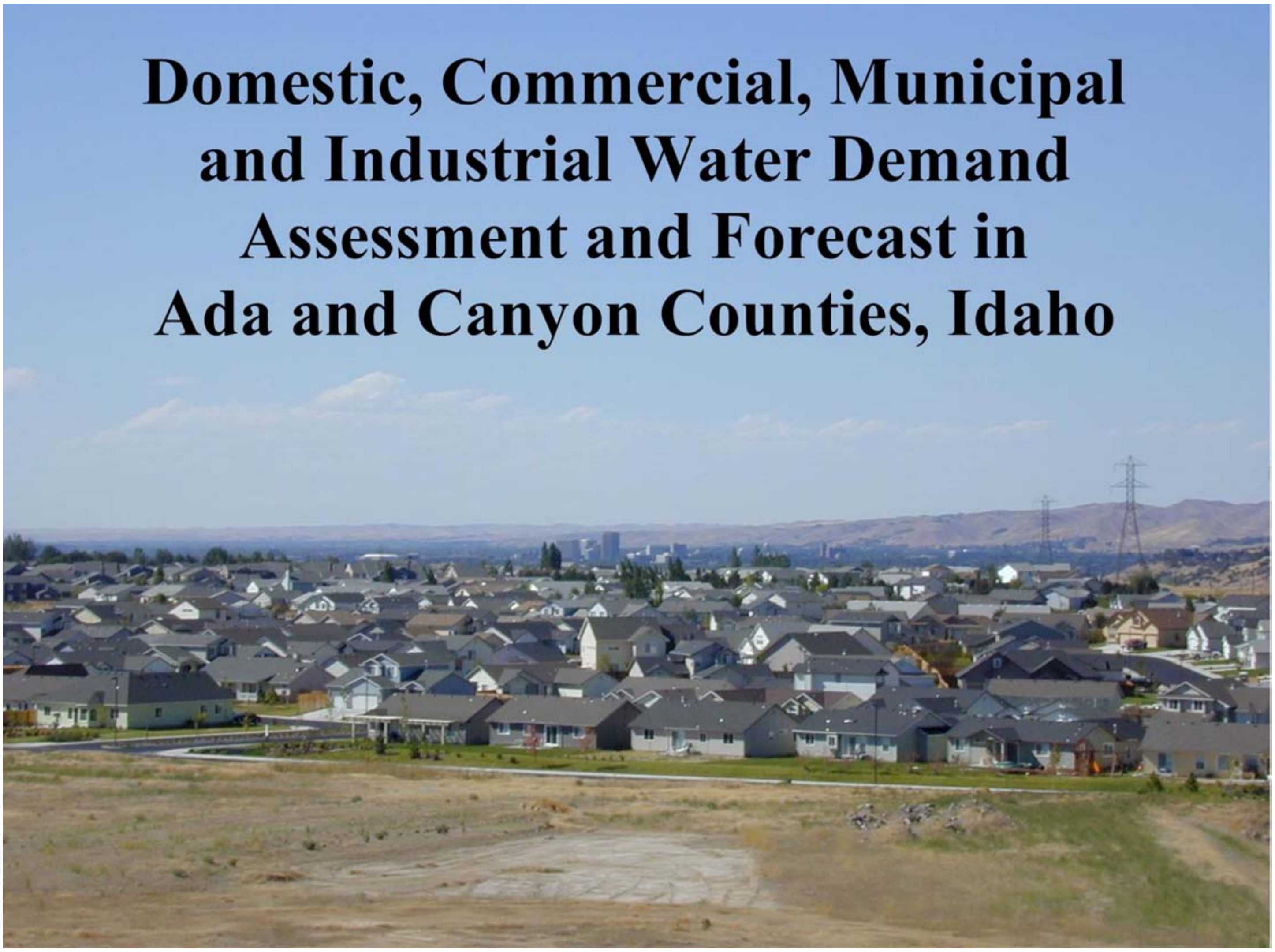
Domestic, Commercial, Municipal and Industrial Water Demand Assessment and Forecast in Ada and Canyon Counties, Idaho



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Executive Summary

Ada and Canyon counties of southwestern Idaho incurred a significant population growth between 1988 and 2000, an increase of 44 percent. This rapid growth has led to concerns that continued growth will cause an increasing demand for water resources in the valley. A major concern is the ability of the water resources, especially potable water supplies from groundwater sources, to meet the increasing demand. Due to uncertainty about the availability of groundwater supplies in some parts of the valley, municipal providers must consider alternative sources. Surface water sources will be needed in order to supply the valley's growing needs for domestic, commercial, municipal, and industrial (DCMI) uses. However, a clearer vision of the present and future DCMI demands is also required.

This report describes a cooperative effort between the Community Planning Association of Ada and Canyon Counties (COMPASS), the United States Geological Survey (USGS), and the Idaho Department of Water Resources (IDWR) to assess current DCMI water-use conditions and project future needs. The U.S. Bureau of Reclamation (USBR) provided the funding for the project.

DCMI water demand estimates were calculated for the entire populations of Ada and Canyon counties. The study used an end-use, sector-based approach in which water demand coefficients were calculated for all major categories of DCMI water demand for the years 2000 to 2025 in five-year increments using data from 1997 and 1998 as the baseline. Using the term residential to describe domestic water demand, sectors reflecting an end-use approach are residential single-family, residential multi-family, municipal, commercial, and industrial.

Two different approaches were used to calculate coefficients in the different sectors. The choice of approach depended primarily on what data were available. A somewhat complex modeling approach was used for residential single-family. Factors or variables explaining single-family household water demand were incorporated into two models of residential water demand. One was a model of individual household demand. The second was a model of aggregate residential water demand. Coefficients estimated by these models measured the effect of each of the explanatory variables on water demand. Using data on publicly supplied water to households, the model of individual household demand estimated the effect of lot size, household size, area characteristics, and weather on water demand. The model of aggregate residential demand included aggregate measures of some of the same variables, but its purpose was to estimate the effect of price on water demand. A third model used the coefficients derived in the first two models, along with present and forecasted values of the explanatory variables, and the forecasted number of households to estimate baseline and future water demand.

Fairly conservative assumptions were adopted for projecting future values of density and price in the single-family residential model. It was assumed that prices rise by the rate of inflation and that density doesn't change over the period. If prices rise by more than the rate of inflation and/or some conservation measures are adopted, actual water demand will be lower than forecasted. Similarly, if density increases over the period, actual water demand will be lower than forecasted.

A second, simpler approach was used to measure the coefficients associated with residential multi-family demand. For this sector, water demand is calculated on a per unit basis. For apartments, water use measurements for each apartment complex are totaled and then averaged over the number of units in the complex. For mobile homes, water use measurements for each mobile home

park are totaled and then averaged over the number of units in the park. Estimated current and future water demand for the groups are obtained by multiplying the estimated gallons per day by estimated current and future households.

The approaches to estimating water demand for single-family dwellings, apartments and mobile homes yielded average per person indoor and outdoor values of 194 gallons for single-family residences, 82 gallons for apartments, and 143 gallons for mobile homes. On average, single-family residences demand a total of 24.3 billion gallons annually, apartments demand 3.1 billion gallons, and mobile homes demand 2.9 billion gallons.

When comparing single-family water demand in the two counties, Ada County is higher. There are two reasons for this: 1) Ada County has a greater absolute number of single-family households, and 2) Ada County has higher household incomes.

For municipal, commercial, and industrial users (MCI), establishments are grouped by Standard Industrial Code (SIC). Examples of the ten, one-digit SIC code groups are manufacturing, services, retail, and government activities. For this study, a water demand coefficient is calculated for all SIC groups at the two-digit level of aggregation. At this level of aggregation, there are 100 groups of establishments. MCI water demand coefficients are ratios of water use to the numbers of employees in a SIC group. Hence, the coefficients represent an amount of water demanded per employee within a SIC group to produce products or supply services. Estimated current and future water demand for a group is obtained by multiplying the computed coefficient by estimated current and future employment.

Data deficiencies may necessitate the need for caution about the commercial results. Most important is the lack of data on groundwater and surface water use by commercial users. This gap may lead to an underestimation of baseline and forecasted commercial water demand.

In total, baseline water demand in 1997 and 1998 is estimated at 33.6 billion gallons or 103,000 acre - feet per year. By 2025, water demand rises to 58.4 billion or 179,000 acre-feet, a 74 percent increase. Residential water demand rises more than commercial demand, 79 percent compared with 64 percent. As a result, there is a slight increase in the ratio of residential water demand to commercial water demand during the period (from 64 percent to 66 percent). Because population was such an important factor, the results of this study, using 1997 population estimates, were compared with results using recently obtained 2001 population estimates. Water demand using the 2001 estimates are 65 billion in 2025 or 199,000 acre-feet compared with 59 billion using the 1997 estimates, a difference of 20 percent.

In conclusion, this study represents the first attempt to measure baseline and future water demand in the valley as a whole. It is predicted that there will be a significant increase in water demand during the next 25 years and that between 76,000 and 96,000 additional acre-feet of water will be needed to accommodate the additional demand.

More work could be done to improve the estimates. More analysis of different scenarios may be warranted with respect to price, conservation, and possibly climate changes. Improvements in the estimates also require better measurements of use by commercial ground and surface water users. Improvements in record keeping and record availability by the public water providers and irrigation districts in the area would greatly aid periodic updates of this study.

Introduction

Ada and Canyon counties are located in southwestern Idaho (Figure 1). The area incurred significant population and household growth between 1988 and 2000 (Figure 2). This rapid growth has led to questioning the consequences of continued growth with respect to an increasing demand for water resources in the valley. A major concern is the ability of the water resources, especially potable water supplies from groundwater sources, to meet the increasing demand. Due to uncertainty about the availability of groundwater supplies, municipal providers must consider alternative sources. Surface water sources will be needed in order to supply the valley's growing demand for domestic, commercial, municipal, and industrial (DCMI) water use. However, a clearer vision of the present and future demands for DCMI is also required.

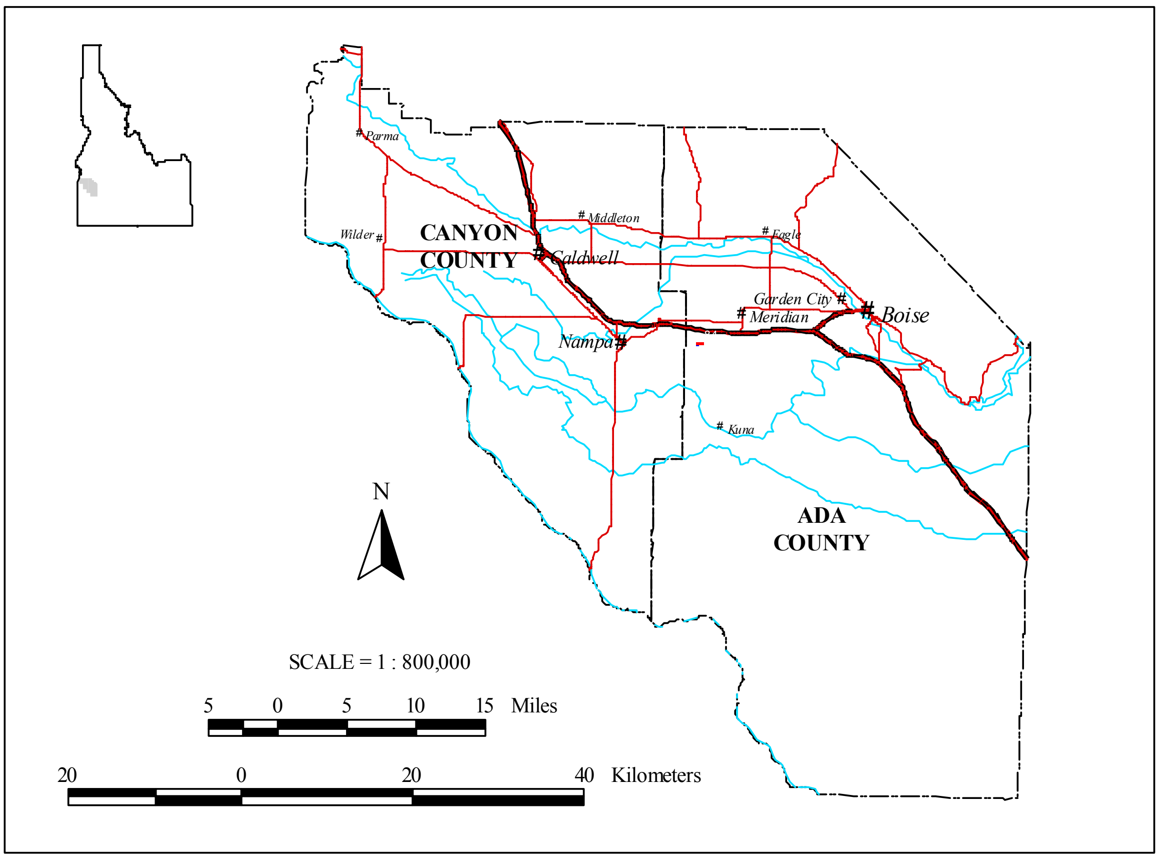

Figure 1. Area Map.

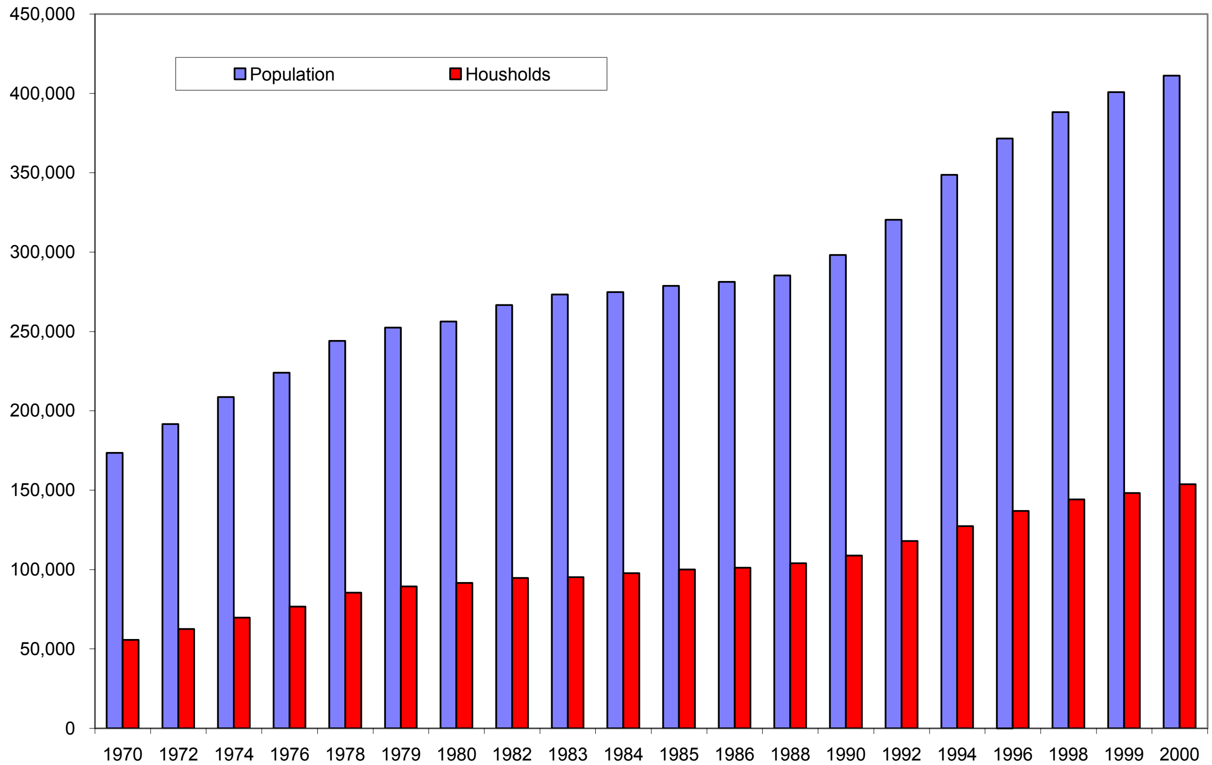

Figure 2. Population and Household Growth (Idaho Power, 2000).

Previous water demand estimates were based on broad assumptions and very general inventories. Estimates were last collected for the two-county area as part of the U.S. Geological Survey's (USGS) National Water Use Information Program (NWUIP) five-year compilation in 1995. For this project, a cooperative effort between the Ada Planning Association (APA), the USGS, the U.S. Bureau of Reclamation (USBR), and the Idaho Department of Water Resources (IDWR) was made to assess current domestic, commercial, municipal, and industrial (DCMI) water-use conditions and project future needs.

DCMI water demand estimates were calculated for the entire populations of Ada and Canyon counties. Major population centers within these counties are Boise, Caldwell, Eagle, Kuna, Meridian, Middleton, Nampa, and Star. An end-use, sector-based approach was adopted, similar to the approach of IWR-MAIN Water Demand forecasting model.[1] Water demand coefficients were calculated for all DCMI sectors: residential single-family, residential multi-family, municipal, commercial, and industrial. The coefficients were used to calculate water demand in the years 2000 to 2025 in five-year increments, using data from 1997 and 1998 as the baseline. Using the term residential to describe domestic water demand, sectors reflecting an end-use approach are residential single-family, residential multi-family (apartments and mobile homes), municipal, commercial, and industrial.

[1] This model is widely used throughout the country by planners to forecast future water use (Planning and Management Consultants Ltd., 1999)

The water estimates presented in this report represent diversionary quantities rather than consumptive quantities. Therefore, some of the water will be returned to the system. Transmission losses are not included (e.g., mainline leaks). Also, the estimates do not reflect peak load demand. Hence, they cannot be used to determine required capacity for water providers.

The water estimates do not include agricultural water demand, which was outside the scope of this study. Nevertheless, these estimates are important and should be included in future studies. Work is currently planned for a study of future agricultural water demand as part of the Boise River Basin Comprehensive Planning Process by IDWR.

In this report, the data, methodologies, coefficients, and baseline and forecast estimates of water demand are presented. The methodology used to estimate the coefficients for the residential single-family sector is more complex than that of the other sectors. Therefore, the methodology for the residential sector is described in Appendix A.

Data Assessment

Data on water use in the valley were gathered from sources best suited to provide both extensive and detailed information on the different sectors. United Water, Idaho (UWI), a privately held company that serves Boise and some surrounding areas, has a customer base and service area that encompasses the largest proportion of publicly supplied water users in the two-county study area (Figure 3). UWI provides water to about 76 percent of the population in this area.[2]

UWI provided records of use for all residential, commercial, and industrial customers. UWI follows the Public Utility Commission's (PUC) definitions of use in separating residential and commercial customers by purpose. Most importantly, this leads to a separation of rental-residential housing from residential owner-occupied housing. Rental-residential housing is found in UWI's commercial database and owner-occupied housing in its residential database. Households in this study were separated by end-use and therefore owner-occupied and rental-residential units were treated the same way, distinguishing only between single-family and multi-family units. A significant reorganization of UWI's database was therefore required. Water use information was also collected from the other municipalities in the area. Their data could not be used, however, because they were only available in an aggregated form.

For the single-family sector, a stratified random sample of 938 customers was chosen from a total single-family customer base of roughly 30,000. These were matched with property assessment records from the Ada County Tax Assessor's Office, which included information on a variety of house and lot characteristics.

Weather data were collected from the National Oceanic and Atmospheric Administration (NOAA). The NOAA provided temperature and precipitation values for the period from January 1997 to December 1998. No data on surface water irrigation use or private well use were available for single-family residential customers.

[2] Compiled by EPA in its Drinking Water Industrial Municipal System database.

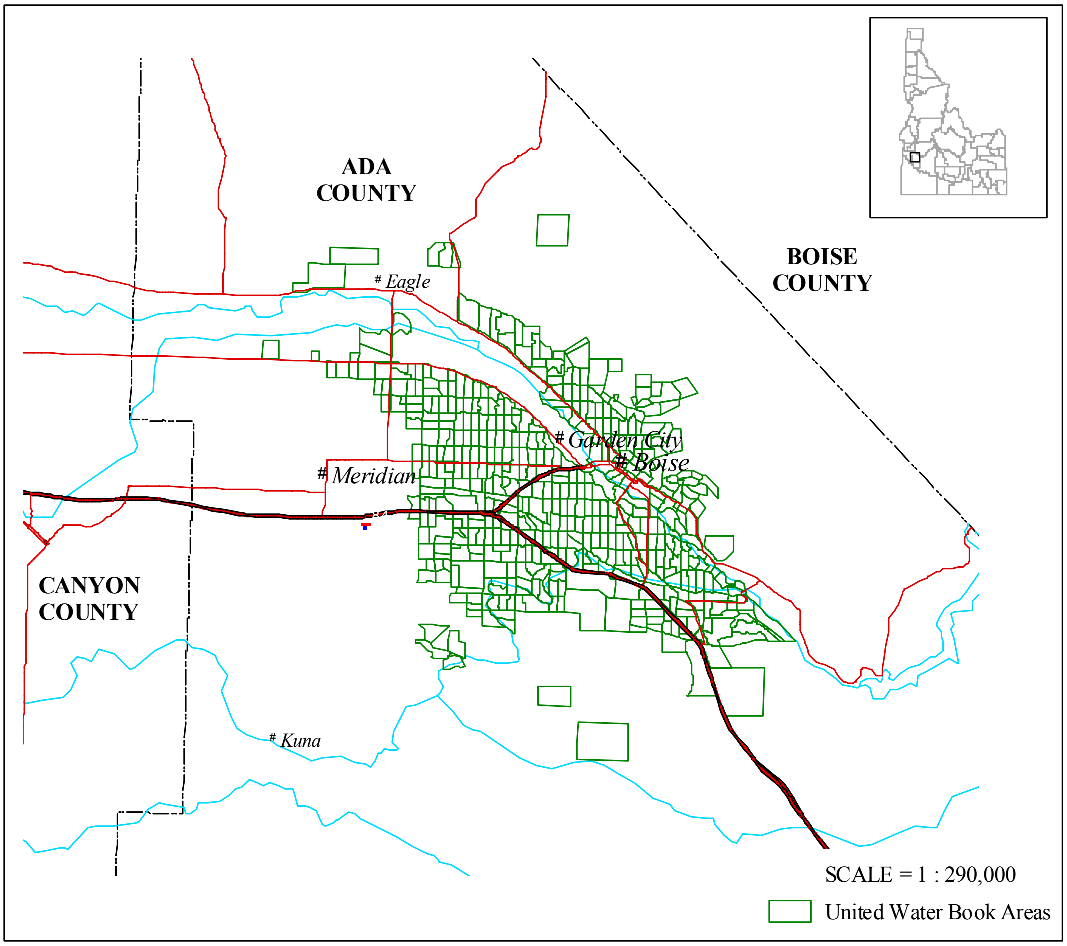

Figure 3. Service area for United Water, Idaho (United Water, Idaho, 2000).

For the multi-family sector, virtually all apartment complexes and mobile home parks in the UWI records were used to estimate water demand. These records were matched with information on the number of units in each complex/park from the Ada County Tax Assessor's Office. No data on surface water irrigation use or private well use were available for multi-family residential customers.

For the commercial, industrial, and municipal sectors, a subset of customers within the UWI service area was matched with Idaho State Department of Labor (IDOL) employment records. Records from about 1,095 establishments were included in the data set from which commercial, industrial, and municipal water demand coefficients were derived.

Information on additional water use by private well commercial and industrial users was collected by Community Planning Association (COMPASS), a regional planning authority. COMPASS surveyed establishments with records of current groundwater use to ascertain if the establishments use water from groundwater sources, and if they did, whether there was a record of how much water was withdrawn. The survey provided few instances where establishments were measuring withdrawals or could approximate how much was being pumped. Some limited information on private well use was available from IDWR and was used where available. No primary data on surface water irrigation use were available for commercial and industrial users.

Residential Water Demand

The vast majority of residences in Ada and Canyon counties receive potable water from a public water system. In 1997, roughly 260,000, or 97 percent of Ada County's population, received water from a public water system. The largest public water system, United Water, Idaho, provides water to 72 percent of the Ada County population and if the public supply facilities of Meridian, Kuna, Garden City, and Eagle are added, the percentage relying on public supply systems in Ada County increases to nearly 95 percent. Canyon County has a smaller population than Ada County and a smaller proportion of its population in 1997 (60 percent or 70,200 persons) on public supply. The publicly supplied population in Canyon County typically live in Nampa, Caldwell, Middleton, Parma, or Wilder. The remainder of the population in the two counties is self-supplied, which means that they are not served by a public water system, but by individual or community wells.

Many households on public water systems are also served by surface or well water for irrigation purposes. These are commonly referred to as "dual users." We would expect dual users to use the public system for indoor water demand and the well or surface water system for outdoor demand, since surface water from the latter is not potable and relatively inexpensive from the point of view of the customer. Households having access to surface water systems include some older subdivisions. These households take their water directly from ditches and are likely to use flood irrigation systems to distribute water. Newer subdivisions that have access to surface irrigation water typically operate pressurized irrigation systems that use sprinklers to distribute water.

Water demand from households is expected to vary by residential sector. The size of these sectors was estimated for this study using 1990 census data.[3] In Ada County, about 70 percent of the 100,000 households are estimated to be single-family dwellings. The remainder is multi-family units. Apartments account for approximately 23 percent of households, and mobile homes for 9 percent. In Canyon County, about 70 percent of the 40,000 households are single-family residences. However, there are proportionately fewer apartments and more mobile homes in Canyon County than in Ada County. In Canyon County, 13 percent of households are apartments and 15 percent are mobile homes.

A small number of the single-family households included in the residential totals are connected to farms or farm activities. While it was important to exclude agricultural water demand from the residential calculation of single-family homes, their indoor and lawn irrigation use should be included. This was achieved by including them in the estimates of total households, but excluding them from the calculation of average acreage.

Many of the explanatory factors affecting residential water demand reflect choices made by households. Household choices are constrained by expenses that they face and the income they receive. External factors affecting water demand are weather variables such as precipitation and temperature. The choices made by households and the income constraint they face are captured in variables that describe house and household characteristics. Weather and price information is common to all households within a defined area and would be included in a model of household water demand that is projected through time.

[3] The 2000 census numbers were unavailable for this study.

Single-Family Residential

The explanatory factors or variables explaining single-family household water demand are incorporated into two models of residential water demand. One is a model of individual household demand. The second is a model of aggregate residential water demand. Coefficients estimated by these models measure the effect of the variables on water demand. Using data on publicly supplied water to households, the model of individual household demand estimates the effect of lot size, household size, house characteristics, and weather on water use. The model of aggregate residential demand estimates the effect of price on water use. In combination, these two models are used to estimate baseline water demand. A third model, used for forecasting, uses the coefficients derived in the first two models, (along with present and forecasted values of the independent variables), to forecast future water demand. Details of these models and the data they employ are presented in Appendix A.

Multi-Family Residential

Multi-family units are a mix of rentals and owner-occupied dwellings. Some units pay directly for the water they use indoors; others pay indirectly through a rental charge. Even if households are owner-occupiers, managers rather than households typically make day-to-day decisions about outdoor water use due to the communal nature of the property. Hence, in multi-family units, the characteristics of the residents are not likely to explain water demand very well. Instead, a single indicator of demand was selected, the most appropriate being the number of households in a housing complex. This standard approach is called a “unit use” approach. Under this approach, all United Water, Idaho multi-family accounts were grouped into individual complexes (apartments and mobile home parks) and matched with information provided by the Ada County Tax Assessor’s Office on the number of units in each complex/mobile home park.

Additional surface irrigation water demand by dual users was not included for two reasons. First, there was a lack of data; and second, there are many apartment complexes and mobile home parks that have little or no lawn area and would not be expected to use surface water. In addition, no adjustment was made for 1997 and 1998 not being “normal” years, that is, years in which temperature and precipitation did not reflect their long run averages.

Information was insufficient to project future proportions of single-family and multi-family residences. The proportion of single-family residences is related to interest rates, reflecting the public’s tendency to purchase single-family homes when interest rates are low, and rent apartments when interest rates are high. This proportion is difficult to predict but is likely to be cyclical. Therefore, a simple assumption was made that the proportions of dwellings in each category would remain the same over time.

Total Residential Water Demand

Estimates of current and future water demand for the single-family and multi-family residential sector are presented in Table 1. In 1997 and 1998, a total of 16.6 billion gallons were demanded annually in the two counties by single-family residences, 2.2 billion gallons by apartments and 2.0 billion gallons by mobile homes. Comparing single-family water demand in the two counties, Ada County was greater for two reasons; (1) the greater absolute number of single-family households; and, (2) higher incomes in Ada County compared to Canyon County. These factors more than compensate for the larger average lot sizes in Canyon County.

Table 1. Baseline and Forecasted Residential Water Demand in Ada and Canyon Counties (Millions of Gallons per Year).

	Single Family Residential			Apartments			Mobile Homes		
	Ada	**Canyon**	**Total**	**Ada**	**Canyon**	**Total**	**Ada**	**Canyon**	**Total**
1997/98	11,743	4,831	16,575	1,759	408	2,167	1,269	763	2,032
2000	13,327	5,624	18,951	1,986	476	2,461	1,433	889	2,322
2005	15,040	6,461	21,502	2,231	548	2,779	1,610	1,023	2,633
2010	17,384	7,331	24,715	2,563	621	3,184	1,849	1,160	3,010
2015	19,722	8,252	27,974	2,892	700	3,592	2,087	1,308	3,395
2020	20,335	9,200	29,536	2,963	767	3,730	2,138	1,433	3,571
2025	21,050	9,944	30,994	3,035	841	3,876	2,190	1,571	3,761

Single-family residences demand more water than multi-family residences in either county, on average and in total. On average, a single-family household demands 194 gallons per person per day whereas apartments demand 82 gallons per person per day and mobile homes demand 150 gallons per person per day. Over 50 percent of the single-family demand was estimated to be for outdoor demand.

The simple forecast assumption of constant proportions of multi and single-family dwellings guarantees that the pattern of water demand between the three groups persists through time. Single-family water demand increases to 31.0 billion, apartments to 3.9 billion and mobile homes to 3.8 billion gallons annually by 2025**.**

Commercial, Municipal and Industrial Water Demand

Water demand varies by type of establishment. For example, the water demand of a concrete manufacturing facility will be very different from that of a furniture store. In general, differences in water demand among establishments reflect the type of goods or service being produced. Another indicator of water demand by establishments is the number of people they employ, reflecting size of the operation. In many studies, the number of employees has been found to be highly correlated with water demand and may, in a unit use approach, be used to estimate a water demand coefficient for a group of establishments.[4]

Over the 1997 to 1998 period, the total number of employees in Ada and Canyon counties averaged about 193,310 persons, with 78 percent employed in Ada County (approximately 151,560). Out of a total of 16,347 establishments in the two-county area, 78 percent or 12,771 were in Ada County. A breakdown of employment for the two counties shows that most people in both counties worked in services, manufacturing, and retail trade (Table 2). The three categories combined accounted for 67 percent of total employment in the two counties, with 67 and 69 percent of total county-level employment in Ada and Canyon counties, respectively.

[4] Examples are Dziegielewski et al, 1998, Adams 1991, Mercer et al., 1973 and McCuen, 1975.

Table 2. Average Annual (1997-1998) Employees by Major SIC Categories, Ranked for Each County (Idaho Department of Labor, 1999).

County	Major Category	Average # of Employees	Rank
Ada	Agriculture, Forestry, and Fishing	1,570	9
	Mining	80	10
	Construction	10,520	5
	Manufacturing	23,920	3
	Transportation and Public Utilities	8,690	8
	Wholesale Trade	9,190	6
	Retail Trade	28,230	2
	Finance, Insurance, and Real-estate	9,010	7
	Services	49,050	1
	Public Admin	11,300	4
Canyon	Agriculture, Forestry, and Fishing	3,320	4
	Mining	40	10
	Construction	2,900	5
	Manufacturing	11,240	1
	Transportation and Public Utilities	2,020	6
	Wholesale Trade	1,850	7
	Retail Trade	6,800	3
	Finance, Insurance, and Real-estate	1,140	9
	Services	10,670	2
	Public Admin	1,770	8

For the purpose of this study, Standard Industrialization Classifications (SIC Codes) were used to organize establishments into groups. For example, the one-digit SIC code 3 includes all manufacturing, two-digit SIC code 36 includes non-computer electronics and 3674 includes only semiconductors. For a list of two-digit codes, see Appendix B (U.S. Census, 2001).

Using data from 1997 and 1998, a water demand coefficient is calculated for SIC code groups at each 1, 2 and 4-digit level of aggregation. These water demand coefficients are ratios of water to employees, and each represents the amount of water demand per employee to produce products or supply services within a SIC group. Estimated current and future water demand for the group is obtained by multiplying the ratios by estimated current and future employment. The following sections describe the data sets and methods used to calculate the coefficients and current and future water demand.

Databases

Primarily two sets of data are used to calculate annual water demand coefficients. The first data, from the Idaho Department of Labor, contain monthly counts of employees for establishments covered by unemployment insurance during 1997 and 1998. The second data, from billing records of United Water Idaho, contain bimonthly water usage during 1997 and 1998 for all commercial, municipal, and industrial accounts in their service area. The two sets of data were matched and their data linked using business name and address. The composite data contains a single record for establishments, with annual values for 1997 and 1998 on employees and water usage. All matchable establishments were included in the sample.

The sample was not selected by a stratified random method. Therefore, it is important to ensure that it reflects the character of each SIC group. Overall, the category of retailers in malls tends to be underrepresented. Large malls could not be included in the sample because establishments were not individually metered. Since malls tend to have relatively small per-unit outdoor water demand, summer water demand in the retail group may be over-represented. Large and medium size malls are a relatively small proportion of the overall retail group, however, so this effect may be small.

Overall, the sample represents 58,200 (38 percent) of the estimated 151,560 employees in Ada County, and 1,095 (8 percent), of the estimated 12,771 establishments. The representation of employment and establishments in the three largest sectors (largest by employment) are shown in Table 3.

Table 3. Employment Characteristics of the Composite Data Set.

Category	**Ada County**		**Composite Data Set**		**Percentage**	
	Establishment	**Employment**	**Establishment**	**Employment**	**Establishment**	**Employment**
Services	4,329	49,050	276	21,130	6.3	43.0
Retail Trade	2,199	28,230	337	4,103	15.9	14.5
Manufacturing	495	23,920	60	17,389	10.7	72.6

Table 3 shows that all three sectors are generally well represented in the sample when measured by employment or number of establishments. A large proportion of employment (43 percent) and the smallest proportion of establishments (6.3 percent) represent the service sector. The smallest proportion of employment (14 percent) and the largest proportion of establishments (15 percent) represent the retail sector. The largest proportion of employees (72 percent) and 10 percent of establishments represent the manufacturing sector.[5]

At the sub-sector level, there are very small sample sizes in some cases. In these cases, a one-digit coefficient was used to represent the sub-sector. The Idaho Department of Labor data, used to estimate the coefficients, seriously underestimate employment by the number of self-employed and voluntary workers in some sub-sectors. Self-employed workers typically work at home and are therefore counted in the residential sector. Voluntary workers typically do not work at home and need to be accounted for in the commercial sector. On investigation, it became clear that employment in some SIC groups was under-represented because of the omission of voluntary workers in the data. An attempt to find other sources of data was made where sample sizes were inadequate. More aggregate data from Census Business Patterns were substituted for Idaho Department of Labor data in these cases (U.S. Census, 1998).

Some establishments obtain water from private wells. This information needed to be gathered and used to supplement the data from United Water, Idaho. Establishments with private wells were

[5] Canyon County employment is not included in this discussion. They represent a relatively small proportion of Municipal, Commercial and Industrial users.

identified using information from a database maintained by the Idaho Department of Water Resources (IDWR) on water right holders. A search was conducted to identify holders of ground water rights. COMPASS surveyed large and small establishments by phone. They were asked about the amount of water they pump. Because of the poor quality of the responses to the survey, however, these data were not used. However, some ancillary data were available from the annual reporting of private well water use required by the Southeast Boise Ground Water District. For outdoor demand of wells by schools and parks, other data were collected directly from the municipalities. Despite efforts directed towards collecting groundwater data, groundwater is a source of under-estimation in the estimates of total water demand.

While Idaho Department of Labor data were used to match employment records, more complete aggregated data are used to compute baseline and future water demand. Employment data by one and two-digit SIC codes for all baseline and future years were estimated by Idaho Economics Inc., using data from U.S. Census Business Patterns (U.S. Census, 1998).

Methods

Water demand employment coefficients were calculated for SIC code groups of establishments at one, two, and four-digit levels. The unit use approach to coefficient estimation is a standard technique for estimating water demand of commercial establishments.[6]

The calculations are performed at the level of the individual employee rather than the level of the establishment. Using *i* to represent a SIC group and *j* to represent the level of the group, the method of calculating the coefficients is described as follows: initially, all water use and establishment data in groups *ij* are converted from monthly totals to annual averages. Average water use and employment in group *ij* is then summed separately and summed average water use is divided by summed average employment for group *ij*.

This method of aggregation is weighted by employee rather than by individual establishment. It compensates for the skewness in the distribution of per employee rates of water use in the sample of individual establishments. In our sample of individual establishments, distribution of water use was skewed to the right implying that weighting by establishment rather than employees would result in higher water demand estimates.

Complete sets of coefficients were computed for the one, two, and fourth-digit levels. For the most part, coefficients from the one and two-digit level of aggregation were selected to generate baseline estimates and forecasts. The other coefficients were computed primarily for comparison and completeness. Ideally, the choice of level of disaggregation depends on the variability of water use within a group and the relative magnitude of the water use of a group within the sample. The larger the variation, the more disaggregated the groups need to be. The larger the water use, the more important it is for the group to be represented. These goals were largely achieved, within the constraints of data availability and time.

Different procedures and data are used to calculate coefficients for groups where the number of matched establishments was insufficient. These include fire stations, churches, the Boise airport,

[6] The IWR-Main model (IWR-MAIN, 1999) is a widely used model for water demand forecasting. It uses this method to compute coefficients for multifamily and commercial establishments.

the Gowen Field military installation, and outdoor water demand at parks, schools, and golf courses.

In the case of churches, fire stations, the airport, and the Gowen Field military installation, the entire United Water customer base for group *ij*, rather than the sample, is compared with aggregate employment data for group *ij*. For churches (SIC 8661) and fire stations (SIC 9224), annual water use for all United Water customers were grouped into establishments and divided by the number of establishments in the sample to obtain average water use per establishment in group *ij*. This number is then divided by average employment per establishment, computed with data from Census Business Patterns. For the airport (SIC 4581) and the military (SIC 9711), summed water use from all accounts is simply divided by estimates of annual employment collected from phone surveys.[7]

Outdoor water demand in parks, schools, and golf courses was treated as a residual category outside the SIC classifications because they could not be meaningfully combined with employment data. Instead, a water demand irrigation coefficient was developed on a per acre basis and combined with estimates of total acreage in the counties to calculate total annual water demand directly. In these efforts, care was taken to avoid double counting by making sure institutions were not represented twice. Indoor use was captured in SIC 79 for golf courses and SIC 82 for schools.
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Some adjustments to the coefficients or to baseline and projected future estimates were made to include sources of water other than publicly supplied water. In some cases, the groundwater data were added to the United Water data before the water demand coefficients were computed. In other cases, notably for outdoor demand by schools and parks, groundwater data was treated as a residual component outside the SIC classification system.[8]

Surface water demand is not included in commercial estimates implicitly or explicitly. The only exception is for outdoor demand for water by schools and parks, which use a combination of ground and surface water for irrigation. The method used to estimate surface water demand for residential consumers was based on the assumption that, for the most part, the difference between winter and summer demand is outdoor demand. This is not a reasonable assumption for commercial users. Many firms use water as an input to the production of a good or service on a seasonal basis, that is, in the summer only (for example, nurseries). In addition, many businesses, unlike residences, do not have an outdoor water demand. Downtown Boise businesses are less likely to irrigate and are more likely to use groundwater if they do. In any case, it would be very difficult to distinguish between these and surface water users. They would have the same winter - summer water profile.

To forecast future demand for residual categories such as schools, parks, and golf courses, a simple assumption was made that water demand would grow from its current base at half the rate that population grows. A growth rate equal to population growth would be too great, particularly in Ada County where major municipal parks have already been established.

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[7] These were conducted by Molly Maupin (USGS, 1999).

[8] In one case, it was necessary to add groundwater use by one firm in addition to what was estimated for its SIC code category. The number of employees was not known for this firm which would have led to an unreliable coefficient. Since groundwater is an additional source of water this should not lead to an overestimate of use.

Results

Water demand estimates for the commercial, municipal, and industrial sectors are presented in this section. Since the two-digit method of aggregation (using mostly two-digit SIC codes) was chosen for computing the final estimates and forecasts, the results of this effort are discussed first. Results using only the first digit method are discussed subsequently for the purpose of comparison.

Baseline and forecasted estimates of water demand using two-digit SIC coefficients are presented in Table 4 for "groups" at the one-digit level and "sub-groups" at the two-digit level. Baseline results are discussed first, followed by forecasted results. Corresponding baseline and forecasts of employment are presented in Table 5. At the one-digit level, manufacturing has the highest baseline water demand, 5.8 million gallons per day (MGPD), followed closely by services, 5.0 MGPD, then government, 4.0 MGPD and retail, 3.3 MGPD. If the residual demand estimates for parks, schools, and public golf courses are included in the government sector, government increases by approximately 10 MGPD, becoming the largest sector in terms of water demand. Services would increase by around 2 million because of the inclusion of residual demand for private golf courses. The remaining sectors: construction, transportation, communications, utilities, finance, insurance, and real estate are relatively small, demanding less than 2 MGPD combined.

For insight into the estimates, water use may be compared to employment but only at the one-digit level and if residual use is not included. Manufacturing has higher total water use but lower total employment levels and lower water demand coefficients, on average, than services. Inspection of the two sets of sub-groups in Tables 4 and 5 reveal that it is the different distribution of water use and employment among the sub-groups that cause this result. Within manufacturing, employment is concentrated in two sub-groups, both with large water demand coefficients. These are food and kindred products (SIC 20) and electronics other than computer equipment (SIC 36). These two sub-groups dominate the manufacturing group, accounting for approximately 85 percent of baseline water demand. In contrast, in the service group, employment is concentrated in the sub-groups of business services (SIC 73) and health (SIC 80), but water demand coefficients are relatively low for these sub-groups. Water demand is relatively low in the service group and more evenly spread out among the other sub-groups. This result is not surprising since in Idaho, more manufacturers than service providers may be expected to demand water directly in the manufacture of a product as well as indirectly by employees or customers.

Other important one-digit level groups are government and retail. Even without the outdoor residual categories, the government is third highest in terms of water use, but fourth in terms of employment. Fire stations (SIC 92) are the highest water users in this group, using 3 MGPD, explaining this result. Other sub-groups are relatively small water users. Retail is the second highest sector for employment but only the fourth highest for water use. With the exception of nurseries (SIC 52), the retail group tends to use relatively little water since there are few production processes involved.

Table 4. Water Demand Coefficients, Baseline, and Forecasts.

SIC Codes	Coefficients	Baseline	Forecasted Water Demand (gallons per day)					
		1997/8	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
1-Construction								
15	71.87	138,709	154,521	166,020	176,082	189,018	201,955	214,173
16	24.63	119,086	132,509	142,361	151,475	162,558	173,888	183,986
17	15.5	105,633	117,645	126,480	134,385	144,305	154,225	163,370
Total		**363,428**	**404,675**	**434,861**	**461,941**	**495,881**	**530,068**	**561,529**
2/3-Manufacture								
20	400.25	2,377,485	2,473,545	2,577,610	2,565,603	2,553,595	2,477,548	2,345,465
24	39.64	148,254	152,614	158,164	156,974	155,389	149,839	140,722
25	45.66	12,557	13,241	13,698	14,611	15,524	16,438	17,351
26	156.67	29,767	29,767	29,767	29,767	29,767	29,767	29,767
27	58.82	117,346	124,698	137,051	144,697	154,108	160,579	165,284
28	19.66	1,180	1,180	1,376	1,376	1,573	1,573	1,573
30	10.16	4,572	4,877	5,690	6,401	7,417	8,230	8,941
32	44.03	25,317	26,858	30,381	33,463	36,545	39,627	42,269
34	37.59	50,559	50,747	56,761	61,272	66,534	70,669	74,052
35	39.64	336,147	312,760	349,625	376,184	408,292	434,454	455,067
36	259.76	2,550,843	3,000,228	3,613,262	4,135,379	4,722,437	5,283,518	5,813,429
37	65.82	125,387	133,615	149,411	160,601	174,423	185,612	194,169
38	156.67	47,784	50,134	65,801	79,902	87,735	95,569	103,402
other	25.94	12,840	16,342	13,748	11,154	12,970	14,008	13,748
Total		**5,840,038**	**6,390,606**	**7,202,344**	**7,777,384**	**8,426,310**	**8,967,430**	**9,405,239**
4-TCU								
41	46.86	32,568	40,768	45,923	48,734	51,077	53,420	56,232
42	35.91	97,675	101,266	108,448	115,630	122,812	129,994	137,176
43	49.93	36,948	40,943	46,435	50,929	55,922	60,415	64,909
45	66.06	72,996	78,611	82,575	86,539	90,502	94,466	98,429
47	26.18	9,032	9,687	11,257	12,828	14,399	15,970	17,541
48	46.06	121,829	158,446	181,937	192,070	195,755	201,282	208,191
49	34.08	59,470	63,730	71,227	75,658	79,406	83,496	87,586
Total		**430,518**	**493,451**	**547,803**	**582,388**	**609,874**	**639,044**	**670,064**
5-W&Retail								
50	20.58	139,944	156,820	181,721	207,035	235,847	268,569	307,259
51	77.36	367,847	411,555	476,538	543,067	618,880	703,976	806,091
52	59.58	74,177	79,837	91,157	104,265	117,968	132,268	147,758
53	68.17	257,683	287,677	333,351	379,707	432,880	492,869	563,766
54	73.29	476,385	520,359	603,910	691,858	787,868	900,734	1,034,855
55	87.10	367,127	395,434	457,275	521,729	594,022	676,767	773,448
56	135.12	172,954	181,061	210,787	241,865	272,942	304,020	336,449
57	24.30	44,348	52,002	59,535	67,797	76,788	85,536	94,527
58	103.81	1,302,816	1,370,292	1,605,941	1,841,589	2,109,419	2,412,544	2,771,727
59	28.83	106,527	118,491	137,519	159,430	184,800	214,207	248,226
other	78.30	72,428	114,318	121,365	116,667	119,016	123,714	142,506
Total		**3,382,233**	**3,687,847**	**4,279,099**	**4,875,009**	**5,550,430**	**6,315,204**	**7,226,613**

Table 4. Water Demand Coefficients, Baseline, and Forecasts (Continued).

SIC Codes	Coefficients	Baseline	Forecasted Water Demand (gallons per day)					
			2000	2005	2010	2015	2020	2025
6-F,I&RE								
60	107.90	354,452	353,912	367,939	383,045	399,230	418,652	440,232
61	31.92	29,366	32,558	36,389	40,538	45,646	50,753	56,179
63	76.71	114,298	125,037	136,544	150,352	164,927	177,967	189,474
65	313.20	535,572	607,608	657,720	720,360	786,132	842,508	880,092
67	56.51	180,832	198,915	209,652	222,649	237,342	250,339	265,597
Total		**1,214,520**	**1,318,031**	**1,408,244**	**1,516,944**	**1,633,276**	**1,740,219**	**1,831,574**
7/8-Services								
70	625.89	1,423,900	1,527,172	1,783,787	2,071,696	2,390,900	2,710,104	3,073,120
72	126.34	298,162	323,430	382,810	447,244	521,784	606,432	696,133
73	23.15	285,440	315,303	372,484	438,693	517,403	608,845	715,104
75	153.34	314,347	348,082	417,085	496,822	587,292	683,896	794,301
76	23.76	23,879	27,799	33,026	38,966	45,857	53,222	61,301
78	56.39	31,860	33,834	37,217	40,601	43,984	47,932	52,443
79	104.24	185,547	195,971	224,116	254,346	286,660	320,017	352,331
80	61.24	906,046	977,390	1,168,459	1,387,086	1,616,124	1,869,045	2,142,788
81	1.29	1,774	1,871	2,180	2,541	2,954	3,431	3,986
82	137.65	295,948	323,478	377,161	439,104	512,058	594,648	689,627
83	167.58	745,731	821,142	958,558	1,116,083	1,300,421	1,496,489	1,716,019
86	117.16	330,977	363,196	439,350	516,676	599,859	687,729	775,599
87	56.15	189,226	211,686	251,552	297,034	348,130	404,842	467,168
Total		**5,032,836**	**5,470,353**	**6,447,785**	**7,546,889**	**8,773,425**	**10,086,632**	**11,539,919**
9-Govt								
91	7.96	10,467	11,542	11,781	12,418	13,134	13,930	14,726
92	416.41	3,489,516	3,839,300	3,910,090	4,126,623	4,363,977	4,622,151	4,901,146
93	86.77	9,111	9,545	10,412	10,412	11,280	12,148	13,016
94	52.07	680,815	738,873	833,120	919,556	1,002,868	1,086,701	1,164,806
95	18.81	11,192	12,415	12,603	13,355	14,108	14,860	15,800
96	22.37	91,605	100,889	102,678	108,271	114,534	121,469	128,628
97	143.25	389,640	428,318	436,913	459,833	487,050	515,700	547,215
99	86.77	3,471	4,339	4,339	4,339	4,339	4,339	5,206
Total		**4,685,817**	**5,145,220**	**5,321,935**	**5,654,806**	**6,011,290**	**6,391,297**	**6,790,542**
Total SIC(MGPD)		**20.9**	**22.9**	**25.6**	**28.4**	**31.5**	**34.7**	**38.0**
Total Annual Galls in SIC (mills)		**7,646.5**	**8,362.2**	**9,359.4**	**10,371.6**	**11,497.7**	**12,654.5**	**13,879.3**
Water Demand Not Included in SIC Categories								
24*		6,964	6,964	6,964	6,964	6,964	6,964	6,964
Misc.		13,125	13,125	13,125	13,125	13,125	13,125	13,125
Schools		1,262,070	1,336,081	1,423,784	1,526,774	1,624,464	1,660,820	1,698,814
Parks		6,521,832	6,903,790	7,356,970	7,889,141	8,393,921	8,581,782	8,778,104
Golf		4,329,992	4,584,167	4,885,082	5,238,448	5,573,625	5,698,366	5,828,725
Grand Total MGPD		**33.1**	**35.8**	**39.3**	**43.1**	**47.1**	**50.6**	**54.4**
Grand Total Annual Gallons (mills)		**12,075.4**	**13,050.3**	**14,354.7**	**15,727.8**	**17,196.1**	**18,480.3**	**19,838.2**

*Groundwater only

Table 5. Baseline and Forecasted Employment (Idaho Power, 2001).

SIC Codes	Baseline Employment		Forecasted Employment					
	1997	1998	2000	2005	2010	2015	2020	2025
1-Construction								
15	1920	1940	2150	2310	2450	2630	2810	2980
16	4810	4860	5380	5780	6150	6600	7060	7470
17	6780	6850	7590	8160	8670	9310	9950	10540
Total	**13510**	**13650**	**15,120**	**16,250**	**17,270**	**18,540**	**19,820**	**20,990**
2/3-Manufacture								
20	6030	5850	6180	6440	6410	6380	6190	5860
24	3700	3780	3850	3990	3960	3920	3780	3550
25	270	280	290	300	320	340	360	380
26	190	190	190	190	190	190	190	190
27	1960	2030	2120	2330	2460	2620	2730	2810
28	60	60	60	70	70	80	80	80
30	440	460	480	560	630	730	810	880
32	560	590	610	690	760	830	900	960
34	1320	1370	1350	1510	1630	1770	1880	1970
35	8380	8580	7890	8820	9490	10300	10960	11480
36	9180	10460	11550	13910	15920	20340	20340	22380
37	1830	1980	2030	2270	2440	2820	2820	2950
38	300	310	320	420	510	610	610	660
other	520	470	630	530	430	540	540	530
Total	**34740**	**36410**	**37,550**	**42,030**	**45,220**	**51,470**	**52,190**	**54,680**
4-TCU								
41	690	700	870	980	1040	1090	1140	1200
42	2700	2740	2820	3020	3220	3420	3620	3820
43	730	750	820	930	1020	1120	1210	1300
45	1080	1130	1190	1250	1310	1370	1430	1490
47	340	350	370	430	490	550	610	670
48	2390	2900	3440	3950	4170	4250	4370	4520
49	1700	1790	1870	2090	2220	2330	2450	2570
Total	**9630**	**10360**	**11,380**	**12,650**	**13,470**	**14,130**	**14,830**	**15,570**
5-W&Retail								
50	6630	6970	7620	8830	10060	11460	13050	14930
51	4750	4760	5320	6160	7020	8000	9100	10420
52	1200	1290	1340	1530	1750	1980	2220	2480
53	3600	3960	4220	4890	5570	6350	7230	8270
54	6400	6600	7100	8240	9440	10750	12290	14120
55	4120	4310	4540	5250	5990	6820	7770	8880
56	1270	1290	1340	1560	1790	2020	2250	2490
57	1700	1950	2140	2450	2790	3160	3520	3890
58	12400	12700	13200	15470	17740	20320	23240	26700
59	3590	3800	4110	4770	5530	6410	7430	8610
other	900	950	1.46	1550	1490	1520	1580	1820
Total	**46560**	**48580**	**50,931**	**60,700**	**69,170**	**78,790**	**89,680**	**102,610**

Table 5. Baseline and Forecasted Employment (Continued).

SIC Codes	Baseline Employment		Forecasted Employment					
	1997	1998	2000	2005	2010	2015	2020	2025
6-F,I&RE								
60	3,270	3,300	3,280	3,410	3,550	3,700	3,880	4,080
61	900	940	1,020	1,140	1,270	1,430	1,590	1,760
63	1,460	1,520	1,630	1,780	1,960	2,150	2,320	2,470
65	1,660	1,760	1,940	2,100	2,300	2,510	2,690	2,810
67	3,100	3,300	3,520	3,710	3,940	4,200	4,430	4,700
Total	**10,390**	**10,820**	**11,390**	**12,140**	**13,020**	**13,990**	**14,910**	**15,820**
7/8-Services								
70	2,240	2,310	2,440	2,850	3,310	3,820	4,330	4,910
72	2,310	2,410	2,560	3,030	3,540	4,130	4,800	5,510
73	12,120	12,540	13,620	16,090	18,950	22,350	26,300	30,890
75	2,000	2,100	2,270	2,720	3,240	3,830	4,460	5,180
76	970	1,040	1,170	1,390	1,640	1,930	2,240	2,580
78	560	570	600	660	720	780	850	930
79	1,770	1,790	1,880	2,150	2,440	2,750	3,070	3,380
80	14,460	15,130	15,960	19,080	22,650	26,390	30,520	34,990
81	1,360	1,390	1,450	1,690	1,970	2,290	2,660	3,090
82	2,100	2,200	2,350	2,740	3,190	3,720	4,320	5,010
83	4,300	4,600	4,900	5,720	6,660	7,760	8,930	10,240
86	2,770	2,880	3,100	3,750	4,410	5,120	5,870	6,620
87	3,200	3,540	3,770	4,480	5,290	6,200	7,210	8,320
Total	**50,160**	**52,500**	**56,070**	**66,350**	**78,010**	**91,070**	**105,560**	**121,650**
9-Govt								
91	1280	1350	1450	1480	1560	1650	1750	1850
92	8170	8590	9220	9390	9910	10480	11100	11770
93	100	110	110	120	120	130	140	150
94	12700	13450	14190	16000	17660	19260	20870	22370
95	580	610	660	670	710	750	790	840
96	3990	4200	4510	4590	4840	5120	5430	5750
97	2650	2790	2990	3050	3210	3400	3600	3820
99	40	40	50	50	50	50	50	60
Total	**29510**	**31140**	**33,180**	**35,350**	**38,060**	**40,840**	**43,730**	**46,610**

An illustration of the forecasted trend of water demand using the two-digit method of aggregation is presented in Figure 4. It shows changes in sector demand for the four largest sectors over the forecast period. Without the residual categories included, services demonstrate the largest increase in water demand over the period, followed by retail and wholesale. The increase in manufacturing water demand is moderate, initially, but then gets smaller towards the end of the period. Therefore, while manufacturing has the largest demands at the beginning of the period, services has the largest at the end.

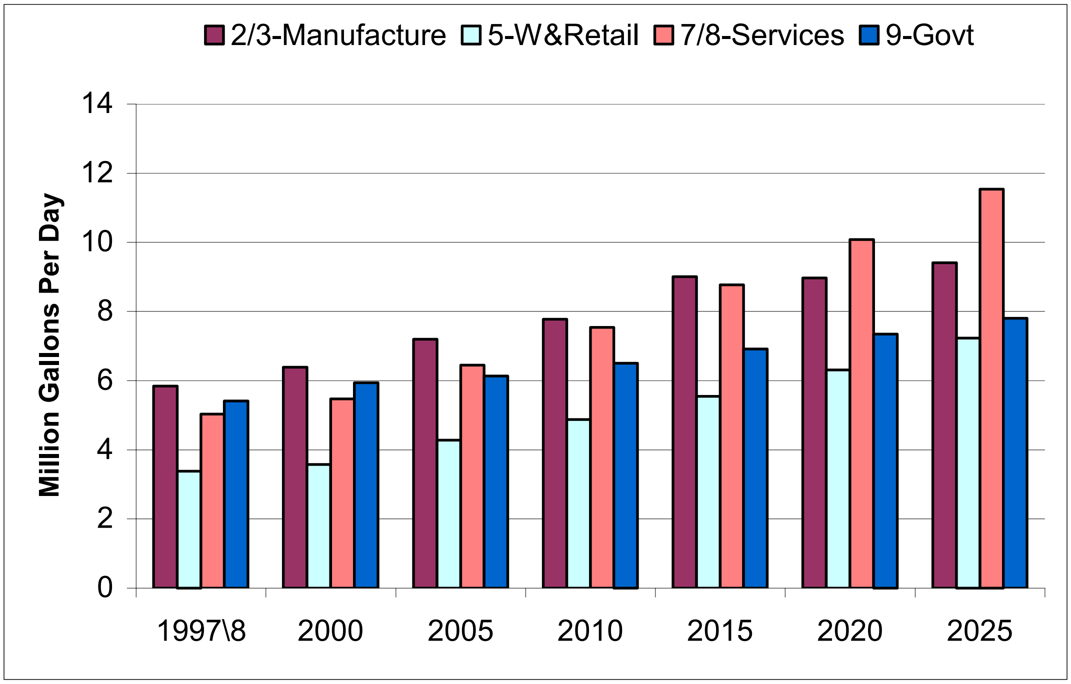

Figure 4. Commercial Water Demand Forecast for Ada and Canyon Counties, Idaho.

A comparison with the trend of employment by group in Table 5 reveals that the smaller increase in water demand in the manufacturing group is partly explained by the relatively small increase in employment in that group. This in turn is explained at the sub-group level. Observing the trend in the two largest manufacturing sub-groups in Table 5, employment in electronics other than computer equipment (SIC 36) more than doubles, while food and kindred products (SIC 20) declines slightly, dampening down the overall increase in the group.

Comparing the two methods of aggregation demonstrates similarities and differences between the two approaches. Baseline (1997/8) and forecasted estimates of water demand, estimated using one-digit coefficients only, are presented in Table 6. When measured by the one-digit code method (Table 6) total water demand is 22 million gallons per day in the baseline period and demand rises by 80 percent to 39 million gallons per day. In contrast, when measured using the two-digit aggregation procedure, water demand is 18 million per day during the baseline period and demand rises by 76 percent to 33 million per day (Table 4). While the percentage increases are similar, the baseline and forecast totals are significantly different. Retail, services and government sectors demonstrate the biggest differences.

Table 6. Water Use Estimated by One-Digit Coefficients (gallons per day).

Year	1997/8	2000	2005	2010	2015	2020	2025
Manufacture	5,581,604	5,882,959	6,581,707	7,083,051	7,683,097	8,173,474	8,565,149
Construction	337,657	366,600	393,738	418,452	449,467	480,239	508,588
TCU*	487,017	565,707	633,612	672,557	705,012	739,963	776,911
Wholesale&Retail	2,984,268	3,291,664	4,346,579	4,346,579	4,949,747	5,633,966	6,446,358
F,I&RE**	1,602,153	1,508,220	1,607,445	1,722,546	1,850,877	1,972,593	2,092,986
Services	3,510,703	3,884,958	4,597,362	5,406,786	6,311,151	7,315,308	8,430,345
Government	2,656,116	2,877,293	3,066,452	3,301,599	3,542,819	3,792,717	4,042,614
Total	18,516,811	18,377,400	21,226,894	22,951,570	25,492,169	28,108,259	30,862,951
Annual (millions)	6,759	6,708	7,748	8,377	9,305	10,260	11,265

*Transportation, Construction and Utilities
**Finance, Insurance and Real Estate

Conclusions and Recommendations

In total, baseline water demand in 1997 and 1998 is estimated at around 33.6 billion gallons per year (Table 7). By 2025, water demand rises to 58.5 billion, a 74 percent increase. Residential water demand rises by more than commercial demand, 79 percent compared with 64 percent. As a result, there is a slight increase in the ratio of residential water demand to commercial water demand during the period (from 64 percent to 66 percent).

Table 7. Baseline and Forecasted Water Demand by Sector (millions of gallons per year).

Year	Residential Ada	Residential Canyon	Residential Total	Total CMI	Total DCMI	Percent Residential
1998	14,771	6,796	21,567	12,075	33,642	64%
2000	16,745	7,827	24,572	13,050	37,622	65%
2005	18,880	8,902	27,783	14,354	42,137	66%
2010	21,796	10,034	31,830	15,727	47,557	67%
2015	24,701	11,208	35,909	17,196	53,105	68%
2020	25,436	12,145	37,581	18,480	56,061	67%
2025	26,276	12,356	38,632	19,838	58,470	66%
%change	78%	82%	79%	64%	74%	

CMI = Commercial, Municipal and Industrial
DCMI = Domestic (Residential), Commercial, Municipal and Industrial

These results are illustrated in Figure 5. The pattern of residential demand in the two counties rises steeply at first, but its path flattens out between 2015 and 2025. This is mainly caused by the reduced rate of population increase in Ada County in the last part of the forecast period, which is somewhat, but not entirely, offset by the increase in the rate of growth in Canyon County. It is thought that Ada County will be sufficiently “filled in” by that time.

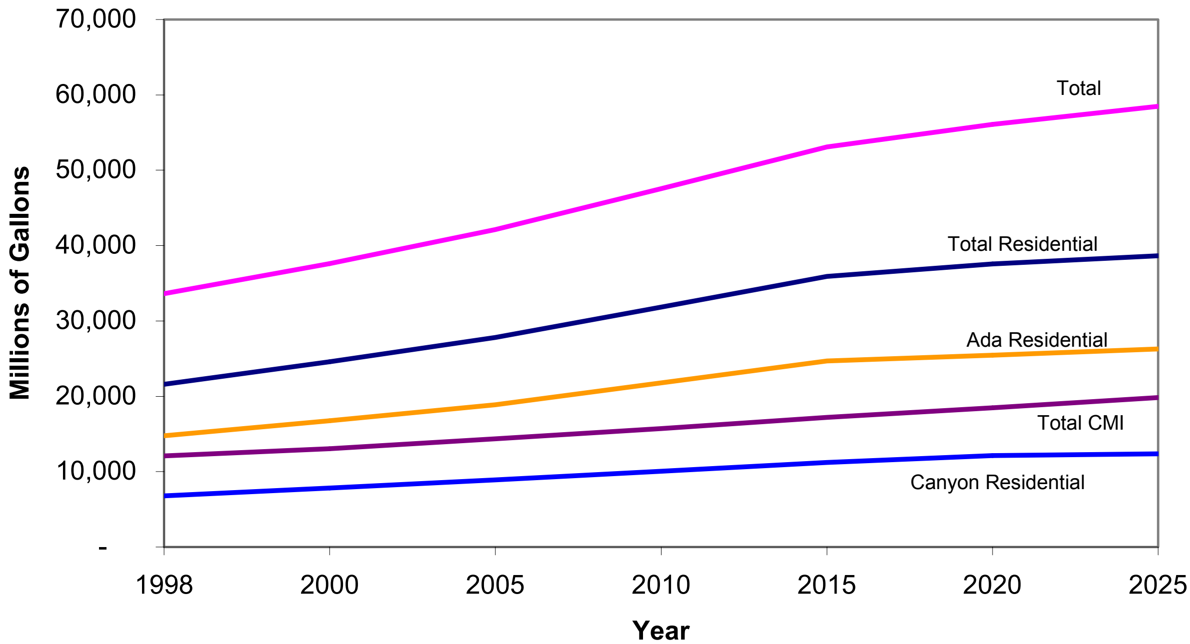

Figure 5. Water Demand Forecasts

Data deficiencies may reduce confidence in the commercial results. Most important is the lack of data on groundwater and surface water use by commercial users. Our inability to collect reliable data on both groundwater and surface water use by all commercial users in the area and our inability to estimate use using alternative methods leads to a probable underestimation of commercial water demand. These sources of underestimation affect baseline and forecasted water demand.

There are also sources of underestimation in residential demand. The main source of underestimation is in well and surface water demand because it was estimated with data on publicly provided water use without adjusting for the differences in prices. Publicly provided households face a higher price for additional water than self-supplied ground or surface water households and are therefore expected to use less water. The price coefficient estimated for this study was inadequate to address this problem.

The residential model results demonstrate that socio-economic variables like income, density, and to a lessor extent, price, are important determinants of water demand. Their computed coefficients demonstrate that a significant change in their values would affect water demand noticeably. A recent study by United Water, Idaho suggests a much higher price effect on demand than the one reported here.[9] Moreover, while it has been assumed that average water prices will keep up with inflation, price may actually decline for some households, which could result in increased water use. The proportion of irrigation users is expected to increase through time as new residential

[9] Idaho Economics recently calculated this coefficient for United Water, Idaho.

developments located close to irrigation canals install pressurized irrigation systems. This reduces summer demand for public supply systems and changes the incremental price users face for their summer irrigation water to zero, in many cases eliminating any incentive for conservation.

Income, density, and price are not expected to change significantly over the next 25 years; therefore, the dominant variable affecting water demand is population growth. The trend in water demand follows the trend in population for the most part. Because population was such an important factor, the results of this study using 1997 population estimates were compared with results from the recently obtained 2001 estimates.[10] Using the 2001 population projections, water demand in 2025 increases to 65.0 billion rather than 58.5 billion, a difference of 20 percent.

One variable that might be expected to change its value is weather. Normal weather has been assumed for the forecast period. Warming and cooling trends may increase or decrease water demand respectively.

In conclusion, water demand is likely to follow population trends if the factors that influence water demand the most (weather, income, and price) do not change significantly during the forecasted period. In our forecasts, none of these are expected to change substantially. However, this conclusion also assumes no improvement in water saving technologies, and that households do not change their behavior in any significant way (e.g., in response to an increase in education on water conservation). Some preliminary work was done for this study to measure the effect of passive indoor conservation, (i.e., "automatic" conversion of household appliances to low flow, following the Energy Conservation Act of 1992 that required their production). Passive conservation provided only a five percent decrease in water demand.

With exception of United Water, Idaho, public water providers were unable to provide any sort of individual customer data for this study. It is recommended that companies make this data available. Also, United Water and other utilities in the area follow the Public Utility Commission's categories by defining customers by commercial and residential purpose rather than use. This leads to rental-residential housing in the commercial database and owner-occupied housing in the residential database. An end-use approach to water forecasting requires treating rental and owner- occupied units the same. Therefore, United Water, Idaho and other water providers in the area, at a minimum, should add a column to their databases indicating the type of customer.

There are no reporting requirements for irrigation companies, for example, at the level of a diversion for a community irrigation system. An effort should be made to encourage them to cooperate in water measurement efforts. Finally, groundwater data need to be collected on a regular and consistent basis from commercial establishments and an effort made to monitor domestic well use.

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[10] These latest (2001) estimates are from Idaho Economics, the 1997 estimates were from COMPASS.

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Glossary

Commercial water use. Water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. The water may be obtained from a public supply or may be self supplied. *See also* public supply and self-supplied water.

Consumptive use. That part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.

Diversionary use. Total water withdrawn.

Domestic water use. Water for household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. Also called residential water use. The water may be obtained from a public water supply or may be self supplied. *See also* public supply and self-supplied water.

Double Log specification. Double log specification is one where both the dependent and an independent variable are transformed into logs. (Greene W. 1990).

Dual users. Households using both a public water system and either a private irrigation system or private well.

Durban Watson statistic. A test performed to check for serial correlation of the error terms. (Greene W. 1990).

Elasticity. The percentage change in the dependent variable that results from a one-percentage change in an independent variable.

Fixed charge. A charge levied which is independent of amount used.

Groundwater. Generally all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone (a zone in which all voids are filled with water).

Household. A household includes all persons who occupy a housing unit. A housing unit is a house, an apartment, a mobile home, a group of rooms, or a single room that is occupied as separate living quarters.

Heteroscedasticity. A problem associated with the error term in the estimated regression equation in cross section analysis, where the errors associated with each observation have different variances. Typically, the variance is proportional to one of the independent variables, making the observations with the larger variances less reliable than the ones with the smaller variance. (Greene W. 1990).

Incremental price. A price which is charged per unit of use.

Industrial water use. Water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining. The water may be obtained from a public supply or may be self supplied. *See also* public supply and self-supplied water.

Multicoliniarity. A problem associated with the independent variables where two or more are highly correlated with each other, i.e. not independent. The resulting coefficients will not be reliable. See Bibliography (Greene W. 1990).

Ordinary least squares method of estimation. See Bibliography (Greene W. 1990).

Public water supply. Water withdrawn by public and private water suppliers and delivered to users (USGS definition). A system that serves 25 people or has 15 or more connections (EPA definition). Public suppliers provide water for a variety of demands, such as domestic, commercial, thermoelectric power, industrial, and municipal water demand.

Residential water use. S*ee* domestic water use.

Self-supplied water. Water withdrawn from a surface or groundwater source rather than being obtained from a public supply.

Semi Log specification. Semi log specification is one where an independent variable is transformed into logs. See Bibliography (Greene W. 1990).

Serial correlation. Serial correlation is a problem associated with the error term in the estimated regression equation in time series analysis, where the errors associated with each observation are correlated with one or more of its previous values instead of being independent of them. The estimated regression equation tends to be a poor estimate of the true regression line in this case. See Bibliography (Greene W. 1990).

Skewness. A distribution which is non-normal shaped.

Standard industrial classification (SIC) codes. Four-digit codes established by the Office of Management and Budget and used in the classification of establishments by type of activity in which they are engaged.

Stratified Random Sample. A sampling method that divides the sample into subgroups and takes the same number of sample points from each group.

Surface water. An open body of water, such as a stream or a lake.

Water demand. The relationship between the quantity of water demanded by consumers, water price, characteristics of water users and other factors. In this report the term “water demand” is used to refer to the model or conceptual framework and the term “water use” to data describing actual use. Total water demand refers to the combination of demands for self-supplied withdrawals and public-supply deliveries.

Appendix A:

Estimating Current and Future Single Family Residential Water Demand

Theoretical and Empirical Models of Water Demand

The demand for water, *w*, by an average residential household is typically described by the following equation or function:

$$w = f(p; y, d, g, k, v)$$

where: *p*= price, *y* = income, *d* = residential density, *g* = tastes, *k* = persons per household and *v* = weather.

This general approach has been tested and used for forecasting water demand extensively.[11] Two econometric models were developed to estimate the coefficients used to generate baseline and forecasting estimates. The first econometric model uses pooled data and may in general be described as follows:

Model I: $$W_{it} = \alpha + \chi Y_i + \delta G_i + \varsigma D_i + \phi K_i + \gamma V_t + \tau I_i + \psi X_{it} + \varepsilon_{it}$$

where water demand is for household *i* using the public supply system for twelve bi-monthly
periods *t*, between January 1997 and December 1998,
the variables *Y, G, D, K* and V represent income, tastes, density, persons per household and weather,
variable I represents customers of more than one water supply system,
variable X is a binary variable representing part of the residual component of water use,
The variables *Y, G, D, K* and *I* vary by household *i.*
V varies by the same bi-monthly periods *t* as water demand,
X varies both over time and by household,
The hypothesized signs of the coefficients are $\alpha \neq 0, \chi > 0, \delta > 0, \phi > 0, \tau < 0, \varsigma < 0$,
and ε is the error term.

A complete description of the variables used in Model I is presented in Tables A-1 and A-2. Table A-1 provides descriptions of all the intermediate and final versions of the variables used. Intermediate variables are used to arrive at the final versions of the variables. Table A-2 presents summary statistics for the intermediate and final versions. A more general discussion of the variables is presented below.

[11] The IWR-Main model (IWR-MAIN, 1999) uses approximately 100 empirical studies to estimate its residential forecasting water use equation, similar the to one used here.

The weather variables are time series variables in Model I. The effect of weather may be positive or negative depending on the relative magnitude of the coefficients on temperature and precipitation. Temperature is expected to be positively correlated and precipitation negatively correlated to water demand. Typically, both are expected to effect summer outdoor water demand only (Danielson 1977). Hence, average monthly temperature is hypothesized to be positively correlated to water demand in the summer. A significant relationship between winter water demand and average temperature is not considered. Also, average monthly precipitation is hypothesized to be negatively correlated to water demand in the summer only, when rain is a substitute for sprinkling activity. A significant relationship between winter water demand and average precipitation is not considered.

Proxy variables were used to represent income, tastes, density, persons per household, and irrigation water demand. Assessed value of the house and lot is used to represent income through its relationship with house prices. In the short run, house prices are more influenced by interest rates; in the long run, higher house prices are more likely to reflect higher income levels. It is assumed that income is also reflected in the use of factors such as the number of water-using appliances (e.g. dish and clothes washers). The presence and size of a swimming pool reflects a taste for certain kinds of landscaping and is likely to be positively related to income levels. The number of bathrooms is assumed to be positively related to the number of persons per household, which is expected to be positively related to water demand. Density is represented by lot size minus the footprint of the house, garage, and patio areas. The higher the density and smaller the lot size, the lower the water demand. While density is expected to be negatively correlated with water demand, lot size is positively related to it.

The variable I is a binary variable included in Model I to represent users of surface or well irrigation water in the summer. Recall that W refers only to publicly supplied water only in Model I. For users of surface irrigation water or wells; an underestimate of total water demand will result. Therefore, it is necessary to account for the lower demand for publicly supplied water by households using surface irrigation or well water in the summer.

Data are not available to directly identify these households, so an indirect approach is used. Total water demand for all users increases during the summer months because of irrigation. Thus, a publicly supplied user will demonstrate a pattern of greater public water demand during the summer. The difference between summer and winter water demand may be attributed to outdoor demand. A "dual" user, in contrast, is likely to use publicly supplied water for indoor demand only, so their demand for of publicly supplied water would not change much from winter to summer. The variable I is constructed by expressing each user's monthly water demand as a percentage of total annual demand, calculating the standard deviation of each month's use from an average of the year's, and then separating households by the magnitude of the standard deviations of monthly use from the average.

Table A-1. Definitions of Intermediate and Final Variables Used in Model I.

	<u>Variable W</u>	
	Days	= Actual number of days in the billing cycle.
	Water	= Actual water consumption (in 100 cu. ft.) as billed by United Water for the billing cycle.
*	**WaterD**	= Actual water consumption (in 100 cu. ft.) divided by number of days in the billing cycle.
	<u>Variable I</u>	
	AWater	= Annual (calendar year) actual water consumption (in 100 cu. ft.).
	AAvg	= Actual calendar year water consumption divided by 6 - the number of billing cycles in each calendar year.
	AWPct	= Billing cycle water consumption as a percent of annual (calendar year) water consumption. **Avg** divided by **AWater** times 100.
	Stdev	= Standard deviation of AWPct, for each customer, over 2 years in the residential sample - a measure of variability of water consumption.
	Grp1	= Binary - customers with **Stdev** from 0 to 3%
	Grp2	= Binary - customers with **Stdev** from 4 to 7%
*	**Grp12**	= Binary - customers with **Stdev** from 0 to 7% A combination of the **Grp1** and **Grp2** binaries.
	Grp3	= Binary - customers with **Stdev** from 8 to 12%
	Grp4	= Binary - customers with **Stdev** 13% or greater.
	<u>Variable V</u>	
	Precip	= Actual precipitation, the sum of all daily precipitation, that occurred during the billing cycle
	Max	= Actual maximum temperature, the sum of all daily maximum temperatures, during the billing cycle.
	Min	= Actual minimum temperature, the sum of all daily minimum temperatures, during the billing cycle.
	PrecipD	= Precip divided by **Days**.
	MaxD	= **Max** divided by **Days**.
	MinD	= **Min** divided by **Days**.
	WSBinary	= Winter/Summer seasonal binary. Winter -- Oct. to Apr. = 0, Summer -- May to Sept. = 1.
	PrecipB	= Actual precipitation weighted by the winter/summer binary variable (**WSBinary**).
	MaxB	= Actual maximum temperature variable weighted by the winter/summer binary variable (**WSBinary**).
*	**PrecipBD**	= **PrecipB** divided by **Days**.
*	**MaxBD**	= **MaxB** divided by **Days**.
	PrecipN	= Normal precipitation, the sum of all daily normal precipitation figures, during the billing cycle.
	MaxN	= Normal maximum temperature, the sum of all daily normal maximum temperatures, during the billing cycle.
	MinN	= Normal minimum temperature, the sum of all daily normal minimum temperatures, during the billing cycle.
*	**PrecipND**	= **PrecipN** divided by **Days** weighted by the winter/summer binary variable (**WSBinary**).
*	**MaxND**	= **MaxN** divided by **Days** weighted by the winter/summer binary variable (**WSBinary**).

Table A-1. Definitions of Intermediate and Final Variables Used in Model I (Continued).

	Variable Y	
	House	= Total square footage of the residence.
*	**Value**	= Total dollar value of the house.
	Variable K	
	BdRms	= Total number of bedrooms in the house.
*	**BthRms**	= Total number of bathrooms in the house.
	Variable D and Variable G	
	GrdFl	= Total square footage of the ground floor of the residence. The "footprint" of the house on the lot.
	LotSizeA	= Property lot size expressed in acres.
	LotSizeSF	= Property lot size expressed in square feet.
	PatioSF	= Sq. ft. of patio areas on the property.
	Car1SF	= Sq. ft. - parking/garage areas on the property.
	Car2SF	= Sq. ft. - 2nd parking area on the property.
	DeckSF	= Total square footage of deck areas associated with the property.
*G	**PoolSF**	= Total square footage of swimming pools associated with the property.
*D	**LotSize2SF**	= Lotsize that may be subject to irrigation**. LotSizeSF minus GrdFl, PatioSF, Car1SF, Car2SF, DeckSF, PoolSF**.
	LotsizeB	= **Lotsize2SF** variable weighted by the winter/summer binary variable (**WSBinary**).
	LndScp	= Landscape variable. Ranges from 0 to 6. Zero = minimal landscaping; 6 = extensive landscaping.
	Variable P	
*	**Price**	= Marginal cost of an additional 100 cu. ft. of water from United Water - Idaho in the sample period.
	Variable X	
*	**Xbinary**	= A binary variable accounting for unusual observations of water consumption and very high water

* Indicates the final value that is used in the model.

Table A-2. Summary Values of Model I Variables.

	Days	Water	WaterD*	AWater	AAvg	AWPct	Stdev	Grp1	Grp2
Total	606,310	369,197	6,029	2,215,182	369,197	166,183	98,016	756	2,112
Average	60.801	37.023	0.605	222.140	37.023	16.665	9.829	0.076	0.212
Median	61.000	24.000	0.397	199.500	33.250	14.634	10.000	0.000	0.000
Std. Deviation	2.998	37.022	0.598	131.437	21.906	10.160	3.995	0.265	0.409

	GRP12*	Grp3	Grp4	Precip	Max	Min	PrecipD	MaxD	MinD
Total	2,868	4,128	2,976	24,582	39,167,473	25,718,122	402	642,601	421,637
Average	0.288	0.414	0.298	2.465	3,928	2,579	0.040	64	42
Median	0.000	0.000	0.000	2.010	3,814	2,419	0.032	63	40
Std. Deviation	0.453	0.493	0.458	1.554	1,064	752	0.025	16	12

	WSBinary	PrecipB	MaxB	PrecipBD*	MaxBD*	PrecipN	MaxN	MinN	PrecipND*
Total	5,002	11,232	24,101,833	182.5	391,438	332	630844	389907	125
Average	0.502	1.126	2,417	0.0183	39.254	0.033	63.262	39.100	0.0125
Median	0.500	0.660	1,910	0.0112	31.323	0.037	62.525	37.984	0.0140
Std. Deviation	0.454	1.435	2,321	0.0234	37.455	0.011	29.080	11.662	0.0117

	MaxND*	House	Value*	BdRms	BthRms*	GndFl	LotSizeA	LotSizeSF	PatioSF
Total	392864	20,291,496	1,281,2848,220	28,379	17,208	24,499,797	2,438	106,204,805	1,591,368
Average	39.397	2,035	128,545	2.85	1.88	2,457	0.244	10,650	160
Median	31.328	2,039	106,000	3.00	2.00	2,146	0.200	8,712	126
Std. Deviation	44.039	664	69,039	0.55	0.76	1,178	0.158	6,888	232

	Car1SF	Car2SF	DeckSF	PoolSF*	LotSize2SF	LotSizeB*	LndScp	Xbinary*	Price
Total	4,806,168	302,844	605,676	133,968	88,751,002	44,463,533	84	1,574	9,418
Average	482	30	61	13.434	8,900	4,459	4	0.158	0.944
Median	484	0	0	0.000	6,733	2,827	4	0.000	0.927
Std. Deviation	239	130	162	91.16	9,161	7,313	1	0.805	0.107

* Variable Values Used in Model I

The variable *X* is a binary variable which was included to represent an important phenomenon in a subset of the sample: extremely high water demand in the summer months that is not explained by other variables in the model. Because the purpose of the model is to extrapolate and predict rather than establish causation for the possible purpose of policy analysis, a fairly mechanistic approach to improve the explanatory power of the equation is justified. By omitting this, an important sub-group of behavior of water users would be lost, leading to underestimates of water demand. Alternative explanations for the extremely high water demand were examined extensively. For example, a variable describing the quality of landscaping, constructed to determine tax assessment value, was tested in the equation. It failed to explain the unusually large water demand, however. Clearly, the phenomenon reflects unusual demand which cannot be captured by the conventional variables but appears to be associated with taste. In addition to high water demand, the variable *X* also reflects some anomalies in the data. For example, enormous fluctuations within a single household's demand probably reflect meter-reading errors or leaks, which are also captured by this variable.

The presence of non-continuous variables, such as the variable *X,* in the equation has important implications for the constant term. The effects on water consumption of groups that are given a value of zero are captured in the constant term. The effect of the group given a value of one is captured in the coefficient associated with *I*. Thus, the constant term can take a positive or negative value, but is not likely to be zero, except by coincidence.

A variable missing from the first econometric model is price. While price data were collected for the two-year period, initial model runs demonstrated that there was not enough variation in the data to separate the effects of price from the effects of weather for this period alone. As a result, it is not possible to estimate a coefficient on price with the correct sign. A second model was constructed to measure the effect of price on water demand. The second model uses aggregate household data over a longer time period. It may be described as follows:

Model II: $$W^{D}{}_{t} = \eta + \beta P_{t-1} + \mu Y_{t} + \nu V_{t} + \rho H_{t} + \sigma_{t}$$

where the expected signs of the coefficients are $\eta \neq 0, \beta < 0, \mu > 0, \rho > 0$ and σ is the error term. The coefficient *v* may be positive or negative and *H* represents the number of customers. The other variables represent aggregate values but otherwise have a similar interpretation as in model I. The exception is household income which is represented directly by household income rather than house values. Prices represent real summer average incremental price, lagged one year.

In theory, the responsiveness of water demand to price levels is greater in the long run compared with the short run. People take time to make major changes in the way they use water, in the type of landscaping they use and in the size of lot they purchase, for example. Small changes such as fixing leaks and/or using more water efficient appliances tend to produce smaller water savings. By measuring price elasticity with time series data, we are likely to capture the short run response to price changes. In other words, where changes in prices have taken place during the time horizon of the data, only relatively small changes in behavior are likely to have occurred and are therefore measurable. Stretching out the period households have to respond to the change in price is likely to increase the measured response. Therefore, prices were lagged one year in the equation.

Another way of improve the measurement of the price response is to recognize that the main changes during the measured period were in summer incremental prices only. United Water Idaho, whose data are being used in this study, practices flat rate pricing. However, since 1994 they have increased the rate during the summer months (May to September). Since most of the water demand takes place in the summer, the summer rate was used to reflect incremental pricing in any given year. Notwithstanding these modifications to the specification of the variable, however, the coefficient on price is likely to be lower than it would be with better data.

The models described above are used to generate a set of coefficients to perform two tasks, one to extrapolate to populations outside the sample area in the baseline period and the second to forecast over a twenty-five year horizon. Average per household water demand in the two counties in the baseline period is estimated by multiplying the coefficients by the appropriate value of the variables in Ada and Canyon County. Average demand is then multiplied by the number of households in the county to obtain total publicly supplied water demand. To compute average demand, assumptions are made about the number of "dual" users in Canyon County and the amount of "unusual" water demand captured by the "X binary". Since data is currently not available for either of these variables, it is assumed that the two counties are similar in these regards. This might underestimate the number of dual users but may also overestimate the unusual demand if it is in any way related to income.

Two coefficients are then used to make adjustments to household average demand in the baseline period. The variable "*I*" is used to estimate additional water demand by households supplied by surface irrigation or well water. This is easily done by assuming that the lower amount of public water demanded by dual users is roughly equivalent to the irrigation water they demand. Clearly, because they typically face a zero incremental price for water from irrigation companies, this would represent an underestimate of water demand.[12]

The model used to derive future water demand can be described as follows:

Model III: $$W^D{}_t = H_t(\alpha + \sum_i \theta_i Z_{it}),$$

where: α is the constant term estimated in Model I,
H is the number of households in forecast year t where t = 5, 10, 15, 20, and 25,
Z is the vector of the variables used in Model I with the addition of P and
θ is a vector of coefficients, i derived in Models I with the addition of the one estimated for P.

The variables expected to change their average values over time are price *P*, income *Y*, numbers of bathrooms *K*, and the proportion of users of surface irrigation systems or wells for outdoor use, represented by variable *I*. The variables *P* and *I* are interrelated as follows. The proportion of irrigation users is expected to increase through time as new residential developments close to irrigation canals install pressurized irrigation systems. This reduces summer demand for public supply systems and changes the incremental price households face for their summer irrigation water to zero in many cases. Variables not expected to change, on average, over time are lot size (*D*), the residual variable (*X*), and the weather variables (*V*).

During the last ten years, the number of lots per acre for new development in Ada County has increased from roughly one and a half lots per acre to two lots per acre

[12] This is because irrigation companies charge a fixed fee for irrigation water use. No part of their charge is linked to use.

(COMPASS).[13] This number remains well below three, the current average of lots per acre in Ada County. As long as new lots per acre remain below this average, it will continue to pull down the average.

A linear extrapolation of the trend line of new development towards more lots per acre demonstrates that the trend line will approach the current average by the year 2010 (Figure A-1). Since the number of lots per acre will be lower than the average until 2010, the overall average will continue to fall. After 2010, the number of lots per acre will be greater than the average and the average will begin to rise. Hence, our variable of concern, the average, is expected to decrease and then increase. In Canyon County, lot sizes are larger than in Ada County and it is uncertain (because of lack of data) what will happen. For all these reasons, an assumption of no change in average lot size was adopted for the area as a whole.

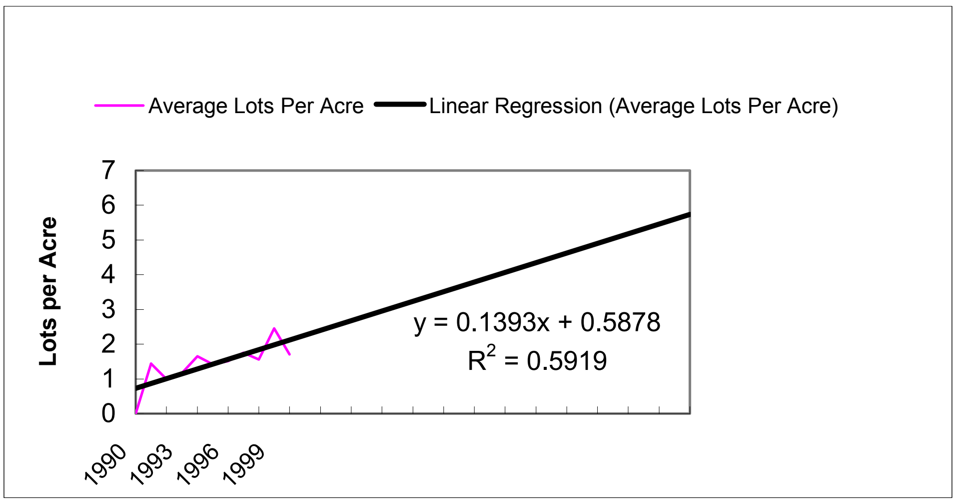

Figure A-1. Lots per Acre in Ada County.

Since the unusual water demand reflected by the "residual" variable *X* appears to be related to technology (leaks) and tastes, it seems reasonable to make the conservative assumption of no change over time. While average weather conditions over the next 25 years are not assumed to change in this study, it is necessary to adjust the forecast for normal weather conditions. The forecast was adjusted for each weather variable by subtracting the yearly average from the normal average and multiplying the difference by the coefficients estimated for *V*.

Data for projected changes in house values, the proxy variable for income, were not available. However, projections on real household income were available. Hence, it was assumed that house values follow the same path as income over time. In the short run, house values are more influenced by interest rates, but over the long run they are more likely to reflect income levels.

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[13] Development Monitoring Reports (1990 to 2000)

Data Collection

Information on year-round residential water use was obtained from water billing records from the largest municipal supplier in the area, United Water Idaho. For Model I a stratified random sample of 927 customers was drawn from a list of all customers in United Water Idaho's residential data set. Households were deleted from the sample if residence was not continuous during the period or, if for other reasons, a complete set of data was not available. In addition, the initial sample of 927 customers was reduced to 835, because either they were found to be commercial, or it was not possible to obtain property information for them. A list of reasons for exclusion is presented in Table A-3. A total of 9,972 billing records were obtained for the remaining customers in the sample reflecting bi-monthly billings between January 1997 and December 1998.

Table A-3. Residential Customers Excluded From Sample, and Reasons for Exclusion.

	Reasons for Exclusion from the Residential Customer Sample	**Number of Customers Excluded**
1	Incomplete Property Information.	20
2	Unable to Obtain Property Information.	44
3	Not Residential The "residential" customer was not a single-family residential, but was rather multi-family or commercial.	24
4	Lot Size Greater Than One Acre. Residential properties with lot sizes greater than one acre were removed from the sample to be treated separately.	7
5	Water Consumption was a Severe Deviation from The Sample Norm	1

United Water Idaho divides its area of operation into billing areas called blocks, and reads them one by one. Over a two-month period, each block would be read once. Hence, per period consumption does not reflect usage during the same calendar days for all customers. To ensure that per period observations on the explanatory variables cover the same calendar period as does metered consumption, all time series data have to be obtained on a daily basis. Daily readings are used to obtain appropriate per period readings. Time series data affected by this counting procedure are weather variables. Bi-monthly water data are matched to weather data obtained from NOAA for the Boise Air Terminal at Gowen Field. Daily weather values are matched to each billing cycle and average values derived for the cycle.

United Water Idaho's area of operation is almost entirely in Ada County. To link the water use readings with the cross section explanatory variables, street addresses are matched to parcel numbers in the Ada County Tax Assessors database. In this way, tax assessment data on households are obtained for each household in the sample.

For the extrapolation to the entire basin, average values of the variables for Ada County, both inside and outside the United Water Idaho area of operations, are obtained by COMPASS from the tax assessor's office. Data from Canyon County are obtained by

COMPASS from the Canyon County Tax Assessment Office. While information for all the variable values are available from Ada County, information for only two variables, density and house value, are available from Canyon County.

Aggregate data for Model 2 is obtained from United Water Idaho for all but the weather variables. Data are available for the period 1985 to 1999. While no years were deleted from the sample, it was recognized that 1999 was an atypical year, one in which South County Water was acquired by United Water Idaho.

Results

More than 50 versions of Model I are tested with the ordinary least squares method of estimation. Semi log, double log specifications of included variables are tested as well as linear specifications of variables not ultimately included. These other variables are descriptive residence characteristics such as quality of landscaping, house size, and number of bedrooms. It was thought that quality of landscaping might explain the very high summer water use of a few households in the sample. Also, house size is tested as an alternative proxy for income to house value. Finally, the number of bedrooms is tested as an alternative proxy for persons per household to bathrooms.

In the final equation, a linear specification was used to derive the coefficients for both the extrapolation and the forecast. While this specification of the final equation is consistent with theory, the statistical reliability of the coefficients needed to be investigated to test for multicoliniarity, heteroscedasticity, and serial correlation. Heteroscedasticity was not tested because the test involves a large amount of manual data sorting. It might be expected to be present in the income variable, Y. After accounting for the difference in water use on the basis of house value or income, we may still observe a greater variation in the use of water among high-income families due to the greater discretion allowed by high income users. To check for multicoliniarity, all the variables were introduced one by one (step-wise). The stability of the coefficients and the fact that they had the correct signs, were plausible in magnitude, and that they had low standard errors implied multicoliniarity was not present. Indeed, the coefficients were found to be consistent and unbiased with standard errors statistically significant at the 99% level. However, there is a possibility that the standard errors may be biased since an initial indicator of serial correlation, the Durban Watson Test statistic is 1.14, suggesting the presence of serial correlation at the 95% level of confidence. The possible presence of heteroscedasticity mentioned earlier would only increase the likelihood of unreliable standard errors. However, unreliable standard errors are not a cause for deleting a variable from the model if the underlying theory and a great amount of evidence from other studies supports their inclusion. Also, from a purely forecasting point of view, it is not necessary to be overly concerned with the statistical properties of the estimates. Nevertheless, a cautious approach is required towards interpreting the model for policy implications.

The final equation selected for Model I is presented in Table A-4 and demonstrates the contribution of each variable to water demand. The equation is presented in the form of daily water demand. In order to use the model to extrapolate to its own or other populations, it is necessary to multiply the coefficient by the number of days in the year, as well as by the average value of the independent variable. The average maximum daily temperature has the most impact on water demand of any of the explanatory variables, other than the constant, accounting for 45 percent of the total effect of the variables on water demand. The proxy for people per household and the number of bathrooms explains 19 percent; house values, 13 percent; dual users and the very high summer demand, 11 percent. The remaining variables account for no more than 5 percent each.

The coefficients are readily changed into elasticities (percentage changes rather than absolute changes) in order to compare them with the results of other studies. The elasticities computed from variables in this study are presented in Table A-5. The elasticities computed from variables in other studies are presented in the IWR-Main Water Demand Management Suite (IWR-MAIN 1999). In most cases, where there is a comparable coefficient, the values associated with this study are at the low end of the range. In some case they are under the range. Temperature is 0.44, compared with the range of values 0.8 to 1.5. Precipitation is 0.08 compared with the range 0.05 to .2. Income is 0.13 compared with the range 0.2 to 0.6. Person per household is 0.2 compared with the range 0.2 to 0.6. Housing density is 0.04 compared with the range 0.2 to 0.8.

A description of the variables used in Model II is presented in Table A-6. Table A-6 also presents the regression equation: the coefficients and summary statistics. Overall, the model is "a good fit" with an R squared statistic of 0.98. The coefficients and the standard errors are unbiased (the Durban Watson statistic is 2.16). The t statistic on the coefficient of interest, the real price level, is the correct sign but not statistically significant at the usual levels of significance. Nevertheless, its value is lower but not inconsistent with those of other studies. The elasticity is 0.0815, compared with the range of 0.05 to 0.35 from other studies (IWR-MAIN 1999).

The relevant coefficients of the two models are combined with future values of the variables to generate forecasts for Ada and Canyon Counties. As an example, the forecast for Ada County is presented in Table A-7. Some small adjustments had to be made for differences between the water use of the selected sample and the population of users. For the most part this occurred because the population of customers was initially screened for continuous water using households. The average number of days for all customers is calculated to be 338 because of part-time occupancy and vacancies. But there was also a small difference between the sample average and the population average before the screening, hence the adjustment for "low water use". Normalization is done by applying the normal average to the coefficients instead of the actual 1997/98 averages. The price term is introduced by applying the coefficient to the difference between the United Water Idaho price and the average price level in the county. This is done because price is implicitly captured in one or more of the other variables in Model I and cannot be added in its entirety without double counting. Table A-7 shows that GPD per person increases from 185.1 in 1997/8 to 215.9 in 2025 in Ada County and total annual demand increases from 11.7 MG to 19.7 MG.

Table A-4. Model I - Residential Water Demand Regression Equation and Table of Results.

Number of cubic feet of water demanded per day (WaterD*100)

$$= 15.024 + 6.064*K - 21.45*I + 43.888*X - 292.074*V1 + 0.684*V2 + 0.06126*Y + 2.017*G + 0.631*D$$

Regression Coefficients

Coefficients	t stat (SE)	Independent Variables	Days	Average Independent Variable Value	Annual Water Demand
15.024	16.99(.884)	Constant Term	365	15.024	5,483.8
6.064	11.89(0.506)	K: Number of Bathrooms in the House (Bthrms).	365	1.88	4,161.1
-21.450	32.357(.663)	I: Binary Variable for probable irrigation water users (group12)	365	0.288	(2,254.8)
43.888	111.831(.39)	X: Binary Variable for peak/high water use (X Binary)	365	0.158	2,531.0
-292.074	17.379(16.8)	V1: Average Daily Precipitation during the billing cycle applicable only to the summer months of May - Sept. (PrecipDB)	365	0.018	(1,950.9)
0.684	57.836(.012)	V2: Average Maximum Daily Temperatures during the billing cycle applicable only to the summer months of May - Sept. (MaxDB)	365	39.254	9,800.2
0.061	9.948(.071)	Y: House Value in thousands of dollars (Value/1000)	365	128.545	2,874.3
2.017	6.068(.031)	G: Swimming Pools in 100 of sq. ft. (PoolSF/100)	365	0.134	98.9
0.631	11.126(.070)	D: Lot Size minus house foot print minus Carports, Patios, Decks and Swimming pools in 1000cu. ft. and applicable only to the summer months of May - Sept. (LotSizeB/1000)	365	4.459	1,027.0

Summary	Statistics		
		(1) Annual Water Demand per Customer (cu. ft.)…..……...……………..……	21,770.42
R Square	0.757	(2) Annual Water Demand per Customer (100 cu. ft.)………...………………	217.70
Durbin-Watson	1.146	(3) Annual Water Demand per Customer from Residential Sample………....	222.14
F	3879.469	(4) Percent Difference (2)/(3)……………………………………………….	-2.0%

Table A-5. Sensitivity Analysis for the Estimation of Elasticities for Model I Variables.

	Predicted Water Demand Prior to Change	Predicted Water Demand With Change	Difference	Percent Difference	Implied Elasticity
Variable V1 (PrecipD)	(100 cu. ft.)	(100 cu. ft.)	(100 cu. ft.)	(%)	(with 1% chg.)
(2) Changed Precipitation (+10%)	368,176	364,896	-3,280	-0.89%	-0.089088
(3) Changed Precipitation (+5%)	368,176	366,536	-1,640	-0.45%	-0.089088
(4) Implied Elasticity with 1% Change					-0.0891
Variable V2 (MaxD)					
(5) Changed Maximum Temperature (+10%)	368,176	384,663	16,487	4.48%	0.4478021
(6) Changed Maximum Temperature (+5%)	368,176	376,420	8,244	2.24%	0.4478293
(7) Implied Elasticity with 1% Change					0.4478
Variable Y (Value)					
(8) Changed House Value (+10%)	368,176	372,950	4,774	1.30%	0.1296662
(9) Changed House Value (+5%)	368,176	370,563	2,387	0.65%	0.1296662
(10) Implied Elasticity with 1% Change					0.1297
Variable D (LotSizeSF)					
(11) Changed Lot Size (+10%)	368,176	369,903	1,727	0.47%	0.0469069
(12) Changed Lot Size (+5%)	368,176	369,040	864	0.23%	0.0469341
(13) Implied Elasticity with 1% Change					0.0469
Variable G (PoolSF)					
(14) Changed Pool Square Footage (+10%)	368,176	368,341	165	0.04%	0.0044816
(15) Changed Pool Square Footage (+5%)	368,176	368,259	83	0.02%	0.0045087
(16) Implied Elasticity with 1% Change					0.0045
Variable X (Xbinary)					
(17) Changed Xbinary (+10%)	368,176	372,445	4,269	1.16%	0.1159500
(18) Changed Xbinary (+5%)	368,176	370,311	2,135	0.58%	0.1159771
(19) Implied Elasticity with 1% Change					0.1159
Variable I (Group12)					
(20) Changed Xbinary (+10%)	368,176	364,436	-3,740	-1.02%	-0.001016
(21) Changed Xbinary (+5%)	368,176	366,306	-1,870	-0.51%	-0.001016
(22) Implied Elasticity with 1% Change					-0.0010
Variable K (Bthrms)					
(23) Changed Xbinary (+10%)	368,176	375,486	7,310	1.99%	0.0019855
(24) Changed Xbinary (+5%)	368,176	371,831	3,655	0.99%	0.0019855
(25) Implied Elasticity with 1% Change					0.0020

Table A-6. 1985 - 1999 United Water Idaho Residential Customer Water Use Data, Weather, and Income Data Used to Estimate Price Coefficient.

Year	Residential Customers	Residential Annual Water Delivered (cu. ft x 100)	Annual Precip-itation	Annual Summer Precip-itation	Annual Average Temp.	Annual Average Summer Temp.	Summer Month Incremental Water Price ($/100 cu. Ft.)	Boise MSA Nominal Personal Income (billions $)	Consumer Price Index ('82-'84 = 100)	Summer Month Real Incremental Water Price ('82-'84 $/100 cu. Ft.)	Boise MSA Real Personal Income (billions '82-84 $)
1985	35,915	6,104,356	11.14	4.59	45.8	65.8	$0.510	$18.902	107.57	$0.474	$17.572
1986	36,605	6,447,339	14.31	4.62	51.8	66.8	0.538	19.243	109.61	0.491	17.556
1987	37,288	7,125,339	8.49	2.08	52.8	67.8	0.547	19.396	113.63	0.481	17.070
1988	38,078	7,018,685	11.30	2.15	51.9	67.3	0.543	19.904	118.26	0.459	16.831
1989	38,143	6,694,777	10.44	2.30	50.1	67.0	0.543	20.535	123.97	0.438	16.565
1990	40,064	6,675,794	12.07	5.49	51.7	68.5	0.543	20.795	130.66	0.416	15.916
1991	41,356	6,992,695	9.47	2.83	51.2	67.1	0.638	20.706	136.30	0.468	15.191
1992	42,932	7,622,561	7.67	2.40	53.3	68.6	0.638	21.666	140.36	0.455	15.436
1993	44,372	6,939,170	12.76	3.78	48.7	64.3	0.638	22.366	144.60	0.441	15.467
1994	46,041	8,245,150	9.40	1.45	52.4	69.8	0.924	23.333	148.30	0.623	15.734
1995	47,078	7,243,951	14.07	4.11	52.3	66.2	1.011	24.348	152.50	0.663	15.966
1996	48,455	8,008,659	14.16	2.46	52.3	67.1	1.011	24.222	157.00	0.644	15.428
1997	50,028	7,934,999	11.09	3.88	52.9	69.0	1.048	24.416	160.60	0.652	15.203
1998	51,177	7,774,576	16.71	8.06	53.7	69.1	1.093	24.427	163.10	0.670	14.977
1999	57,638	9,535,471	8.59	1.86	52.6	67.0	1.139	24.438	166.70	0.683	14.660

Regression Simulation

Year	Actual Residential Annual Water Delivered (cu. ft x 100)	Predicted Residential Annual Water Delivered (cu. ft x 100)	Difference Predicted vs. Actual (cu. ft x 100)	Percent Difference Predicted vs. Actual (%)
1985	6,104,356	6,253,277	148,921	2.4%
1986	6,447,339	6,460,188	12,849	0.2%
1987	7,125,339	6,948,218	(177,121)	-2.5%
1988	7,018,685	6,946,290	(72,395)	-1.0%
1989	6,694,777	6,832,492	137,715	2.1%
1990	6,675,794	6,864,024	188,230	2.8%
1991	6,992,695	7,051,968	59,273	0.8%
1992	7,622,561	7,608,963	(13,598)	-0.2%
1993	6,939,170	6,903,557	(35,613)	-0.5%
1994	8,245,150	8,335,851	90,701	1.1%
1995	7,243,951	7,421,036	177,085	2.4%
1996	8,008,659	7,940,457	(68,202)	-0.9%
1997	7,934,999	8,221,712	286,713	3.6%
1998	7,774,576	7,599,893	(174,683)	-2.2%
1999	9,535,471	9,580,658	45,187	0.5%

Estimated Regression Equation & Statistics

United Water: Annual Residential Water Consumption per Customer =

2,247.854 + 3.20 * Ada County Real Personal Income - 1.188 * Year
-3.431 * Summer Month Precipitation
+ 3.811* Average Summer Month Temperature
+ 7.328 *Binary for Year 1999
- 14.910 * Real Summer Month Incremental Water Price

N = 15 **R = .962** **R Squared = .926**
F = 16.765 **Adjusted R Squared = .871**
Standard Error of Estimate = 4.0820

Notes: All Weather Observations are for the US Weather Bureau Office at Gowen Field, Boise, ID.
Summer Months are defined as the months of May - September of each year, inclusive.
Summer Precipitation is the sum of the monthly precipitation occurring during the May- September period of each year. Summer Average Temperature is the average of the monthly average temperatures for the months May - September each year. Binary for the year 1999 is to account for the acquisition of South County Water by United Water - Idaho.

Table A-7. Model I - Forecasting Single Family Residential Water Demand for Ada County

Regression Coefficients Cu. Ft. of Water per Day	Independent Variables	Days	Average Independent Variable Value	United Water Customers Annual Water Demand	Average Variable Value	ADA Annual Water Demand 1998
15.024	**Constant Term**	338	15.024	5,078.1	15.024	5,078.1
6.064	***K**	338	1.88	3,853.3	1.95	3,996.8
-21.450	***I**	338	0.288	(2,088.0)		
43.888	***X**	338	0.158	2,343.8	0.158	2,343.8
-292.074	***V1**	338	0.018	(1,806.6)	0.0125	(1,234.0)
0.684	***V2**	338	39.254	9,075.2	39.397	9,108.3
0.061	***Y**	338	128.545	2,661.6	138.32	2,864.0
2.017	***G**	338	0.134	91.6	0.134	91.4
0.631	***D**	338	4.459	951.0	12.98	2,768.3
-4.082191781	Price (from annual regression)			(109.1)	0.0791	(109.1)

(1) Daily Water Use per Customer (100 cu. ft.)	0.552	0.682
Adjustment for low water use	-0.022	-0.022
(1) Daily Adjusted Water Demand per Customer (100 cu. ft.)	0.018	0.018
(1) Annual Water Demand per Customer in the sample (cu. ft.)	0.530	0.660
Households	17,915.0	22,311.3
GPD (persons)	51,907.0	70,361.0
GPD (household)	148.6	185.1
Annual Water Demand (MG.)	367.2	457.3
	6,956.2	11,743.2

*Refer to Table 4 for definitions.

Table A7. Model I - Forecasting Single Family Residential Water Demand for Ada County (Continued).

Independent Variables	Independent Variable Value	ADA Annual Water Demand 2000	Variable Value	ADA Annual Water Demand 2005	Variable Value	ADA Annual Water Demand 2010	Variable Value	ADA Annual Water Demand 2015
Constant Term	15.024	5,078	15.024	5,078	15.024	5,078	15.024	5,078
***K**	1.98	4,038	1.98	4,058	1.98	4,058	1.94	3,976
***I**								
***X**	0.158	2,343.8	0.158	2,343.8	0.158	2,343.8	0.158	2,343.8
***V1**	0.0125	(1,234)	0.0125	(1,234)	0.0125	(1,234)	0.0125	(1,234)
***V2**	39.397	9,108	39.397	9,108	39.397	9,108	39.397	9,108
***Y**	142.31	2,947	146.69	3,037	153.64	3,181	163.97	3,395
***G**	0.134	91	0.134	91	0.134	91	0.134	91
***D**	12.98	2,768	12.98	2,768	12.98	2,768	12.98	2,768
	0.0791	(109)	0.0791	(109)	0.0791	(109)	0.0791	(109)
		0.686		0.689		0.693		0.696
		-0.022		-0.022		-0.022		-0.022
		0.663		0.667		0.670		0.674
		22,425.8		22,528.8		22,662.0		22,784.2
		79,440		89,245		102,544		115,712
		185.3		194.0		201.9		206.6
		459.6		461.7		464.4		467.0
		13,326.5		15,040.1		17,383.6		19,721.6

*Refer to Table 4 for definitions

Table A7. Model I - Forecasting Single Family Residential Water Demand for Ada County (Continued).

Independent Variables	Variable Value	ADA Annual Water Demand 2020	Variable Value	ADA Annual Water Demand 2025
Constant Term	15.024	5,078	15.024	5,078
***K**	1.91	3,915	1.89	3,874
***I**				
***X**	0.158	2,343.8	0.158	2,344
***V1**	0.0125	(1,234)	0.0125	(1,234)
***V2**	39.397	9,108	39.397	9,108
***Y**	174.64	3,616	189.12	3,916
***G**	0.134	91	0.134	91
***D**	12.98	2,768	12.98	2,768
	0.0791	(109)	0.0791	(109)
		0.701		0.708
		-0.022		-0.022
		0.678		0.686
		22,931.8		23,171.5
		118,542		121,441
		211.7		215.9
		470.0		474.9
		20,334.9		21,049.9

*Refer to Table 4 for definitions.

Appendix B:

SIC Division Structure

A. **Division A: Agriculture, Forestry, And Fishing**
   - Major Group 01: Agricultural Production Crops
   - Major Group 02: Agricultural Production Livestock And Animal Specialties
   - Major Group 07: Agricultural Services
   - Major Group 08: Forestry
   - Major Group 09: Fishing, Hunting, And Trapping

B. **Division B: Mining**
   - Major Group 10: Metal Mining
   - Major Group 12: Coal Mining
   - Major Group 13: Oil And Gas Extraction
   - Major Group 14: Mining And Quarrying Of Nonmetallic Minerals, Except Fuels

C. **Division C: Construction**
   - Major Group 15: Building Construction General Contractors And Operative Builders
   - Major Group 16: Heavy Construction Other Than Building Construction Contractors
   - Major Group 17: Construction Special Trade Contractors

D. **Division D: Manufacturing**
   - Major Group 20: - Food And Kindred Products
   - Major Group 21: Tobacco Products
   - Major Group 22: Textile Mill Products
   - Major Group 23: Apparel And Other Finished Products Made From Fabrics And Similar Materials
   - Major Group 24: Lumber And Wood Products, Except Furniture
   - Major Group 25: Furniture And Fixtures
   - Major Group 26: Paper And Allied Products
   - Major Group 27: Printing, Publishing, And Allied Industries
   - Major Group 28: Chemicals And Allied Products
   - Major Group 29: Petroleum Refining And Related Industries
   - Major Group 30: Rubber And Miscellaneous Plastics Products
   - Major Group 31: Leather And Leather Products
   - Major Group 32: Stone, Clay, Glass, And Concrete Products
   - Major Group 33: Primary Metal Industries
   - Major Group 34: Fabricated Metal Products, Except Machinery And Transportation Equipment
   - Major Group 35: Industrial And Commercial Machinery And Computer Equipment

- Major Group 36: Electronic And Other Electrical Equipment And Components, Except Computer Equipment
- Major Group 37: Transportation Equipment
- Major Group 38: Measuring, Analyzing, And Controlling Instruments; Photographic, Medical And Optical Goods; Watches And Clocks
- Major Group 39: Miscellaneous Manufacturing Industries

E. **Division E: Transportation, Communications, Electric, Gas, And Sanitary Services**
- Major Group 40: Railroad Transportation
- Major Group 41: Local And Suburban Transit And Interurban Highway Passenger Transportation
- Major Group 42: Motor Freight Transportation And Warehousing
- Major Group 43: United States Postal Service
- Major Group 44: Water Transportation
- Major Group 45: Transportation By Air
- Major Group 46: Pipelines, Except Natural Gas
- Major Group 47: Transportation Services
- Major Group 48: Communications
- Major Group 49: Electric, Gas, And Sanitary Services

F. **Division F: Wholesale Trade**
- Major Group 50: Wholesale Trade-durable Goods
- Major Group 51: Wholesale Trade-non-durable Goods

G. **Division G: Retail Trade**
- Major Group 52: Building Materials, Hardware, Garden Supply, And Mobile Home Dealers
- Major Group 53: General Merchandise Stores
- Major Group 54: Food Stores
- Major Group 55: Automotive Dealers And Gasoline Service Stations
- Major Group 56: Apparel And Accessory Stores
- Major Group 57: Home Furniture, Furnishings, And Equipment Stores
- Major Group 58: Eating And Drinking Places
- Major Group 59: Miscellaneous Retail

H. **Division H: Finance, Insurance, And Real Estate**
- Major Group 60: Depository Institutions
- Major Group 61: Non-depository Credit Institutions
- Major Group 62: Security And Commodity Brokers, Dealers, Exchanges, And Services
- Major Group 63: Insurance Carriers
- Major Group 64: Insurance Agents, Brokers, And Service
- Major Group 65: Real Estate
- Major Group 67: Holding And Other Investment Offices

I. **Division I: Services**
- Major Group 70: Hotels, Rooming Houses, Camps, And Other Lodging Places
- Major Group 72: Personal Services
- Major Group 73: Business Services

- Major Group 75: Automotive Repair, Services, And Parking
- Major Group 76: Miscellaneous Repair Services
- Major Group 78: Motion Pictures
- Major Group 79: Amusement And Recreation Services
- Major Group 80: Health Services
- Major Group 81: Legal Services
- Major Group 82: Educational Services
- Major Group 83: Social Services
- Major Group 84: Museums, Art Galleries, And Botanical And Zoological Gardens
- Major Group 86: Membership Organizations
- Major Group 87: Engineering, Accounting, Research, Management, And Related Services
- Major Group 88: Private Households

J. Division J: Public Administration

- Major Group 91: Executive, Legislative, And General Government, Except Finance
- Major Group 92: Justice, Public Order, And Safety
- Major Group 93: Public Finance, Taxation, And Monetary Policy
- Major Group 94: Administration Of Human Resource Programs
- Major Group 95: Administration Of Environmental Quality And Housing Programs
- Major Group 96: Administration Of Economic Programs
- Major Group 97: National Security And International Affairs
- Major Group 99: Nonclassifiable Establishments