shows for various future years the implicit price per thousand gallons for total average water use of 160 gpcd. This price represents the amount that average Gallup water users would be willing to pay for water, at the 160 gpcd level of average consumption. The price that we expect Gallup water users to be willing to pay for water increases over time as incomes rise and household size decreases.

Table 3

Estimated Willingness to Pay for Domestic Water (160 gpcd)

Price Per Thousand Gallons of Water, Gallup, New Mexico (2007$)

YEAR	PRICE PER THOUSAND GALLONS
2020	$2.44
2030	$2.65
2040	$2.88
2050	$3.08
2060	$3.16
2070	$3.27

d. Climate variables

Some researchers have found a significant relationship between per capita water use in an area and climatic variables for that area, such as rainfall or growing season temperatures. We compiled data on average annual rainfall and average annual growing degree hours[1] for each community in our data set. While we found plausible results from statistical analyses (linear regression) that included those variables the coefficients were not significant at reasonable levels (less that 80% likely different from zero and they did not add to the overall explanatory power of the overall equation. Accordingly, the linear regression

[1] "Growing degree hours" is a measure of the temperature above a certain threshold multiplied by the hours at that temperature, accumulated throughout the growing season. It is an indication of how vigorously plants will grow and is generally correlated with water use by plants.

equation used to estimate Gallup's willingness to pay for water does not include those variables.

e. Other Variables

Although our demand equation includes water price, household income, household size and rainfall variables, other factors may also influence per capita water use in different cities. Differences in water quality and reliability, for example, may affect per capita water use. We have no reason to suspect that these and other omitted variables significantly affect our results, and we expect that any bias from omitting these variables would be small. However, to the extent that an omitted water quality variable would be significant we have probably underestimated the project benefits because the project will provide very high quality water to its users.

f. Gallup Without-Project Condition

Gallup currently relies on groundwater pumping to supply water to its residents. The water levels have been falling by 7 to 29 feet per year over an extended period, and at some point the production capacity of the current well system is expected to diminish. For purposes of our analysis we have assumed that annual production capacity will peak at 5MGD (5600 afy) in the year 2010, and that the production capacity will decline linearly to 1439 afy by the year 2040 [Navajo Nation et al., "Technical Memorandum", Table 4.2]. The production capacity of 5600 afy exceeds the City's projected water needs of about 4500 afy in 2010, but the progressively increasing needs and diminishing capacity indicate that Gallup will need a supplemental water supply to meet demand by the year 2016. Gallup is currently investigating a water reuse facility to treat effluent as a source for this supplemental supply. For purpose of our analyses we have assumed that by 2012 Gallup will construct such a reuse facility that will supply one MGD (1,120 afy) to help meet forecasted water needs [Allgood]. Once the Project is operating, Gallup plans to shut down its wells and rely entirely on water from the Project and from the planned reuse facility.

Even following implementation of the assumed additional water reuse facility, due to population growth the City of Gallup cannot continue to supply its residents with their current level of average per capita water use (171 gpcd) beyond the year 2018. Absent the Project, therefore, Gallup would be faced with some combination of the following scenarios: (1) development of alternative water supply projects, (2) diminishing per capita water supply, and/or (3) curtailment of population growth. Gallup has not been able to identify any other water supply project that is as cost-effective as the Navajo Gallup Water Supply Project. Without new water supplies in addition to the assumed water reuse facility it is estimated that the available water per capita would fall to about 100 gpcd by the year 2030, and continue to decline thereafter. Thus without the Project, Gallup would have to make major changes in water use patterns, with consequential negative implications for the city's economic well-being. While the Willingness to Pay approach does address the amount of money that Gallup residents would be willing to spend for a supplemental water supply, the approach does not address the overall economic losses to the City that would occur if future water shortages caused residents and businesses to locate elsewhere.

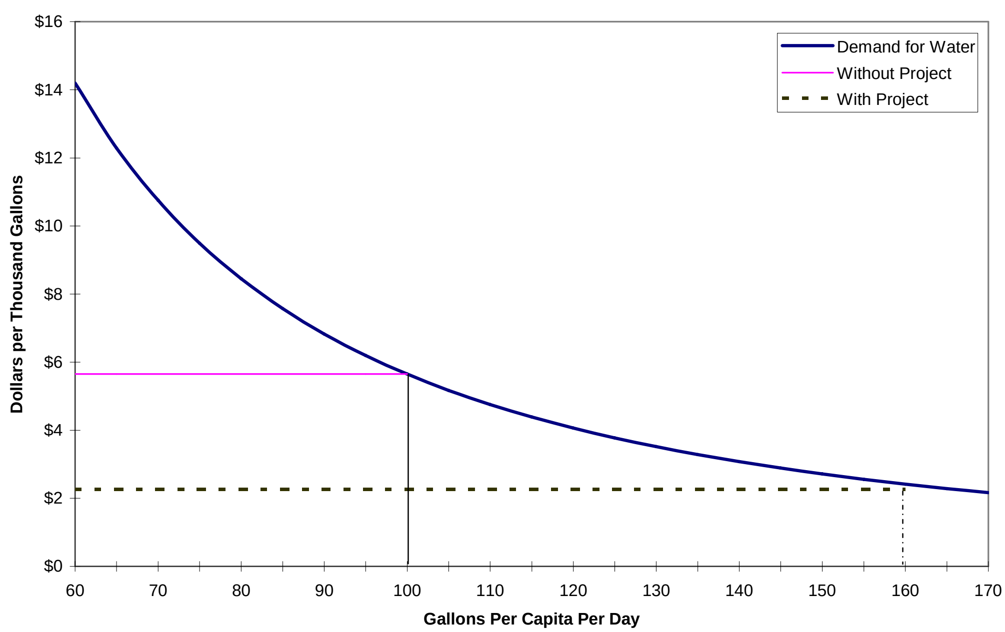
g. Gallup With-Project Condition

For purposes of the economic analysis we assume that the Project will be operational by January, 2027. We further assume that in the future, average Gallup water consumption per capita will decline slightly from today's 171 gpcd to 160 gpcd. Two factors should affect per capita water consumption in the future. First, water rates may be somewhat higher in the future in order to pay for a supplemental water supply, and higher rates should cause water use per capita to decline. Second, per capita water use may currently be somewhat elevated due to water use by non-Gallup residents who haul water from Gallup sources. When the Project is completed the need for water hauling should diminish.

h. Calculation of Project Benefits for Gallup

The potential economic benefits to Gallup from the Project can be measured by the area under the demand curve between (1) the projected use without the Project and (2) 160 gpcd. We measured this area for each year for the 50 year period beginning with planned Project completion in 2027. Each year's benefits are slightly different, due to decreasing household size and increasing population and income. Figure 1 shows Gallup's demand for water estimated for the year 2030 (curved line). The area below the demand curve and to the left of 160 gpcd shows the total willingness to pay (WTP) for 160 gpcd. However, the area below the demand curve and to the left of 100 gpcd indicates WTP for water that could be supplied by Gallup in 2030 even in the absence of the Project; and that area is not included in the benefit calculation. In addition to the benefits from supplemental water Gallup residents will benefit from the cost savings generated by replacing expensive deep wells with Project water. Gallup estimates that the city will save approximately $790,000 per year once the Project water supplies allow it to shut down deep wells [Munn]. Future benefits were discounted back to 2027, using the current (FY2007) federal discount rate of 4.875%. The discounted estimated annual benefits of the Project sum to a total present value of $361 million (2007$).

Figure 1
Demand for Water in 2030
Gallup, New Mexico



Note 1: The area under the demand curve was calculated by integrating equation (2) and solving for the area under the demand curve between the implicit price for projected water use without the project and the price at 160 gpcd water use with the project. This calculation is shown as equation (3).

(3) $\text{Area} = 18.405 * \text{HHY}^{..372} * \text{HHS}^{-1.348} * (\text{P1}^{(1-.554)} - \text{P0}^{(1-.554)}) / (1-.554)$,

where Area = area under demand curve between P1 and P0

HHY = household income

HHS = household size

P1 = price at 160 gpcd

P0 = price at base (without Project) per capita water use

Coefficients and exponents as estimated in equation (2)

The above calculation provides the area under the demand curve and to the right of the y-axis. Finally, to derive the economic benefits we adjust the above calculation to find the area below the demand curve but above the x-axis. This was done by subtracting the rectangle Q0 * (P1-P0) and adding the rectangle P1 * (Q1-Q0), where Q0 is the base (without Project) per capita water use and Q1 is the per capita water use with the Project.

2. Navajo Nation Willingness to Pay

Water use patterns on the Navajo Indian Reservation are substantially different from that in most off-Reservation communities, including Gallup. Most notably, about 40 percent of Navajo Reservation residents have no piped water supply so they must haul water to their homes. Water hauling is time consuming and expensive, with the result that those Navajos who do haul water tend to consume far less water per capita than those who have piped water. The circumstances of water hauling (price and per capita water use) are completely outside the range of data for any community surveyed as part of the Gallup analysis. Hence we concluded that it would be questionable to apply the price elasticity used for Gallup or that for any other community with a predominantly piped water supply to an assessment of Navajo willingness to pay for water. Instead, because of the importance of water hauling among the Navajo people we have estimated a Navajo-specific water demand function instead of using the demand curve developed for Gallup.

The Navajo water demand equation is based on fitting a log-log equation (similar to that used in the Gallup analysis) to the year 2005 water use and price data from Navajos who either (1) pay for water piped to their homes by the Navajo Tribal Utilities Authority (NTUA), or (2) purchase bulk water and haul it to their homes.[2] This estimated demand relationship is shown in equation (4).

(4) $\ln GPCD = -.1454 + -.8402 * \ln P$

where GPCD = water use in gallons per capita per day

P = price for water[3]

Converting the logarithmic equation (4) to an exponential equation form gives equation (5):

(5) $GPCD = .8646 * P^{-.8402}$

The price elasticity of negative .8402 estimated in equation (5) is somewhat higher than the average reported for communities having piped water supplies but is within the range of reported results (shown in Table 2).

Because the Navajo water use data did not include income for the water users we could not estimate a Navajo-specific income elasticity for water use. Since the Navajo household income is within the range of incomes in our community survey, we used the income elasticity from that survey for that Navajos. Essentially, we assumed that the Navajo would exhibit the same income response to water use (income elasticity) as we found in our sample of 79 mountain state communities in equation (2). We therefore added the income

[2] We recognize that piped and hauled water are dissimilar commodities. However, by including the cost of hauling to and storing at the household we attempted to define both as an “in-home water supply.” There remains the possibility that even after accounting for the difference in cost, people’s demand for hauled water would be less than that for piped water, due to the heightened awareness of resource scarcity. To the extent that this difference exists we may have underestimated the project benefits.

[3] The demand curve was estimated using 2005 prices. Once Willingness to Pay was determined from the demand curve we adjusted the valued to 2007$ using the CPI.

elasticity term to equation (5) and solved for an adjusted constant term, deriving equation (6) that was used to estimate Navajo benefits from water use.

$$(6)\quad GPCD = .021 * P^{-.840} * HHY^{.372}$$

where HHY = median household income

a. NTUA Water Use

About 60 percent of Navajo Reservation households obtain piped water supplied by the NTUA. Average annual consumption is about 100 gpcd [Foley]. Average household size is 4.5 persons per household [U.S. Census Bureau], which translates to an average monthly household water consumption of 13,500 gallons (100 x 4.5 x 30 = 13,500). NTUA charges $2.20 per thousand gallons for the first 3,000 gallons per month and $3.35 per thousand gallons for additional use [Navajo Tribal Utility Authority]. NTUA also levies a monthly service charge of $5.50 for each hook-up. Given the average monthly household water use of 13,500 gallons the average monthly household water bill is $47.28 (3 x $2.20 + 10.5 x $3.35 + $5.50 = $47.28). Dividing the monthly bill by average monthly water use gives an average price of $3.502 per thousand gallons.

b. Water Hauling

About 40 percent of Navajo Reservation households do not have water piped to their homes [Navajo Department of Water Resources, 2000, p. ES-3]. These households instead haul water from NTUA distribution points, from wells, from vending machines, or from other water sources. Data from a recent survey indicates that Navajo households without a piped water supply haul an average of 5.4 gpcd [Ecosystem, 2003]. We used data for about 45 households from the same survey to estimate a delivered cost for hauled water. The delivered cost is necessary for the demand analysis so the cost for hauled water can be put in comparable terms to the cost for piped (delivered) water. We estimated four components of the delivered cost of hauled water: (1) purchase cost, (2) container cost, (3) transportation cost and (4) the opportunity cost of time.

Navajos hauling water pay a range of prices for water, from zero for water obtained from wells to as much a $0.25 per gallon for water purchased from vending machines. The survey average price paid for water in 2003 was $0.032 per gallon, or $32.00 per thousand gallons [Ibid.]. We used the Consumer Price Index (CPI) to convert this cost to a January, 2005 cost of $33.17 per thousand gallons.

The cost of sanitary containers used to haul water averaged $35.00 per household in 2003 [Ibid.]. Indexed by the CPI to 2005$ this cost is $36.27. We assume that the containers are replaced annually. Given water use of 5.4 gpcd and 4.5 persons per household, the 2005 container cost is $4.09 per thousand gallons ($36.27 per container per year / 5.4 gpcd x 4.5 persons per household x 365 days/year = $4.09 per thousand gallons).

The Ecosystem survey found that the average distance per hauling trip was 14 miles each way, for a 28 mile round trip [Ibid.]. We value the economic cost of transportation at the marginal cost for a light truck or van. This marginal cost includes both variable operating costs (gasoline, oil, tires, repairs, etc.), as well as additional vehicle depreciation associated with excess vehicle mileage. The variable operating costs are estimated to average $0.1755 per mile [Victoria Transport Policy Institute, indexed to 2005$ by CPI]. Additional depreciation was estimated to average $0.1085 per mile [Kelly Blue Book]. Total marginal cost per mile is thus estimated at $0.2840. The Ecosystem report adds 25% to average vehicle operating costs to allow for the use of more expensive than average vehicle maintenance and for extra costs due to rough roads. We have addressed the first issue by using data for light trucks instead of for automobiles. Our resulting costs per vehicle-mile may still be conservative because we have not made any allowance for extra costs due to rough roads. Given an average roundtrip mileage of 28 miles and average haulage of 173 gallons per load, transportation costs are estimated to be $45.97 per thousand gallons (28 miles per load x $0.2840 per mile / 173 gallons per load = $45.97 per thousand gallons).

Finally, we estimated the value of the time spent by Navajos who haul water. While in a financial analysis we would value their time only at whatever monetary compensation was sacrificed in order to haul water, in an economic analysis such as this it is important to consider the implicit value that people hauling water place on their time. [see, eg., Asian

Development Bank]. Economists recognize that people place a value on their time, even if they are unemployed. While employment status may affect the magnitude of the value that water haulers place on their time it does not affect the principle that people generally put some positive value on the time they spend doing chores. The value of time is recognized repeatedly as people make choices that trade off money against time. A good example is the premium people pay for convenience food over food needing preparation.

The value of time spent in transit is an issue that is commonly addressed in studies of recreational values. Many such studies simply assume that time spent traveling to a recreation site has some value relative to the wage rate, typically 25% to 50%, regardless of the employment status of those traveling [Cesario, Smith, Chia-Yu, Bhat, Bowder, Loomis]. Some recreational studies have attempted to calculate the value of time in transit in comparison to the wage rate [Bockstael (one to three times the wage rate), Feather (6% to 100% of the wage rate), Larson (48% to 79% of the wage rate), Shaikh (65% to 90% of the wage rate)]. A few studies have tried to estimate directly the value of time spent to haul water [World Bank (52% of wage rate), Whittington (100% or more of wage rate)]. For purposes of this economic analysis we have assumed that Navajo people value their time hauling water at 50 percent of the minimum wage rate. A Navajo survey cited in the Ecosystems report found that average hauling time was 52 minutes. Doubling that to allow for a round trip and rounding up to allow for filling and emptying time we assume that each load takes 2 hours. At one-half of the 2005 New Mexico minimum wage of $5.15 per hour and 173 gallons per load, the estimated opportunity cost per thousand gallons is $29.77 per thousand gallons ($5.15 per hour x one-half x 2 hours/load / 173 gallons/load = $29.77 per thousand gallons).

This approach implicitly assumes that the sole purpose of the trips is for water hauling. Unfortunately, the survey did not collect trip purpose information, so we assumed that water hauling was the primary purpose of each trip and that other trip purposes were incidental. Given the importance of water hauling and the relatively small window of time that each household may have to schedule trip when their water containers are nearing empty, this assumption may be generally reasonable.

The total economic cost for hauling water is the sum of the costs for purchasing water, purchasing containers, operating a vehicle and allowing for the opportunity cost of the time required. This sum is $113.00 per thousand gallons ($33.17 + $4.09 + $45.97 + $29.77 = $113.00)(2005$).

We also contacted two commercial water haulers who were prepared to deliver water to Navajo households. Including the cost of a 1,000 gallon cistern (amortized over 25 years) the delivered cost of water averaged about $133 (2005$) per thousand gallons, about 20% higher than the $113 per TG used in this analysis.

Note 2: The water use and cost per thousand gallons data for NTUA customers and for water haulers, described above, was used to estimate the a and b parameters in equation (4).

$Q = a * P^{b}$

NTUA customers: $Q1 = 100, P1 = 3.502$

Water haulers: $Q2 = 5.4, P2 = 113.00$

$\ln Q = \ln(a) + b * \ln P$

NTUA customers: $\ln Q1 = 4.605, \ln P1 = -5.654$

Water haulers: $\ln Q2 = 1.686, \ln P2 = -2.180$

$$b = \frac{\ln Q1 - \ln Q2}{\ln P1 - \ln P2} = -0.8402$$

$\ln a = \ln Q1 - b * \ln P1 = -0.1454$

c. Navajo Without-Project Condition

In the absence of the Project the Navajo Nation will continue to extend piped water service to a portion of its growing population, but for this analysis we assume that in the future the proportion of Navajos who haul water will remain at today's 40 percent. We also assume that without water from the Project and the economic growth facilitated by the Project that per capita water use among NTUA customers will remain at 100 gpcd into the foreseeable future.

d. Navajo With-Project Condition

The Project will deliver water to two different areas of the Navajo Reservation. The Cutter Lateral will convey water to a corridor of communities on the far eastern edge of the Navajo Reservation, eventually delivering water to the Jicarilla Apache Nation as well. We assume that this lateral will be operational by 2019.

A western lateral (San Juan Lateral) will convey water from the San Juan River directly south to Gallup, serving Navajo chapters along the way, with a branch that delivers water as far west as Window Rock and Fort Defiance. This analysis assumes that the section of this lateral that serves the Twin Lakes Chapter and is connected to the Chapters around Gallup will be completed by 2016. A well field will supply up to 2,000 afy to these chapters until the entire San Juan Lateral is completed in 2027.

For purposes of this economic analysis we assume that Project water will go first to NTUA customers to supplement their existing water supplies, and then to Navajos who would otherwise be hauling water. The reason is that the delivery infrastructure is already largely in place for NTUA customers but still needs to be constructed for water haulers. Because of the remote location for some water haulers we assume that 10 percent of today's Navajo population will continue to haul water despite implementation of the Project.

e. Calculation of Project Benefits for the Navajo Nation

The calculation of Project benefits accruing to the Navajo Nation is similar to that for the City of Gallup in that Willingness to Pay is measured by the area under a demand curve. We used the demand curve shown as equation (6) to estimate these benefits. We assume that household use for NTUA customers will increase from 100 gpcd to 130 gpcd, and that household water use for people who would otherwise haul water would increase from 5.4 gpcd to 130 gpcd. We further assume that an additional 22.5 gpcd will be used to support increased commercial activity and non-metered productive uses, such as community landscaping, construction and fire protection. A final 7.5 gpcd will go to other non-metered uses and losses. Benefits for NTUA customers were measured as the willingness to pay for supplemental water to increase per capita consumption from 100 gpcd to 130 gpcd. Benefits to commercial and other productive uses were assumed proportional to residential uses, so the final benefit is 152.5/130 times the residential-only benefit. No benefits were counted for system losses and any other non-productive uses. Per capita benefits were calculated for each year of the 50-year Project life, multiplied by the projected population in that year, and discounted using the current federal discount rate of 4.875% per year. Based on this calculation, the estimated present value of benefits of the Project to the Navajo Nation is $1,488 million (2007$).

Note 3: The area under the demand curve was calculated by integrating equation (6) and solving for the area under the demand curve between the implicit price for projected water use without the project and the price at 130 gpcd water use with the project. This calculation is shown as equation (7).

(7) $\text{Area} = .021 * \text{HHY}^{.372} * (\text{P1}^{(1-.846)} - \text{P0}^{(1-.846)}) / (1-.846)$,

where Area = area under demand curve between P1 and P0

HHY = household income

P1 = price at 130 gpcd

P0 = price at base (without Project) per capita water use

Coefficients and exponents as estimated in equation (6)

The above calculation provides the area under the demand curve and to the right of the y-axis. Finally, to derive the economic benefits we adjust the above calculation to find the area below the demand curve but above the x-axis. This was done by subtracting the rectangle Q0 * (P1-P0) and adding the rectangle P1 * (Q1-Q0). The calculations were done separately for water haulers and for NTUA customers because their respective base prices (P) and quantities of water use (Q) were different.

3. Jicarilla Apache Nation Willingness to Pay

The Jicarilla Apache Nation has long-term plans to develop the southwest area of their reservation, which is not presently populated. The Nation's development plans include housing and commercial projects, and are contingent on securing a reliable and high-quality water supply for the area [Jicarilla Apache Nation].

a. Basis for Estimating Benefits

The absence of a population base for which to estimate Willingness to Pay for the Navajo Gallup Water Supply Project makes it difficult to use a demand function to estimate benefits for the Jicarilla Apache Nation as was done for the City of Gallup and the Navajo Nation. Moreover, much of the anticipated Project benefit is expected to come from the commercial enterprises facilitated by the new water supply, rather than from household use. Under these circumstances, coupled with the articulated tribal policy to develop this area, we believe it is appropriate to estimate Project benefits by comparing the cost of the Project to the most likely alternative means of supplying water to the area. This method is a proxy for willingness to pay insofar as it reflects the amount the Apache Nation is willing to pay to secure a water supply, and is also consistent with the approach recommended by the Water Resource Council's Principles and Guidelines [Water Resource Council, section 2.2.2].

b. Jicarilla Without-Project Condition

As discussed above, The Jicarilla Apache Nation has adopted a policy of developing the southwest area of their reservation, and in case the Navajo Gallup Water Supply Project is not approved, they have investigated alternative means of conveying water to this area. We reviewed the associated project construction and operating cost estimates provided to the Nation [Frick (September) and Frick (October)], and adjusted those cost estimates to be comparable to the estimated costs for the NGWSP. These adjustments include (1) updating the costs to January, 2007 dollar terms, (2) making consistent assumptions regarding unlisted items (10% of listed items), contingencies (22.5% of listed plus unlisted items), engineering (27% of listed plus unlisted items plus contingencies), and cultural resource investigations (4.2% of listed plus unlisted items plus contingencies), and (3) adding interest during construction at the current federal rate for project analysis of 4.875%. Following these adjustments, we calculate that the average of the high and low cost estimates for the Jicarilla Nation's alternative water supply project is approximately $57 million (2007$).

c. Jicarilla With-Project Condition

The Jicarilla Apache Nation would be full partners in the Navajo Gallup Water Supply Project. They would receive 1,200 afy through the Cutter Lateral, which is assumed to be operational by 2020. The costs for the Jicarilla Apache Nation are included in the construction cost estimates discussed below.

d. Calculation of Project Benefits for Jicarilla Apache Nation

The Jicarilla Apache Nation would receive Project benefits of $57 million (2007$), measured by the cost of constructing and operating an alternative water supply project, discussed in section b, above.

4. Comparison of benefits per thousand gallons

Because Project benefits were estimated for the three participants using separate analytical techniques we believe it useful to compare the per unit benefits for the participants. Table 4 shows that the benefits are in fact reasonably similar. This table shows only direct benefits and does not include regional benefits such as unemployment relief or health care efficiency improvement.

Table 4

Comparison of Benefits per Thousand Gallons among Project Participants

	Navajo	**Gallup**	**Jicarilla Apache**
Present Value of Benefits	$1,488,000,000	$361,000,000	$57,000,000
Annualized Benefits	$79,939,000	$19,394,000	$3,062,000
Levelized Water Use (TG/yr)	9,890,000	2,444,000	560,000
Benefits / TG	$8.08	$7.94	$5.47

5. Unemployment Relief Benefits – Construction Employment

As discussed in section A.5, above, in an economic analysis the measured cost of employing labor is less than the wage rate if the labor would otherwise be unemployed. The Principles and Guidelines recognize this principle [Water Resource Council, section

2.11] and recommend applying a zero opportunity cost to construction phase labor that would otherwise be unemployed.

Unemployment is well above the national average in the Project area. Table 5 shows recent unemployment rates for the two counties and two Indian reservations in the Project area, as well as nationally. Most of the Project would be constructed on Navajo Reservation land to serve Navajo chapters, and we are assuming that a local hire rule encouraging Indian employment would be in effect. The very high unemployment rates on the Indian reservations clearly support the conclusion that much of the labor force used to construct the Project would come from the ranks of the otherwise unemployed.

Table 5

Unemployment Rates in United States and Vicinity of Navajo Gallup Water Supply Project

Year	United States	San Juan County, NM	McKinley County, NM	Navajo Reservation	Jicarilla Apache Reservation
1999	4.2%	7.5%	7.1%	34%	40%
2000	4.0%	5.8%	6.6%		
2001	4.7%	6.2%	6.2%	52%	33%
2002	5.8%	6.9%	6.2%		
2003	6.0%	7.6%	7.4%		
2004	5.5%	6.1%	7.6%		
2005	5.1%	5.5%	6.8%		
2006	4.8%	4.3%	5.6%		

Sources: National and county unemployment rates from U.S. Bureau of Labor Statistics, “Local Area Unemployment Statistics;” Reservation unemployment rates from U.S. Bureau of Indian Affairs, “American Indian Population and Labor Force Report,” 1999 and 2001.

The Principles and Guidelines recommend that in an area of substantial and persistent unemployment and in the case of a local hire rule we assume for the economic analysis that 43% of skilled workers and 58% of unskilled workers be considered as otherwise unemployed during the construction phase of the Project [Water Resource Council, section 2.11.4]. We used an IMPLAN input-output model [IMPLAN, “Professional 2.0;”

IMPLAN, “County Data”]to estimate the average earnings of workers needed for the Project, and used Bureau of Reclamation data to split the total earnings estimate between earnings for skilled and unskilled workers [U.S. Bureau of Reclamation, 1988]. We estimated the earnings for each year of construction, and accumulated interest during construction until the year of completion (2027) using the federal discount rate of 4.875%. The estimated present value (as of 2027) of the construction earnings going to otherwise unemployed persons is $231 million (in 2007$).

6. Other Project Benefits

a. Unemployment Relief Benefits – Secondary Employment

The wages and salaries paid to area construction employees will in turn provide a substantial boost to the local economy, known as an “induced” impact. The Principles and Guidelines suggest that because of measurement and identification problems and because unemployment is regarded as a temporary phenonemon that a project analysis should only account for the benefits from employing construction labor and not the associated induced employment [Water Resource Council, section 2.11.2]. However, high unemployment levels have been persistent on both the Navajo and Jicarilla Apache reservations for generations, directly contrary to the “full employment economy” premise of the Principles and Guidelines [Water Resource Council, section 1.7.2(e)(3)]. We have therefore estimated the value of earnings going to otherwise unemployed people in the non-construction industries stimulated by local construction spending, particularly for labor. We used the same methodology as in estimating earnings of construction workers, except that we did not assume any local hiring preference and assume that only 30 percent of skilled workers and 47 percent of unskilled workers would be otherwise unemployed [Water Resources Council, p. 94]. The present value of wages in non-construction industries that will go to otherwise unemployed persons is estimated at $111 million (in 2007$)

b. Health Benefits

A primary rationale for the public policy of providing clean and reliable water to all people in the United States is the resulting health benefit. For example, Congress has found specifically for Indians that a "major national goal of the United States is to provide the quantity and quality of health services which will permit the health status of Indians to be raised to the highest possible level …" [25 USC 1601], and that "the provision of safe water supply systems and sanitary sewage and solid waste disposal systems is primarily a health consideration and function," and that "it is in the interest of the United States, and it is the policy of the United States, that all Indian communities and Indian homes, new and existing, be provided with safe and adequate water supply systems… as soon as possible." [25 USC 1632].

There is a clear connection between sanitation facilities (water & sewerage) and Indian health. The Indian Health Service considers the availability of essential sanitation facilities to be "critical to breaking the chain of waterborne communicable disease episodes… In addition, many other communicable diseases, including hepatitis A, shigella, and impetigo are associated with the limited hand washing and bathing practices often found in households lacking adequate water supplies. This is particularly true for families that haul water" [Indian Health Service, 2004]. The Indian Health Service reports that American Indian families living in homes with satisfactory environmental conditions required about one-fourth the medical services as those with unsatisfactory environmental conditions [Ibid.].

Benefits from an improved water supply will accrue both to consumers and providers of health care. The Navajo people will enjoy better health as a result of their access to a clean and reliable water supply. Their benefit should be reflected in their willingness to pay for water and is already addressed in that analysis. The Indian Health Service, which provides health care to the Navajos, will also experience a reduction in their cost of providing health care services as a result of the reduced case load from water-related illness. This efficiency improvement is the focus of the present section.

The Indian Health Service concludes that the average annual cost for medical care in the Shiprock-Gallup-Fort Defiance area that would be equivalent to the Federal Employees Health Plan is $3,415 per person in 2007$ [Indian Health Service, 2002, US BLS, 2007]. If even 10% of this cost could be saved by the provision of a clean piped water supply to those households who would otherwise haul water, that savings would amount to a present value of as much as $11,000 per person for those people connecting to the Project by 2016, or $5,400 per person for those connecting by 2030. The Navajo-Gallup Water Supply Project will ultimately provide water to over 100,000 people who would otherwise haul water, for an estimated total savings in medical expenses of over $435 million over the life of the Project (in 2007$).

c. Increase in Economic Activity

The entire project area and the Navajo Reservation in particular are characterized by persistent poverty and above national average unemployment rates [USDA; Table 4, supra]. Over 40 percent of Navajo families have income below the poverty level, compared with less than 10 percent nationwide [Navajo Division of Community Development, 2004, p. 22], and median income for Navajo households is less than one-half of the national average [Ibid.].

Provision of a clean, reliable water supply can serve to promote economic activity in the project area. International agencies recognize that not only is water an important factor of production in some industries (eg. cooling water in a power plant), but that investments in water infrastructure can also serve as a catalyst for more general development [Lenton, p. 129]. A recent study of foreign aid focused on short-term projects (eg. roads, irrigation systems, electricity generators and ports) concluded that every $1 invested in short-term aid returned a present value of $1.64 in increased output and income [Clemens]. Although the study objective was to estimate the effect from short-term aid the results also suggest “an important long-run positive impact on growth from long-term aid” (such as a water supply project)[Clemens, p. 41 and Table 5].

Two recent studies in the United States examined the extent to which development of water projects stimulated the regional economy. The first study investigated the effects of dams on local economic growth and development by analyzing the effects on county income, employment, population and earnings [Aleseyed]. Control group counties were paired with counties with new water projects. The study concluded that large dam reservoirs had a statistically significant positive effect on growth in the local areas, with the strongest positive effects from non-flood control projects, and weaker effects from regions without a large city [Aleseyed, pp. 17-18].

The second study focused on the extent to which water and sewer projects can save and/or create jobs, spur private investment, attract government funds and enlarge the property tax base [Bagi]. The study found that "[e]very dollar spent in constructing an average water/sewer project generated almost $15 of private investment, leveraged $2 of public funds, and added $14 to the local property tax base" [Bagi, p. 46]. In addition, the study found that many more permanent jobs were either saved or created by the project than the number of construction jobs needed to build the project [Bagi, p. 49].

It is difficult to forecast the extent to which the NGWSP will promote economic growth in the region. The evidence cited above, however, clearly indicates that we should expect a substantial regional economic stimulus from the project. The Anderson School of Management at University of New Mexico recently evaluated the economic impacts from the proposed San Juan River Settlement Agreement and related NGWSP [UNM]. Their report discusses state and level construction impacts, tax revenues, social benefits and the effect on the regional economy from improving the water supply. The report concludes that "improving the water infrastructure in economically depressed areas can be the catalyst for the development of small economic clusters such as those centered around manufacturing" [Ibid., p. 34]. The report also makes the important point that the NGWSP will increase the flexibility of water use in northern New Mexico [Ibid., pp. 38-9], thereby potentially increasing the economic efficiency of water use.

d. Curtailment of Navajo Outmigration

Finally, the Project may indirectly help reduce the outmigration of Navajo people. The improved economic climate facilitated by the Project will provide more employment opportunities for the minority and low-income populations. This increased employment opportunity, together with an improved water infrastructure, will make the area more attractive for young adults who might otherwise consider moving outside the area. This impact is discussed in the companion report "Social Impacts from the Navajo-Gallup Water Supply Project." [Merchant, 2007b]

D. Economic Costs

The Project's economic costs were estimated using the same principles as in estimating project benefits. The primary categories of Project costs include (1) Project construction costs, (2) distribution line construction costs, (3) operation, maintenance and replacement costs, (4) costs for water, (5) downstream effects on power generation, and (6) downstream effects on salinity.

1. Project Construction Cost

In a companion report we estimated the total financial Project costs and the respective shares of cost for each of the three Project participants [Merchant, 2007a]. The total project capital cost before interest during construction (IDC) is estimated at $865 million. Two adjustments of this number are necessary to derive the Project's economic cost. First, as explained in section A.3, above, the $53 million of taxes included in this total are transfer payments and should be excluded [Ibid.], leaving a net cost before taxes of $812 million.

The second adjustment necessary is to add IDC to reflect the cost to the economy of tying up resources used during construction of the Project and before the project begins to deliver water and to provide benefits. We assume that Project construction would begin in 2011, full Project operation would begin in 2027, and we compound IDC to the completion date at the rate of 4.875% per year. IDC based on a pre-tax construction cost of $812 million amounts to $380 million [Ibid., adjusted to remove IDC on taxes]. The total economic construction cost is thus estimated at $1,192 million. This IDC calculation and the associated 16-year construction schedule is assumed to be limited to constant dollar construction funding of $60 million per year (2007$). If the funding level were sufficient to sustain an 8-year construction schedule IDC would be about $185 million, less than one-half of the amount used in this report.

2. Distribution Line Construction Cost

The Project construction cost includes all costs necessary to build the main laterals that would convey water to each participant. It also includes the costs for water treatment, pumping plants and storage tanks. However, it does not include the cost for the distribution lines needed to deliver water to each connection. Because the benefits were estimated based on the assumption that nearly all residents would have a piped water supply, it is important that the costs include whatever additional facilities are needed to provide those connections. Each of the three participants begin with different circumstances.

a. City of Gallup

The Project capital cost estimates for the City of Gallup already includes a substantial portion of the distribution system necessary to deliver water within the City and to the neighboring Navajo Chapters. Additional costs incurred by the City to hook up new customers are normally passed on to the customers by means of a connection fee. These costs will therefore be covered by the water users and will not be charged to the Project.

b. Navajo Nation

Recall that the “Without-Project” condition described in section B.2.c, above, is that even in the absence of the Project the Navajo Nation will continue to extend piped water service to about 60% of a growing population. The Project will deliver supplemental water to these people. The Project will also deliver water to most of the remaining 40%, who are those who would otherwise be hauling water. We have included a cost allowance to provide distribution systems for the Navajos who would otherwise haul water. We estimated the number of connections added per year for the life of the Project and calculated an annual Project cost using a cost of $669 per connection [MSE-HKM, indexed for inflation]. These annual totals were discounted to 2027 using the federal discount rate of 4.875%. The total discounted cost amounts to $48 million (2007$).

c. Jicarilla Apache Nation

Although the Jicarilla Apache Nation will incur some cost for distribution lines they would incur the same cost if they were to develop an alternative water supply in lieu of the Navajo Gallup Water Supply Project. Because the benefits included in the economic analysis are based only on the cost savings of this Project compared to other projects, the added cost of distribution lines does not affect the difference and should therefore not be included as either a Project cost or the cost of any alternative projects.

3. Operation, Maintenance and Replacement Cost

The Project's annual operation, maintenance and replacement (O,M&R) costs were estimated for each year of the Project and discounted to the assumed initial year of full Project operation, 2027. These costs were estimated for both commercial (NTUA) power rates and Colorado River Storage Project rates. A financial analysis would use whichever rates were ultimately charged to the Project. However, an economic analysis from the perspective of the federal government would use the market rate regardless of whether the Project qualified for a concessionary rate since the market rate presumably reflects the value to the Nation of power. (see discussion in section A.1, above). We therefore used the NTUA rates to determine the economic cost of Project O,M&R. This cost is $368 million [Merchant, 2007a].

4. Cost of Water

An economic analysis should address the cost of the water dedicated to the Project. While a financial analysis would consider only the actual payments for water an economic analysis evaluates the opportunity cost of water even in the absence of financial payments (see discussion in section A.6, above). The relevant perspective for the opportunity cost is that of the water rights holder because the uses of water are limited to whatever opportunities are available to whoever owns the water. The analysis is different for all three Project participants.

a. City of Gallup

The City of Gallup does not presently hold the water rights for its intended Project use. The City is negotiating with the Jicarilla Apache Nation and presumably will reach an arms length agreement to appropriately compensate the Jicarilla for Gallup use of Jicarilla watter. This cost will reflect the market conditions for water and should offer a fair assessment of the opportunity cost of water for the Jicarillas. Pending completion of the negotiations we have assumed an annual price of $110 per acre foot during Project operation, plus an option fee to hold the water until the Project is completed, which together have a present value over the life of the Project of $33 million.

b. Navajo Nation

Absent a water rights settlement providing other terms, the Navajo Nation will pay an estimated $4.12 per acre-foot for their non-agricultural use of water from Navajo Reservoir. This cost represents a financial cost to the Navajos, but because it is based on historical investment costs and not a current use of resources it is not an economic cost. The relevant economic cost is the lowest-returning opportunity available to the Navajos that would be displaced by dedicating water to the Project. For the Navajos we assume that this opportunity is probably growing irrigated alfalfa. We used New Mexico Cooperative Extension Service crop budgets [Libbins] and New Mexico Agricultural Statistics [New Mexico Agricultural Statistics Service] to estimate the returns to water used in growing alfalfa. The expected annual average return is $178 per acre in 2007$. Assuming 4 afy are diverted to grow each acre of alfalfa the opportunity cost for each acre-foot is $45. The present value of the opportunity cost for the 28,900 afy of average Project water use is thus estimated at $26 million in 2007$.

c. Jicarilla Apache Nation

Although the Jicarilla Apache Nation will incur some opportunity cost for dedicating some of their water supply to the Project, the Jicarilla Nation would incur the same opportunity cost if they were to develop an alternative water supply besides the Navajo Gallup Water Supply Project. Because the benefits included in the economic analysis are based only on the cost savings of this Project compared to other projects, the added water opportunity cost does not affect the difference and should therefore not be included as either a Project cost or the cost of any alternative projects.

5. Other Project Costs

The Project will have some effect on downstream water users (externalities). These effects include a reduction in Colorado River power generation and increases in Colorado River salinity. Similar downstream effects would result from <u>any</u> depletion in the Upper Colorado River Basin. Because the Project water use will be within the scope of the water rights held (or leased) by Project participants, the participants can legitimately deplete water without regard to the impact on lower priority users. And since there is no mechanism for Lower Basin users (who would be most impacted by any increase in salinity) to compensate Upper Basin water rights holders for not using water, the Upper Basin water users have no financial opportunity cost that recognizes the impact of their water use on Lower Basin users. From a national perspective, however, we should recognize the broader effect of Upper Basin water rights holder exercising their water rights.

a. Loss in Electrical Power Revenues

Water diverted for the Project from the San Juan River will deplete Lake Powell inflow. This depletion could have a range of impacts on power generation at Glen Canyon Dam, depending on total flows into Lake Powell and on total water use in the Upper Basin. The Upper Basin is obligated to release a minimum amount of water from Lake Powell for the benefit of Lower Basin and Mexico users of the Colorado River. Diversions for the Navajo-Gallup Water Supply Project will not relieve the Upper Basin from this obligation, so at one extreme the total releases from Lake Powell may not change. On the other hand, until the Upper Basin uses its full water allocation and during periods of above-normal nature runoff in the Upper Basin, the Upper Basin may release more than its obligated minimum from Lake Powell. Under these circumstances the depletion from the Navajo-Gallup Water Supply Project will cause a reduction in power generation at Glen Canyon Dam. In order to determine the maximum impact of the Navajo-Gallup Project we have estimated the cost of diminished power generation under the second set of assumptions.

The estimated average flow of the Navajo-Gallup Water Supply Project will reach 51.94 cfs [Merchant]. A Bureau of Reclamation study reports that the power generation lost at Glen Canyon Dam amounts to .0408 MW/cfs [U.S. Bureau of Reclamation, 2000b], so the total capacity lost due to the Project would be 2.12 MW. At 8,760 hours per year the total electrical energy lost would be 18,563 MWh. We valued this lost energy at its estimated replacement cost of 55.68 mills per kwh (2007$) [Energy Information Administration, p. 78]. At the federal discount rate of 4.875% the present value of these lost power benefits over the 50 year Project life is estimated to be $19 million.

b. Downstream Salinity Effects

The Navajo-Gallup Water Supply Project will have two effects on downstream salinity. First, the Project depletions will diminish the flow of relatively high quality water into into Lake Powell, raising the average total dissolved solids (TDS) of Lake Powell inflows by an estimated approximately 0.7 mg/L. Second, the Project will produce some return flow that would enter Lake Powell. This return flow is higher in TDS than the average inflow and would raise the average TDS by an estimated about 0.8 mg/L [U.S. Bureau of Reclamation, 2004; Leach]. The total increase in TDS will thus be about 1.5 mg/L.

The cost of this 1.5 mg/L increase in salinity is the lesser of two factors. First, the Bureau of Reclamation has estimated that in 2000 the annual cost to Lower Basin water users for each 1.0 mg/L increase in salinity is about $2,500,000 [U.S. Bureau of Reclamation, 2000a]. Updating this cost to 2007$ [U.S. Bureau of Labor Statistics, CPI] and applying it to the 1.5 mg/L increase converts to an annual cost of $4,000,000. The second factor is the cost of mitigating the increase in salinity. The Bureau of Reclamation is actively soliciting proposals from Colorado Basin water users to reduce the salinity load of the Colorado River. The average cost of this program is less than one-quarter of the cost of tolerating increased salinity loads [[U.S. Bureau of Reclamation, 2003]. The annual cost to mitigate the salinity increase due to the Project would therefore be about $1,000,000. The present value of these mitigation costs over the 50 year Project life would be about $20 million (2007$) (again applying the federal discount rate of 4.875%).

E. Benefit – Cost Summary

Table 6 summarizes the estimated benefits and costs from the Navajo-Gallup Water Supply Project.

Table 6

Summary of Navajo-Gallup Water Supply Project Economic Benefits and Costs

(4.875% discount rate, 50 year project life)

Millions 2007$

BENEFITS	**Direct**	**Direct plus Other**
Gallup Willingness to Pay	361	361
Navajo Willingness to Pay	1,488	1,488
Jicarilla Avoided Cost	57	57
Construction Employment	231	231
Induced Employment	-	111
Health Benefits	-	435
Total Benefits	2,137	2,683
COSTS		
Project Construction	1,192	1,192
Distribution System Construction	48	48
O,M&R	368	368
Gallup Water Cost	33	33
Navajo Water Cost	24	24
Power Generating Cost	19	19
Salinity Increase Cost	20	20
Total Costs	1,704	1,704
BENEFIT/COST RATIO	**1.25**	**1.57+**

F. Discount Rate Sensitivity Analysis

Federal legislation requires an annual determination of a discount rate to be used by federal agencies in water resources planning. During fiscal year 2007 the federal rate is 4.875% [U.S.

Bureau of Reclamation, 2006]. This federal rate is a constrained, lagged, nominal (includes inflation) rate computed annually from U.S. Treasury security yields. The rate is constrained because it cannot move more than .25% per year regardless of how much market interest rates move between consecutive years. The rate is then rounded to the nearest one-eighth of one percent. Absent these constraints the 2007 rate would be 4.9351% [Ibid.].The rate is lagged because it reflects *average* yields on marketable securities with a term of 15 years or more, not just the most recent yields on securities. The rate is nominal because no effort has been made to subtract the expected inflation that is built into the rate (lenders always ask for a premium above a real or inflation-free interest rate to compensate them for the expected loss in purchasing power that is caused by future inflation).

This federal rate is not well suited to cost-benefit analysis because its use violates a fundamental economic principle, viz. consistent treatment of inflation in both the discount rate and the estimation of future benefits and costs. The federal rate is based on nominal (inflation-including) rates because it does not attempt to adjust market rates for the expected inflation that is implicitly built into the rates. On the other hand, the federal rate is not an accurate measure of current nominal rates, either, because the rate is both lagged and constrained, as explained above.

In keeping with the Principles and Guidelines [Water Resources Council, section 1.4.10] all of the future costs and benefits for the Navajo-Gallup Water Supply Project have been estimated in constant 2007 price levels. To maintain consistency these constant dollar prices should be discounted at a rate that also assumes constant price levels, and as explained above, the federal rate does not meet that condition.

The real (net of inflation) cost of long-term federal funds is in the range of 2.0% to 4.0% per year. The Office of Management and Budget, for example, concludes that the real rate on 10-year bonds is 2.8% and the real rate on 30-year bonds is 3.5% [OMB]. For the purpose of evaluating the sensitivity of the benefit cost analysis results to the level of the discount rate we have recomputed all costs and benefits using a real discount rate of 3%. The results of this analysis are shown in Table 7.

Table 7 shows that using a real discount rate of 3% significantly increases the Benefit/Cost ratio. The lower rate increases the importance of future events (predominantly benefits) relative to the near term events (predominantly costs), resulting in the increased ratio of benefits to costs.

Table 7

Summary of Navajo-Gallup Water Supply Project Benefits and Costs

(3% discount rate, 50 year project life, millions 2007$)

	Direct	Direct Plus Other
BENEFITS		
Gallup Willingness to Pay	$596	$596
Navajo Willingness to Pay	$2,137	$2,137
Jicarilla Avoided Cost	$58	$58
Construction Employment	$199	$199
Indirect and Induced Employment	$0	$95
Health Benefits	$0	$630
Total Benefits	$2,990	$3,715
COSTS		
Project Construction	$1,026	$1,026
Distribution System Construction	$53	$53
O,M&R	$486	$486
Gallup Water Cost	$38	$38
Navajo Water Cost	$34	$34
Power Generating Cost	$27	$27
Salinity Increase Cost	$27	$27
Total Costs	$1,691	$1,691
BENEFIT/COST RATIO	1.77	2.20

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APPENDIX A
DATA USED TO ESTIMATE WATER DEMAND FUNCTION

City	State	GPCD	1999 HH Inc	HH size	Cost/ 1000 gal.	ln GPCD	ln HH Inc	ln HH size	ln Cost
Camp Verde	AZ	80	$31,868	2.57	$6.88	4.382	10.369	0.944	1.929
Flagstaff	AZ	122	$37,146	2.59	$3.07	4.804	10.523	0.952	1.122
Page	AZ	141	$46,935	3.26	$2.01	4.950	10.757	1.182	0.700
Payson, AZ	AZ	95	$33,638	2.25	$4.20	4.554	10.423	0.811	1.434
Prescott Valley	AZ	99	$34,341	2.53	$3.36	4.591	10.444	0.928	1.212
Show Low	AZ	126	$32,356	2.85	$6.35	4.836	10.385	1.047	1.848
Brighton	CO	137	$46,779	2.81	$3.09	4.918	10.753	1.033	1.127
Broomfield	CO	142	$63,903	2.82	$2.62	4.955	11.065	1.037	0.965
Brush	CO	282	$31,333	2.48	$2.59	5.641	10.352	0.908	0.950
Canon City	CO	347	$31,736	2.26	$1.97	5.850	10.365	0.815	0.677
Delta	CO	161	$27,415	2.27	$2.65	5.084	10.219	0.820	0.974
Durango	CO	225	$34,892	2.37	$1.51	5.416	10.460	0.863	0.414
Englewood	CO	192	$38,943	2.18	$1.69	5.257	10.570	0.779	0.523
Estes Park	CO	221	$43,262	2.27	$2.73	5.397	10.675	0.820	1.004
Federal Heights	CO	109	$33,750	2.72	$2.71	4.690	10.427	1.001	0.996
Fort Morgan	CO	313	$33,128	2.54	$1.52	5.746	10.408	0.932	0.417
Golden	CO	198	$49,115	2.22	$2.65	5.289	10.802	0.798	0.973
Grand Junction	CO	136	$33,152	2.15	$2.34	4.915	10.409	0.765	0.850
Gunnison	CO	167	$25,768	2.21	$1.40	5.119	10.157	0.793	0.334
La Junta	CO	289	$29,002	2.56	$0.87	5.668	10.275	0.940	-0.137
Lamar	CO	193	$28,660	2.58	$1.34	5.264	10.263	0.948	0.293
Louisville	CO	198	$69,945	2.65	$2.31	5.287	11.155	0.975	0.836
Montrose	CO	173	$33,750	2.29	$2.47	5.152	10.427	0.829	0.906
Northglenn	CO	123	$48,276	2.78	$2.52	4.813	10.785	1.022	0.924
Sterling	CO	207	$27,337	2.33	$1.10	5.335	10.216	0.846	0.097
Alamagordo	NM	185	$30,928	2.57	$1.63	5.220	10.339	0.944	0.488
Aztec	NM	98	$33,110	2.69	$2.76	4.583	10.408	0.990	1.014
Belen	NM	275	$26,754	2.79	$1.63	5.617	10.194	1.026	0.489
Bernalillo	NM	151	$30,864	3.06	$2.37	5.019	10.337	1.118	0.863
Carlsbad	NM	296	$30,658	2.51	$1.55	5.690	10.331	0.920	0.441
Clovis	NM	156	$28,878	2.57	$2.52	5.050	10.271	0.944	0.924
Deming	NM	195	$20,081	2.65	$0.55	5.273	9.908	0.975	-0.597
Farmington	NM	214	$37,663	2.81	$2.14	5.366	10.536	1.033	0.762
Gallup	NM	172	$34,868	2.85	$2.48	5.147	10.459	1.047	0.909
Hobbs	NM	72	$28,100	2.87	$1.43	4.272	10.244	1.054	0.357
Las Cruces	NM	135	$30,375	2.83	$1.71	4.904	10.321	1.040	0.537
Los Alamos	NM	197	$71,536	2.31	$4.22	5.283	11.178	0.837	1.439
Portales	NM	250	$24,658	2.51	$1.40	5.521	10.113	0.920	0.335
Rio Rancho	NM	184	$47,169	2.70	$2.42	5.215	10.761	0.993	0.883
Santa Fe	NM	166	$40,392	2.20	$3.91	5.112	10.606	0.788	1.364
Socorro	NM	110	$20,728	2.58	$3.42	4.700	9.939	0.948	1.230
Tucumcari	NM	123	$22,560	2.40	$2.65	4.808	10.024	0.875	0.976
Boulder City	NV	251	$50,523	2.41	$1.41	5.525	10.830	0.880	0.346
Elko	NV	700	$48,608	2.62	$0.30	6.551	10.792	0.963	-1.207
Fallon	NV	240	$35,935	2.40	$0.63	5.481	10.489	0.875	-0.468
Mesquite	NV	152	$40,392	3.16	$1.88	5.024	10.606	1.151	0.631
Alpine	UT	134	$72,880	4.51	$1.60	4.901	11.197	1.506	0.473
American Fork	UT	186	$51,955	3.74	$1.00	5.228	10.858	1.319	0.002

Brigham City	UT	203	$42,335	3.18	$0.91	5.315	10.653	1.157	-0.090
Centerville	UT	101	$64,818	3.83	$1.76	4.618	11.079	1.343	0.565
Clinton	UT	97	$53,909	3.91	$1.22	4.571	10.895	1.364	0.195
Grantsville	UT	167	$45,614	3.20	$1.83	5.115	10.728	1.163	0.605
Heber	UT	183	$45,394	2.96	$1.08	5.208	10.723	1.085	0.073
Holliday	UT	278	$66,468	2.91	$1.22	5.628	11.104	1.068	0.199
Midvale	UT	388	$40,130	2.56	$0.57	5.962	10.600	0.940	-0.562
Murray	UT	263	$45,569	2.66	$1.05	5.571	10.727	0.978	0.051
North Logan	UT	120	$49,154	3.90	$1.94	4.787	10.803	1.361	0.661
North Salt Lake	UT	219	$47,052	3.14	$1.23	5.391	10.759	1.144	0.209
Park City	UT	224	$65,800	2.50	$1.39	5.413	11.094	0.916	0.331
Pleasant Grove	UT	18	$52,036	3.83	$9.14	2.891	10.860	1.343	2.213
Price	UT	131	$31,687	2.85	$2.93	4.874	10.364	1.047	1.073
Riverdale	UT	326	$44,375	2.78	$0.36	5.788	10.700	1.022	-1.021
Riverton	UT	183	$63,980	4.14	$1.19	5.211	11.066	1.421	0.177
South Jordan	UT	216	$75,433	4.39	$1.31	5.376	11.231	1.479	0.270
Spanish Fork	UT	156	$48,705	3.39	$1.29	5.052	10.794	1.221	0.257
Springville	UT	223	$46,472	3.28	$0.96	5.408	10.747	1.188	-0.038
Sunset	UT	176	$41,726	2.95	$1.02	5.168	10.639	1.082	0.021
Tremonton	UT	196	$44,784	3.12	$1.24	5.276	10.710	1.138	0.214
Washington	UT	201	$35,341	3.29	$0.83	5.301	10.473	1.191	-0.182
Cody	WY	74	$34,450	2.38	$5.41	4.309	10.447	0.867	1.688
Douglas	WY	247	$36,944	2.66	$2.10	5.511	10.517	0.978	0.740
Evanston	WY	234	$42,019	2.99	$1.69	5.456	10.646	1.095	0.522
Lander	WY	121	$32,397	2.48	$3.06	4.798	10.386	0.908	1.117
Powell	WY	131	$27,364	2.41	$4.07	4.877	10.217	0.880	1.405
Rawlins	WY	419	$36,600	2.60	$0.34	6.037	10.508	0.956	-1.092
Riverton	WY	190	$31,531	2.58	$2.24	5.249	10.359	0.948	0.806
Rock Springs	WY	92	$42,584	2.66	$11.24	4.523	10.659	0.978	2.419
Sheridan	WY	177	$31,420	2.31	$1.94	5.175	10.355	0.837	0.664
Worland	WY	95	$31,447	2.63	$2.53	4.556	10.356	0.967	0.926

Sources:

Black & Veatch, “Arizona Water/Wastewater Rate Survey, 2000,” 2000.

Colorado Municipal League, “Water and Wastewate Utility Charges and Practices in Colorado,” 1997.

Dornbusch Associates, telephone interviews.

Utah Department of Environmental Quality, Division of Drinking Water, “1999 Survey of Community Drinking Water Systems,” 2000.

Wyoming Water Development Commission, “1998 Water System Survey Report,” 1998.

APPENDIX B - SUMMARY OUTPUT FROM REGRESSION

Regression Statistics	
Multiple R	0.8028
R Square	0.6445
Adjusted R Square	0.6303
Standard Error	0.2961
Observations	79

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	11.9214	3.9738	45.3229	0.0000
Residual	75	6.5758	0.0877		
Total	78	18.4972			

	Coefficients	*andard Err*	*t Stat*	*P-value*
Intercept	2.9126	1.2897	2.2583	0.0268
Household Income	0.3716	0.1325	2.8051	0.0064
Household Size	-1.3483	0.2374	-5.6802	0.0000
Cost of Water	-0.5538	0.0509	-10.8778	0.0000