CASCADE
WATER ALLIANCE

Water Demand Forecast
Task 600

FINAL DRAFT

December 18, 2009

CDM

In association with

HDR R·W·BECK

Cascade Water Alliance
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1218 3rd Ave
Suite 1100
Seattle, WA 98101
(206) 336-4900

In association with

HDR

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1.0 Background

The purpose of this document is to summarize the methodology, data assumptions and results of a comprehensive water demand forecast for the Cascade Water Alliance (Cascade).

The objective of this analysis was to forecast total water demand for the forecast period 2010 to 2060 for the combined utilities of Cascade. The water demand forecast is designed to serve as a basis for supply and infrastructure decision making, as well as financial planning. In addition, the water demand forecast model will estimate and communicate effects from major sources of uncertainty to assist Cascade decision-makers understand both the upside and downside risks in source and infrastructure planning.

A water demand forecast model (demand model) was estimated based on water billing and production data, demographic and socioeconomic data, weather, and water conservation for the eight utilities within the Cascade service area:

- City of Bellevue
- Covington Water District
- City of Issaquah
- City of Kirkland
- City of Redmond
- Sammamish Plateau Water and Sewer District
- Skyway Water and Sewer District
- City of Tukwila

A comprehensive database was developed, and organized into monthly time series (across historical years 1994 to 2008) and cross sectional (across utilities) data set. It should be noted that not all of the utilities had complete data from 1994 to 2008.

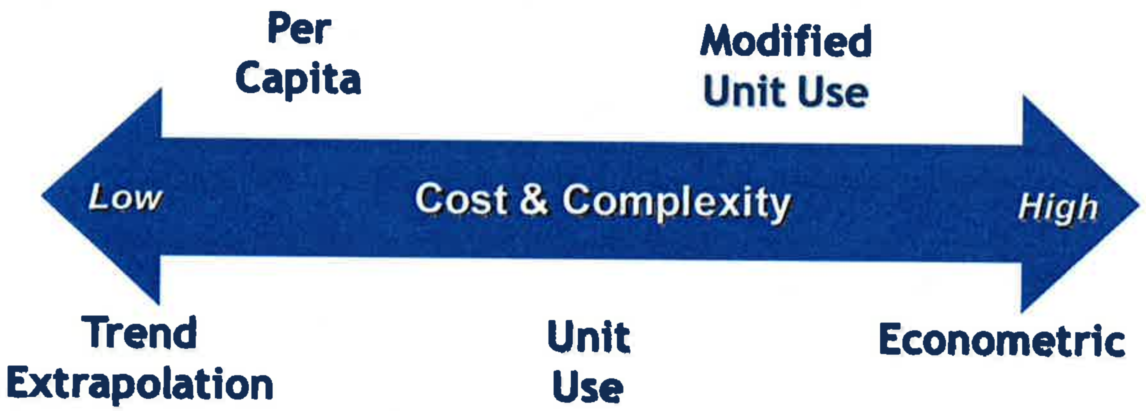
Section 2 reviews common water demand forecasting approaches and discusses the method employed for the Cascade demand model. Section 3 reviews the data used to develop the demand model and generate the water demand forecast. Section 4 presents the results of the statistical regression analyses, which serve as the basis for the demand model. Section 5 provides an overview of the water demand uncertainties, presents the demand forecast scenarios, and summarizes the demand forecast results.

2.0 Water Demand Forecasting Approach

2.1 Overview of Different Demand Forecasting Methods

Common approaches to forecasting water demands range from simple trend extrapolation to detailed econometric models (see Figure 1).

Figure 1. Common Water Demand Forecasting Approaches



The trend extrapolation method simply extends historical trends into the future. The advantage to this method is it is not time consuming to prepare and thus is very low cost to produce. The disadvantages are that it assumes the unlikely scenario that past trends carry into the future unchanged, it has no ability to "explain" water demands, and it cannot account for any changes in factors that influence demand, such as demographics or weather.

The per capita demand forecasting method assumes population is the primary driver in determining future demand. The approach takes historical total demand divided by population to get per capita use and multiplies it by the projected population to calculate future demand. The advantage of this methodology is it is simple to understand and is relatively low cost to produce. The disadvantages are that demand does not always mirror population growth and demographic, socioeconomic, and factors other than population are not accounted for.

A unit use methodology is more costly and complex than the two previous approaches. It is similar to the per capita method, but instead of a single population driver it uses multiple drivers to generate sector water demands (e.g., single-family, multifamily and non-residential). The unit use method involves dividing each sector's water demand by the appropriate drivers (e.g. housing or employment) to calculate a per unit water demand value. Next, the unit use values are multiplied by the projected future number of units to derive a future unit use demand. The primary advantage of the unit use methodology is that it allows for demand in each sector to be projected independently. The primary disadvantage is that important influencing factors such as weather, income, and price of water are not incorporated into the demand forecast.

A modified unit use methodology, such as the one used for the **Central Puget Sound Water Supply Forum's *2009 Regional Water Supply Outlook (2009 Outlook)***, applies factors from other empirical studies of water demands to adjust or modify the unit use rates over time to account for weather, income and price of water impacts.

As decisions regarding development of new water supplies and infrastructure become more complex and costly, many utilities across the country are seeing value in moving towards more sophisticated approaches for forecasting water demands. These econometric methods start with empirical statistical analysis of historical water demands and the factors known to influence water use. Then they use Monte Carlo simulation of key variables in order to produce a statistical range in water demands, which can help decision makers understand uncertainty and the implications of their planning.

To determine the most effective water demand forecasting method, three primary factors should be examined. First, what are the goals and objectives of the forecast? To answer this question one must understand the information needed by the planners or decision-makers as well as the ramifications of the decisions. Second, is there adequate data availability? This requires understanding what data is available, its quality, and the models the data will support. Finally, what are the budget and resources available? In order to select the proper forecasting methodology the financial constraints as well as the project schedule must factor into the decision.

2.2 Recommended Water Demand Forecasting Method for Cascade

Based on the importance of the decisions being made by Cascade, the availability of data, and the fact that much of the information from key utilities had already been collected for the ***2009 Outlook***, CDM recommended that the econometric water demand approach with uncertainty analysis be used to develop the water demand forecast.

An econometric approach statistically correlates sector water demands with factors that influence those demands. The econometric model relies on regression analysis to compute coefficients or elasticities that describe how water use is influenced by a number of explanatory variables (such as weather, price of water, income, etc). For each explanatory variable, elasticity is statistically estimated. For example, a price elasticity of -0.10 implies that a ten percent increase in the real price of water will result in a one percent decrease in water demand.

The following is an example of an equation used to calculate sector water demand using an econometric approach:

$$E(y) = a + b_1x_1 + b_2x_2 + b_nx_n$$

Where:

$E(y)$ = the expected value of dependent variable (y) as estimated by the function

a = intercept, or the value of (y) when $x = 0$

b = coefficient of x, or the change in y given a change in x

x = value of the independent variable

Based on the available data, two statistical models would be generated, one for combined residential (single-family and multifamily) and one for non-residential. The reason for combining single-family and multifamily into one combined model is because the utilities had very different definitions of what constituted multifamily. The independent variables would therefore be:

- Residential Water Use (gallons per household per day)
- Non Residential Water Use (gallons per employee per day)

The explanatory variables that the statistical model will find relationships to water use are:

- Weather (temperature and precipitation)
- Income
- Price of Water
- Mix of Single-Family and Multifamily Households
- Mix of Industrial (Manufacturing) Employment
- Monthly Binary Variables to Capture Seasonal Variability
- Passive Conservation (that which has occurred from state plumbing codes)
- Active Conservation (that which utilities have implemented)

3.0 Data Sources and Assumptions

A database was built containing data for monthly production, billing, maximum temperature, precipitation, the number of single-family households served, the number of multi-family households served, employment, median household income, employment mix, marginal price, passive conservation, and active conservation for each of the eight utilities from 1990 to 2008 where data was available.

3.1 Water Production and Billing Data

Water billing and production data availability was not uniform for all CWA members. Billing and production data was collected by HDR from a variety of sources, including a Cascade utility survey, Seattle Public Utilities, and the Cascade Water Alliance.

Water production data was organized according to the source of the water. Data for water purchases from the Cascade Water Alliance/Seattle Public Utilities dated back to 1990 for some utilities and monthly data was complete across all utilities, where applicable, for the years 2000 to 2008. One utility, Covington, did not directly purchase water from Cascade Water Alliance/Seattle Public Utilities from 1990 to 2008.

Water production data from independent supplies was available beginning in 1990 for some utilities and was complete for all applicable utilities from 1995 to 2008. Three utilities, Bellevue, Kirkland, and Tukwila, did not acquire any water from independent supply production during the period 1990 to 2008.

Water billing data varied among Cascade Members. Monthly billing data supplied by Seattle Public Utilities was the primary source of data from 1994 to 2003 for the following utilities: Bellevue, Kirkland, Redmond, Skyway, and Tukwila. Complete monthly billing data was available for all utilities from 2006 to 2008.

Cascade utilities utilize bi-monthly customer billing cycles which involve reading customer meters at approximately one-month-long time intervals that overlap with two consecutive calendar months. A data smoothing technique was therefore needed in order to generate monthly water consumption. The following formula was used to estimate the monthly consumption during a particular month (Q_N^c) based on bi-monthly billing data:

$$Q_N^c = (0.25 * Q_N^b) + (0.5 * Q_{N+1}^c) + (0.25 * Q_{N+2}^c)$$

Where:

Q_N^c = estimate of water consumed during month N

Q_N^b= estimate of water billed during month N

3.2 Weather

Base year and the historical normal monthly values for average maximum temperature and precipitation are used in forecasting future water use. Two weather stations, SeaTac and Landsburg, where used to represent the Cascade region. SeaTac weather data dated back to 1949, while Landsburg data dated back to 1931. Figure 2 presents the long-term normal values for average maximum temperature for the two weather stations, while Figure 3 presents the long-term normal values for precipitation. Temperature between the two stations is nearly the same, while precipitation is significantly higher for Landsburg.

Figure 2. Long-Term Normal Average Maximum Temperature for Sea Tac and Landsburg Weather Stations

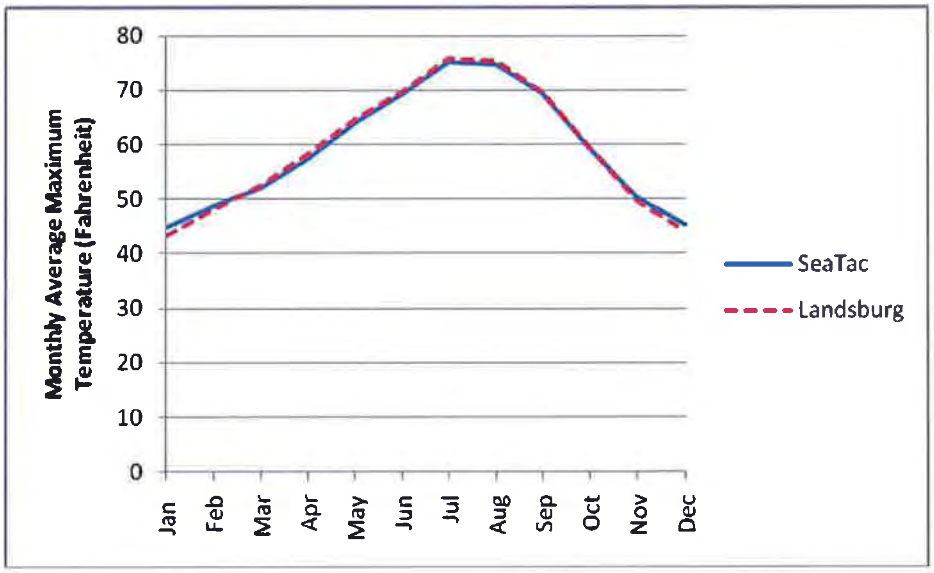
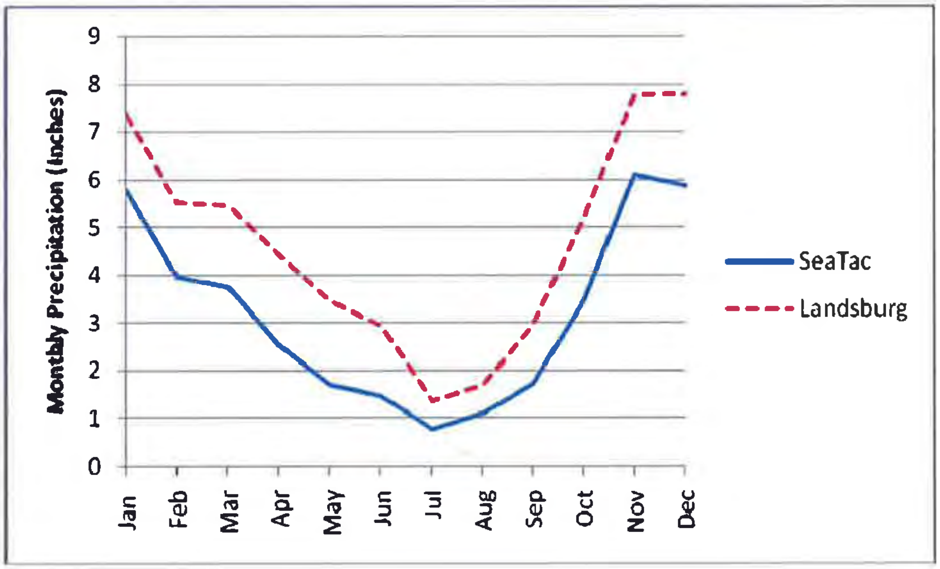


Figure 3. Long-Term Normal Precipitation for Sea Tac and Landsburg Weather Stations



Cascade utilities were assigned to a particular weather station based on geographic proximity to a station. Table 1 lists the assignment of utilities to weather stations.

Table 1
Cascade Utility Weather Station Assignments

SeaTac Weather Station Utilities	Landsburg Weather Station Utilities
Bellevue	Covington
Kirkland	Issaquah
Redmond	Sammamish Plateau
Skyway	
Tukwila	

Temperature and precipitation are strong explanatory variables in predicting water use. Greater temperatures and lower precipitation results in greater water demands due to greater irrigation use and higher process water for industrial and commercial users.

3.3 Demographic and Socioeconomic Data

Demographic data used in the development a water use forecast for Cascade was obtained from the Puget Sound Regional Council (PSRC) from 2000 to 2040. PSRC produces historical and projected demographics at the Traffic Analysis Zone (TAZ) level. A TAZ is an area delimited by a state and/or local transportation official for tabulating traffic and planning related data. A TAZ typically consists of one or more census blocks, block groups, or census tracts. CDM aggregated TAZ level data to each of the Cascade utilities using GIS. Utility boundaries were overlaid against the TAZ boundaries, along with land use data, in order to determine which demographics corresponded to each of the eight Cascade utilities.

Because of the desire to produce a 50-year water demand forecast, CDM extended PSRC demographic projections from 2040 to 2060 using linear extrapolations. Table 2 presents the baseline projections of demographics for the Cascade service area.

Table 2
Baseline Projections of Demographics for Cascade

		Households			Employment	
Year	Population	Total	Single Family	Multifamily	Total	Industrial
2007	357,059	144,481	96,144	48,337	338,152	35,695
2010	371,753	151,150	99,721	51,429	354,101	34,096
2020	423,808	178,798	113,220	65,578	414,296	29,886
2030	465,382	203,705	124,146	79,559	468,547	26,563
2040	507,661	229,508	135,666	93,842	511,342	24,322
2050	554,181	259,387	148,547	110,840	567,427	22,272
2060	605,408	294,074	162,979	131,095	620,523	20,865

Population

Although population as an independent variable is not used to predict water demands using the econometric approach, it is an important driver of other variables such as households and employment. The base year (2007) total population for the eight member utilities was 357,059. The utility with the largest population was Bellevue with 134,221 people, followed by Redmond with 54,811 people. Tukwila had the smallest population in 2007, at just over 7,000 people.

Population is projected to increase to over 605,000 by 2060, representing an average annual growth rate of 1.3 percent.

Households Served

The number of households served water by Cascade utilities is an important forecast driver for future residential water use. Total households are projected to increase from 144,418 in 2007 to just over 294,000 by 2060, representing an annual growth rate of 1.9 percent.

Because single-family homes use more water than multifamily homes, it was also important to track the growth between single-family and multifamily households. Single-family households are expected to increase at an annual rate of 1.3 percent, while multifamily households are expected to increase at an annual rate of 3.1 percent (almost double that of single-family).

Employment

Total employment is the forecast driver non-residential water use. Total employment in the Cascade service area in the base year (2007) is estimated to be 338,152 (or 94 percent of the total population). This does not mean that 94 percent of people living in the Cascade service area are employed. The Cascade service area is rich in employment opportunities, with many corporations and industry located here. People commute from Seattle, and from other counties such as Snohomish and Pierce, to work in Cascade's service area.

Employment is in the area is projected to increase to just over 620,000 by 2060, representing an annual growth rate of 1.5 percent. But because industrial establishments use more water than commercial/institutional establishment, it was important to track industrial employment as well. Due to the changing economy of the region and the loss of many heavy manufacturing, industrial employment is projected to decrease by 42 percent by 2060 from the current level of 36,000.

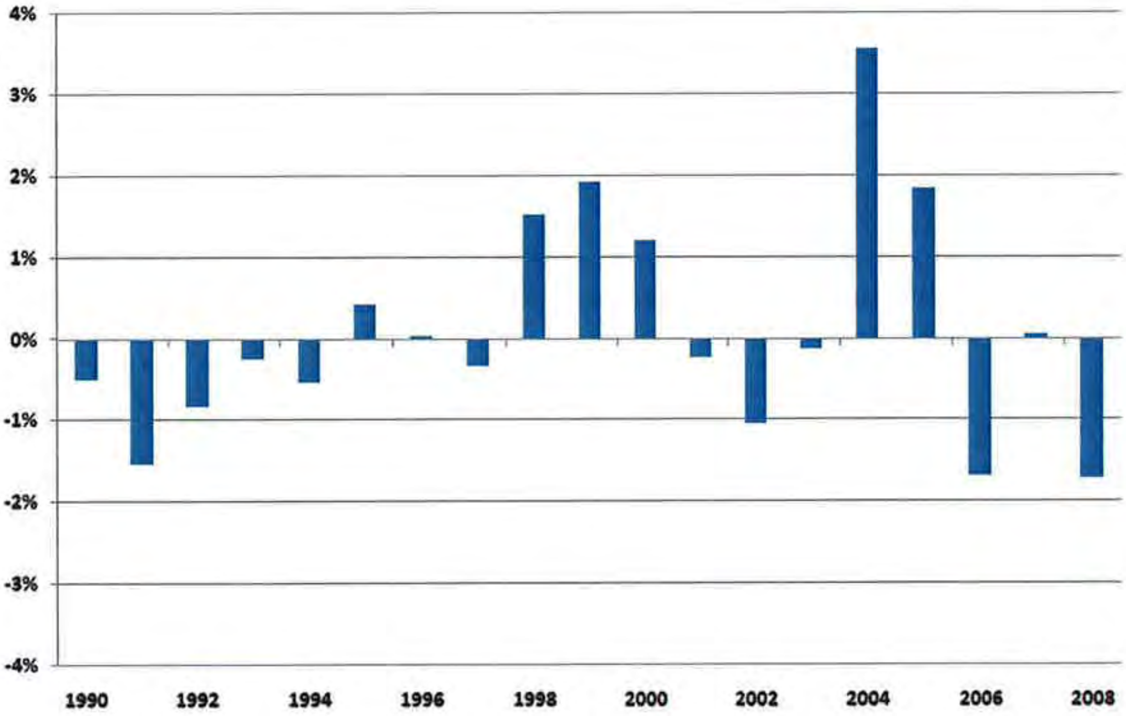
Income

Household income is an important explanatory variable for predicting water demand. Empirical studies across the country for the last 20 years indicate as real (above inflation) incomes go up, so does residential water demand. Homes with greater incomes tend to have bigger yards, irrigate more, have more water using fixtures and use those fixtures with greater frequency.

To generate household income for each of the eight utilities, CDM first used the historical PSRC household income data by quartile. Using this quartile data, CDM estimated the median household income for each utility in 1990 (adjusted to year 2000 dollars). This information was used to get an accurate spatial (across utility) representation of income.

To generate historical income growth from 1990 to 2008, CDM used the personal income data for King County generated by the Washington State Office of Financial Management. This data was adjusted to reflect real income in year 2000 dollars. The real growth rates in personal income were then applied to the 1990 household income by utility in order to get utility specific income data. Figure 4 shows the real income growth for the aggregate of the Cascade utilities from 1990 to 2008. From 1990 to 2000, real income grew by 3 percent, or just under 0.3 percent annually. This was considered to be a period of average economic growth according to the Office of Financial Management. From 2001 to 2008, real income only grew by 0.1 percent. This period was considered to be poor in terms of overall economic growth. Although population and employment continued to increase during this time, wages and the loss of manufacturing in the region produced stagnant income growth.

Figure 4. Annual Changes in Real Household Income for Cascade Service Area



Since no localized projections of personal or household income were available, CDM made baseline assumptions regarding real income growth into the future based on the historical income. From 2010 to 2020, the assumed real increase in income for the Cascade service area is 0.2 percent annually. After 2020, the assumed real increase in income will increase 0.4 percent annually by 2060.

Price of Water

The price of water at the margin is another explanatory variable in predicting both residential and non-residential water use. Empirical studies in the last 30 years indicate that as real marginal price increases, water use tends to decrease. The marginal price of water is determined by the commodity charge to the average customer for water and sewer service. It is an explanatory variable input into the database to forecast both residential and non-residential water demand. Each Cascade utility sets its own pricing structure with the marginal price of water based on the amount of water consumed per account. Pricing structures vary among Cascade utilities. Most have implemented block rate structures whereby the per unit price of water increases as water use increase. Some utilities also employ a higher per unit charges during the summer season as a way to conserve water during times of peak usage. One utility, Tukwila, implements neither a block rate structure, nor a summer season rate.

All Cascade utilities base their water pricing structures on the charge per hundred cubic feet (ccf) of water. To calculate the marginal price of water for a particular utility during a particular month, the water use factor (gallons per day per household/employee) was converted to hundred cubic feet per month.

For the purposes of this forecast the residential marginal price of water was determined using the mean water use factor for single family and multi-family household consumption. The mean single family water use factor was approximately 200 gallons per day (8.1 ccf per month). The mean multifamily water use factor was approximately 120 gallons per day (5 ccf per month). The non-residential marginal price was based on the per unit charge for the highest tier of use or the per unit charge in the absence of a tiered water pricing structure.

Marginal price data was converted to year 2000 dollars using the monthly Consumer Price Index (CPI). The real dollar amount, used to account for inflation, was calculated for the marginal price data and entered into the database for each utility for each month.

To calculate a residential marginal price for each utility, the single family and multi-family marginal price for each month was weighted by the number of single family and multifamily households respectively for each month and for each utility. Next, the base year marginal price was weighted by total households served across all utilities for each month to get an overall Cascade residential marginal price for each month. Finally, the twelve month baseline year marginal price average was calculated and used as the baseline year residential marginal price.

To project real increases in the marginal price of water, financial data and projected costs for Cascade were used. The demand model assumes a 1.4 annual percent increase in real marginal price for both the residential and non-residential sectors for the period 2007 to 2015. A 2 percent annual increase in marginal price is assumed from 2015 to 2025. A 1 percent annual increase in marginal price is assumed from 2025 to 2035. A 0.5 percent increase in marginal price is assumed from 2035 to 2050. The demand model assumes no real increases in price from 2050 to 2060.

3.4 Water Conservation

Passive Conservation

In 1992 Congress passed the Energy Policy Act of 1992 which, among other measures, set maximum flow rates for toilets, urinals, showerheads, and faucets sold in the United States. To estimate passive water conservation, the ratio of post 1992 households to total households was used. The theory is that newer homes will use less water than pre-1992 homes. By 2007, the percentage of post-1992 households was estimated to be 65 percent. Assuming remodeling rates and useful life of plumbing fixtures, it is estimated that 100 percent of households in Cascade's service area will be compliant with the 1992 plumbing codes by 2060.

Active Conservation

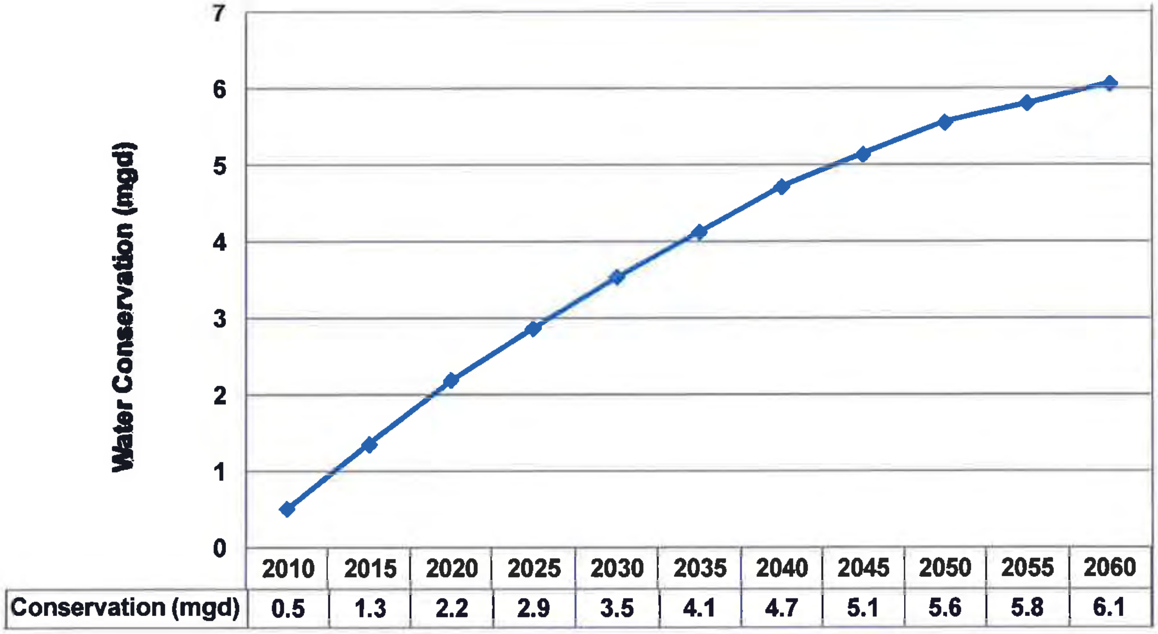
Active water conservation data was collected from individual utility water plans. For the water demand model, a variable called active conservation was created that reflected the number of residential and non-residential active conservation programs being implemented from 1994 to 2008.

Future levels of water conservation were based on active water conservation that Cascade is implementing currently (see Figure 5). This future active conservation is expected to increase from the current (2007) levels of 0.5 million gallons per day (mgd) to 6.1 mgd by 2060. This is considered in the demand forecast as a baseline level of active conservation. More aggressive conservation beyond these levels are evaluated as future water supply options for Cascade.

3.5 Non-Revenue Water

Non-revenue water is that which is not billed to water customers. It can represent water for fire protection, system flushing of mains, unaccounted water, and system losses. Non-revenue water was estimated by taking the difference between total water production and total water consumed (or billed). Using the utility data from 1994 to 2008, the weighted average non-revenue water was estimated to be 7.4 percent of total water production. This number is about average for utilities in the western United States. For forecast purposes, it is assumed that the non-revenue water will remain at 7.4 percent through 2060.

Figure 5. Projected Levels of Baseline Water Conservation for Cascade



	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Conservation (mgd)	0.5	1.3	2.2	2.9	3.5	4.1	4.7	5.1	5.6	5.8	6.1

4.0 Econometric Models for Cascade Forecast

To calculate the explanatory variable coefficients, a multivariate regression analysis was run using Statistics Analysis Software (SAS) to produce a model for both the residential and non-residential sectors. A log model was estimated to improve the overall fit of the data. In a log model, all variables represent the natural log of the raw data. The use of log variables is common practice in estimating econometric models.

The explanatory variable coefficients (or elasticities) derived from these statistical models will result in changes to per household and per employee water use rates over time. These modified use rates will then be multiplied by the number of projected households and employees (drivers) to determine the residential and non-residential water demands.

4.1 Residential Model

The baseline forecast utilizes a combined single family and multi-family residential model. The dependent variable for the model is the log of monthly residential household water use (gallons per home per day). Table 3 presents the estimated residential model, based on 924 observations derived from data from 8 member utilities. The model explains approximately 76 percent of the variation in water use among the residential water use observations.

Table 3
Residential Water Demand Statistical Regression Model

Number of Observations	924
Adj. R-Square	0.765

Explanatory Variables	Parameter Estimate	Standard Error	t Value	Pr >t
Intercept	-0.6036	0.3654	-1.65	0.0989
January Indicator (0/1)	0.0342	0.0168	2.04	0.0421
February Indicator (0/1)	0.0274	0.0164	1.67	0.0957
April Indicator (0/1)	0.3964	0.0164	2.41	0.0160
May Indicator (0/1)	0.1154	0.0164	7.02	<.0001
June Indicator (0/1)	0.2675	0.0165	16.25	<.0001
July Indicator (0/1)	0.3776	0.0166	22.77	<.0001
August Indicator (0/1)	0.4335	0.0169	25.70	<.0001
September Indicator (0/1)	0.3254	0.0166	19.63	<.0001
October Indicator (0/1)	0.1708	0.0166	10.32	<.0001
November Indicator (0/1)	0.0415	0.0168	2.46	0.0140
Departure of log Precipitation from long-term	-0.0111	0.0058	-1.92	0.0546
Departure of log Maximum Temperature from	0.4506	0.1028	4.38	<0.001
log Percent Multifamily Households to Total	-0.1913	0.0095	-19.1	<.0001
log Median Household Income (year 2000 dollars)	0.4947	0.0339	14.59	<.0001
log Marginal Price of Water (year 2000 dollars)	-0.0404	0.0047	-8.67	<.0001
log Passive Conservation Indicator (% new homes	-0.0728	0.0386	-1.89	<.0594
log Active Residential Conservation (# of	-0.0309	0.0054	-5.75	<.0001

All of the variables in the model had the expected correct signs and were significant at the 10 percent level, with many of the variables significant at the one thousand of one percent level.

The weather components of the model include a monthly binary, the monthly precipitation departure from normal, and the monthly maximum temperature departure from normal. The monthly binary variables capture the effects of seasonality on residential water use. The binary variables for March and December were not significant and thus excluded from the model.

The demographic component of the residential model consists of a single variable, percent of total households that are classified as multifamily. This variable captures the effect of multi-family residential water use on the variation in total residential water use. The coefficient indicates that a one percent increase in the percent of multifamily households is estimated to produce a 0.19 percent decrease in residential water use.

The socioeconomic component of the model consists of two variables, median household income and marginal price. According to the model, median household income is the strongest indicator of the variation in residential water use. A one percent increase in median household income is estimated to lead to a 0.49 percent increase in residential water use. The marginal price variable is also a significant explanatory variable. The marginal price coefficient indicates that a one percent increase in price is estimated to produce a 0.04 percent decrease in residential water use.

The passive conservation indicator and the active conservation indicator are the two explanatory conservation variables in the residential model. Each of the two variables is statistically significant and both had the correct sign. A one percent increase in the passive conservation indicator is estimated to produce a 0.07 percent decrease in residential water use. A one percent increase in the active conservation indicator is estimated to produce a 0.03 percent decrease in residential water use.

4.2 Non-Residential Model

Table 4 presents the water demand model for the non-residential sector. The model is based on 910 observations and the four explanatory variables explain about 44 percent of the variation in water use among non-residential water use observations. All variables were significant and had the correct anticipated sign.

The socioeconomic component of the model is the marginal price variable. The model estimates show that a one percent increase in the non-residential marginal price of water is estimated to reduce non-residential water use by about 0.17 percent.

The demographic component of the model is the ratio of manufacturing employment to total employment. The manufacturing ratio is equal to the total number of manufacturing employees for a given month divided by the total number of employees for that month.

The model shows that a one percent increase in the manufacturing employment ratio is estimated to increase non-residential water use by almost 0.21 percent.

The observed maximum temperature is the explanatory weather variable in the non-residential model. The model shows a very strong relationship between maximum temperature and non-residential water use. The observed maximum temperature coefficient implies that a one percent increase in maximum temperature is estimated to produce a 1.4 percent increase in non-residential water use.

The conservation explanatory variable in the model is the count of active non-residential conservation programs. The model shows that a one percent increase in the number of active non-residential water conservation programs is estimated to produce a 0.05 percent decrease in the non-residential sector gallons per day.

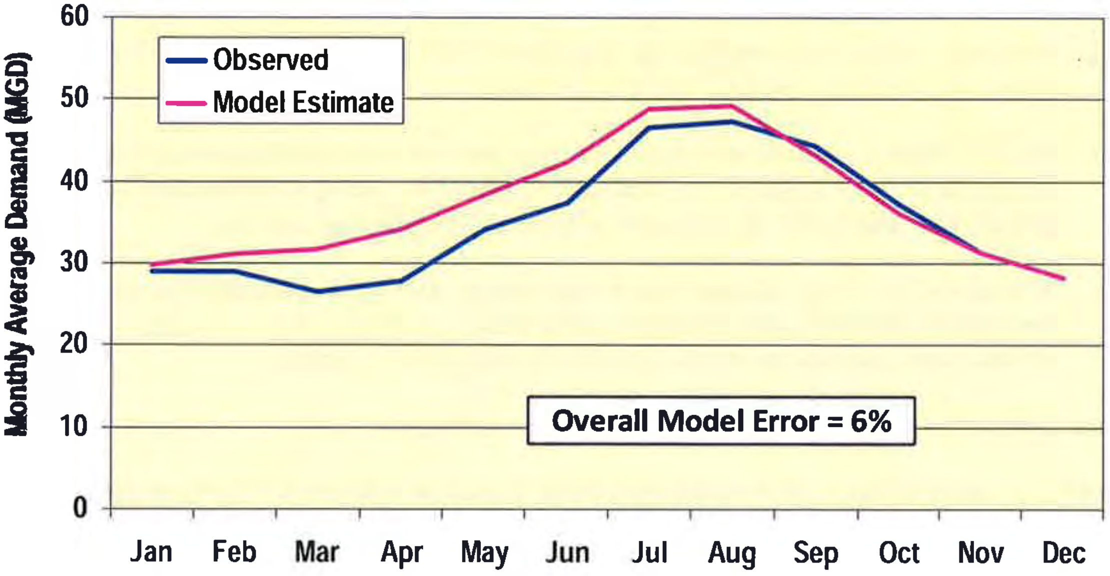
Table 4
Non-Residential Water Demand Model

Number of Observations			910	
Adj. R-Square			0.4444	
Explanatory Variables	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	-1.7232	0.2918	-5.91	<.0001
log Marginal Price of Water (year 2000 dollars)	-0.1757	0.0132	-13.27	<.0001
log Manufacturing Employment Ratio (% to total)	0.2147	0.0135	15.89	<.0001
log Maximum Temperature	1.4589	0.0715	20.41	<.0001
log Active Non-Residential Conservation (# of programs)	-0.0495	0.0180	-2.75	0.0060

4.3 Demand Model Verification

In order to test the overall accuracy of the combined residential and non-residential demand models, actual weather data and demographic data was input to the model for 2007. Then the results of the models were compared to actual water consumption for 2007. Figure 6 presents this comparison. As shown, the empirical demand models represent actual water consumption fairly well. Overall, the model error is approximately 6 percent.

Figure 6. Comparison of Demand Model Results to Actual Consumption for 2007



5.0 Water Demand Forecast

5.1 Uncertainty Approach and Assumptions

CDM developed a spreadsheet tool to forecast water demands, using the econometric models described in Section 4, along with projected demographic drivers and projected explanatory drivers. The software package called @Risk, which works in MS Excel, was utilized to produce probabilistic ranges in the demand forecast based on key uncertainties. For those variables that wish to be evaluated in terms of uncertainty, @Risk produces probability distribution function (PDF) using Monte Carlo simulation. Monte Carlo simulation involves random draws from either a predetermined range of data or estimated range of data using a selected distribution type (e.g., normal distribution, triangular, or skewed). @Risk also allows for correlations between certain variables to be estimated, which can impact the range of outputs. For example, temperature and precipitation are correlated (meaning when temperature increases, precipitation tends to decrease).

The variables that were included as part of the uncertainty analysis of water demand included:

1. Number of Households – Alternative PSRC demographic forecasts were used to establish lower and upper bound estimates, and @Risk was used to generate a normally distributed sample.

2. Total Employment – Alternative PSRC demographic forecasts were used to establish lower and upper bound estimates, and @Risk was used to generate a normally distributed sample.

3. Weather – Historical weather for the years 1949 to 2007 were used to generate a distribution of temperature and precipitation.

4. Price of Water – Upper and lower ranges around the baseline projection of marginal price of water were established by CDM, using professional judgment, and @Risk was used to generate a normally distributed sample.

5. Household Income – Upper and lower ranges around the baseline projection of household income were established by CDM, using professional judgment, and @Risk was used to generate a normally distributed sample.

Table 5 presents the projected ranges for these variables.

In addition, several alternative scenarios were tested as sensitivity in the water demand forecast:

Climate Change Scenario

In 2006, King County formed the Climate Change Technical Committee, made up of participants from King County, Seattle Public Utilities, Cascade Water Alliance, and other members. A technical report was generated that summarized a process used to select a represented sample from a dozen global circulation models and carbon emission scenarios. This sample of climate change was also used for the 2008 Regional Municipal Water Supply Outlook. The three represented climate change scenarios are:

a. GISS_ B1: "warm" regional climate change scenario with nearly the smallest increase in temperature, and nearly the largest decrease in precipitation

b. ECHAM5_A2: "warmer" regional climate change scenario with mid-range increases in both temperature and precipitation

c. IPSL_A2: "warmest" regional climate change scenario with large increase in temperature, and nearly the largest increase in precipitation

@Risk was then used randomly select from these three climate change scenarios in order to produce future estimates of temperature and precipitation. Table 6 presents a summary of how July temperature and annual precipitation change as a result of potential climate change.

Table 5
Ranges in Demographic, Socioeconomic and Weather Data Used for Uncertainty Analysis of Water Demand

	Number of Total Households			Total Employment		
Year	Min Value	Mean Value	Max Value	Min Value	Mean Value	Max Value
2010	148,183	151,638	155,091	349,125	354,060	358,994
2020	172,684	178,936	185,187	405,691	414,739	423,783
2030	192,548	203,242	213,931	449,985	468,082	486,172
2040	214,573	229,378	244,179	483,611	511,582	539,538
2050	237,776	259,161	280,542	525,696	561,888	598,073
2060	265,114	294,722	324,325	571,551	620,908	670,242

	Real Price of Water ($/HCF)			Real Household Income		
Year	Min Value	Mean Value	Max Value	Min Value	Mean Value	Max Value
2010	$2.44	$2.47	$2.50	$72,668	$72,997	$73,326
2020	$2.76	$2.92	$3.08	$73,462	$74,285	$75,107
2030	$3.15	$3.38	$3.61	$74,518	$76,163	$77,807
2040	$3.19	$3.65	$4.11	$75,517	$78,479	$81,439
2050	$3.17	$3.75	$4.33	$76,828	$81,270	$85,711
2060	$3.06	$3.75	$4.44	$77,743	$84,159	$90,573

	Average Monthly Max. Temperature (oF)			Monthly Precipitation (inches)		
Month	Min Value	Mean Value	Max Value	Min Value	Mean Value	Max Value
Jan	21.6	43.6	64.8	2.3	6.6	11.6
Feb	35.5	48.7	61.3	1.7	4.7	8.9
Mar	34.7	51.1	67.0	1.5	4.3	7.0
Apr	44.9	57.5	79.4	1.1	3.3	5.6
May	56.5	64.4	91.7	0.6	2.3	4.0
Jun	56.7	69.4	83.7	0.2	2.0	3.8
Jul	61.0	75.2	88.9	0.0	1.0	2.4
Aug	54.8	74.7	95.3	0.2	1.4	3.7
Sep	57.5	69.6	81.4	0.2	2.1	4.9
Oct	53.8	59.6	65.0	1.0	4.0	8.2
Nov	41.1	50.3	60.4	1.9	6.5	11.2
Dec	33.3	44.7	55.8	2.9	6.6	10.3
Ave/Total	46.0	59.1	74.6	13.7	44.8	81.5

Table 6
Projections of Temperature and Rainfall Based on Climate Change Scenarios

	Average Max. July Temperature (oF)			Mean Annual Precipitation (inches)		
Year	Low Scenario	Av. Scenario	High Scenario	Low Scenario	Av. Scenario	High Scenario
Current	75.2	75.2	75.2	44.8	44.8	44.8
2020	77.8	78.1	78.4	45.0	47.2	49.3
2040	78.7	79.0	79.5	45.3	47.8	50.2
2060	79.1	81.1	81.3	45.8	48.5	51.1

Regional Demand Contingency

One variable that Cascade wanted to test was regional demand contingency. This variable estimates the potential impact of additional demands for Cascade due to: (1) local supplies of water systems outside the eight Cascade members are compromised by contamination or regulatory actions; (2) Climate change leads to higher than expected demand throughout the region or reduced yield of existing regional or local supplies for water systems outside the eight Cascade members; or (3) growth in demand of local water systems not served by a regional supplier exceeds the capacity of local supplies. Any of these scenarios (or a combination of all three) could lead water systems in the region to request supplies from Cascade. This would represent an additional demand on top of the demands forecast by the econometric models discussed above. Therefore a demand contingency of 10 mgd was identified. The lower range of this regional demand contingency was set to 0 mgd, while the upper range was set at 20 mgd. A triangular distribution was assumed using @Risk to generate a sample. Table 7 presents the regional demand contingency.

Table 7
Regional Demand Contingency (mgd)

Year	Low Range	Average Range	High Range
2010	0.0	0.0	0.0
2020	0.0	0.0	0.0
2030	0.0	0.3	2.5
2040	0.0	3.5	8.7
2050	0.0	6.8	14.0
2060	0.0	10.0	20.0

5.2 Demand Forecast Scenarios and Results

Working closely with Cascade, CDM developed three demand forecasting scenarios:

1. No climate change and no regional contingency water demands
2. With climate change and no regional contingency water demands
3. With climate change and with regional contingency water demands

For each of these demand forecast scenarios, a range of water demand forecasts are produced by the @Risk model. Table 8 summarizes the mean (or average) value of water demands for the three scenarios.

Table 8
Mean Water Demand Forecast Results (mgd)

Demand Forecast Scenario	2010	2020	2030	2040	2050	2060
No climate change, no regional demand contingency (baseline)	40.33	43.01	47.87	52.18	57.98	65.60
With climate change, no regional demand contingency	41.16	44.13	49.35	54.05	60.31	68.87
With climate change, with regional demand contingency	41.18	44.14	49.69	57.62	67.13	78.87

Climate change alone adds approximately 3 mgd of water demand to the baseline forecast scenario by 2060, while regional contingency alone adds 10 mgd of water demand by 2060. Table 9 presents the full range of water demand forecasts. The 95% level represents the demand which is expected to be exceeded 95 percent of the time, while the 5% level represents the demand which is expected to be exceeded 5 percent of the time.

Table 9
Full Range of Water Demand Forecast Results (mgd)

	No Climate Change, No Regional Demand Contingency				
Year	min	95%	mean	5%	max
2010	37.75	39.29	40.33	41.39	43.49
2020	39.36	41.52	43.01	44.50	46.93
2030	42.51	45.52	47.87	50.23	53.69
2040	43.75	48.93	52.18	55.41	60.23
2050	46.42	53.39	57.98	62.58	69.72
2060	51.47	59.27	65.60	72.11	80.93

	With Climate Change, No Regional Demand Contingency				
Year	min	95%	mean	5%	max
2010	38.56	40.08	41.16	42.26	44.74
2020	40.20	42.62	44.13	45.67	48.06
2030	43.51	46.95	49.35	51.80	55.33
2040	45.43	50.71	54.05	57.41	62.28
2050	49.55	55.65	60.31	65.05	71.52
2060	53.55	62.25	68.87	75.57	85.26

	With Climate Change, With Regional Demand Contingency				
Year	min	95%	mean	5%	max
2010	38.67	40.10	41.18	42.28	44.74
2020	40.39	42.61	44.14	45.71	48.06
2030	44.34	47.25	49.69	52.13	55.33
2040	47.71	53.49	57.62	61.77	67.12
2050	52.84	60.58	67.13	73.75	81.76
2060	57.59	69.38	78.87	88.44	99.40

Figures 7 through 9 present the full range in water demand forecasts for the three scenarios. The shaded area in these figures represents the entire range of the forecast, while the 95% and 5% exceedance represent the demands that could be exceeded 95 percent of the time or 5 percent of the time, respectively. As shown, the 95% and 5% exceedance forecasts are much tighter than the full range (shaded area). This is due to the normal (or bell shaped) distribution that is assumed for the demand drivers and explanatory variables shown in Table 4. Normal distributions assume that the bulk of the outcomes are clustered closer to the mean, and that the tails of the distribution are less probable.

Figure 7. Demand Forecast: No Climate Change, No Regional Contingency

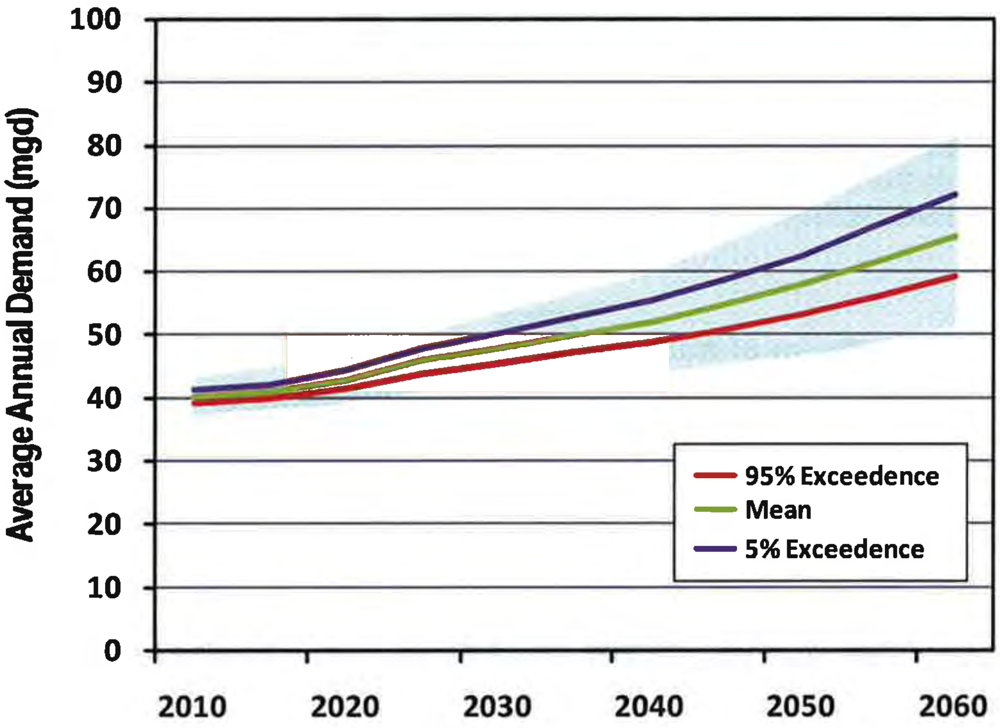


Figure 8. Demand Forecast: With Climate Change, No Regional Contingency

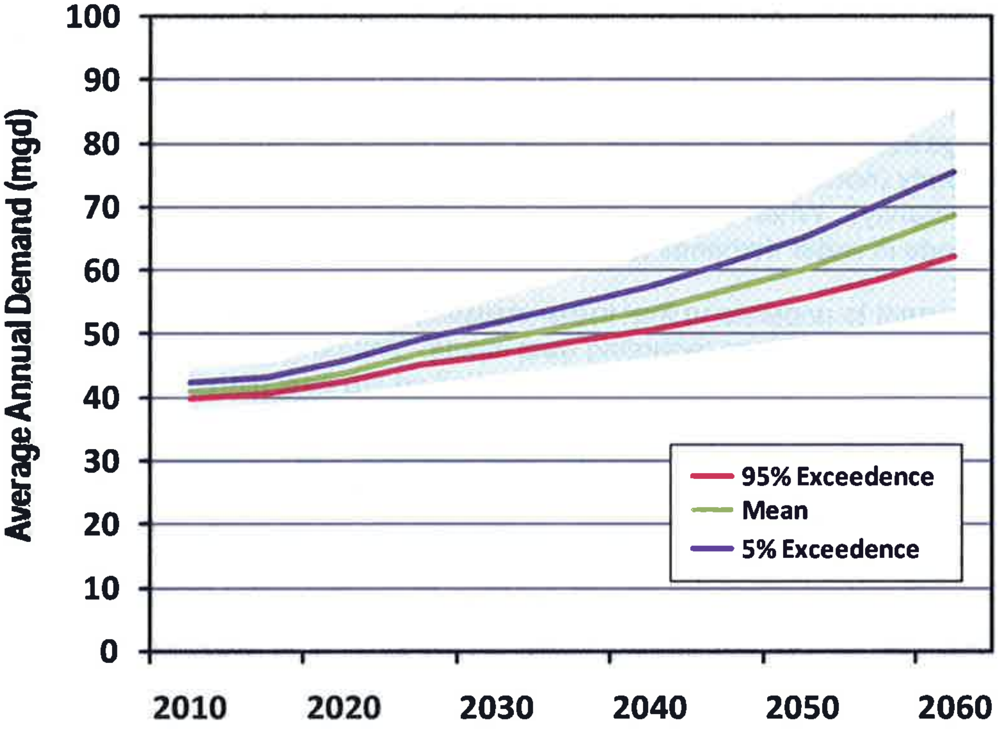
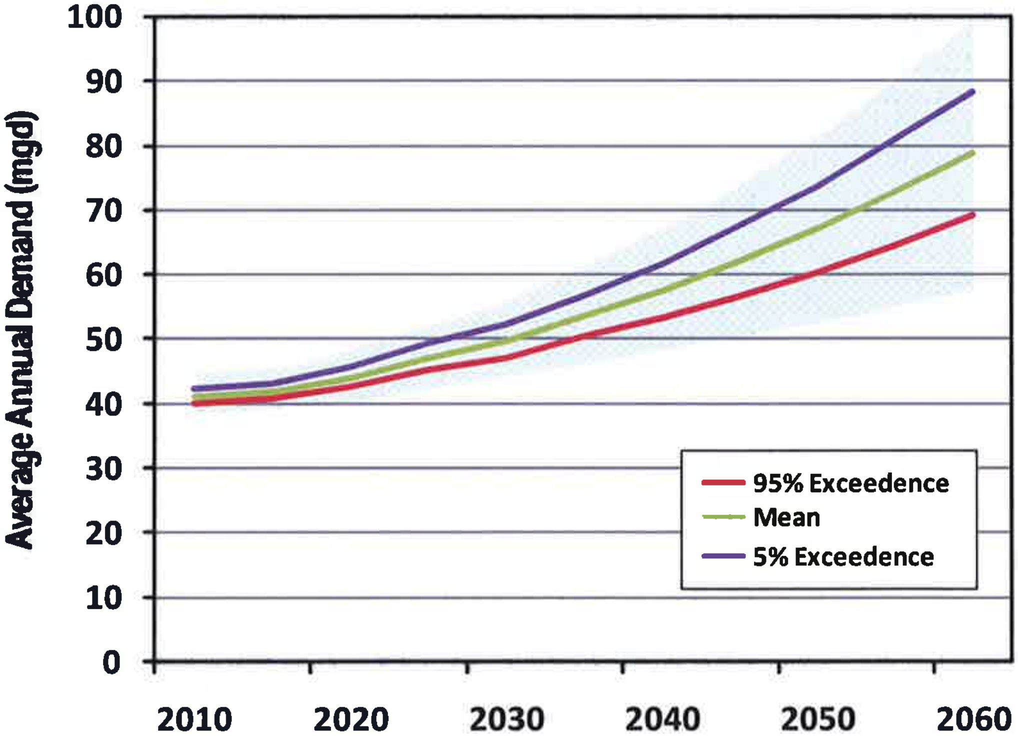


Figure 9. Demand Forecast: With Climate Change, With Regional Contingency



6.0 Conclusion

The comprehensive water demand forecast for Cascade indicates that the most likely range (90% confidence) without climate change or regional demand contingency is between 60 and 72 mgd by 2060. This range increases to 62 to 76 mgd by 2060 if climate change materializes as depicted in the three possible climate change models used in this study (note, there are approximately a dozen climate models vetted by the scientific community). When climate change and regional contingency are included, the most likely range in water demands is 69 to 88 mgd by 2060.

Also, it is important to understand that these statistical ranges in demand forecasts are based on a set of assumptions regarding data inputs. The range in data inputs may not reflect the entire possibility of outcomes. CDM relied on the best planning information available in setting these ranges, and only used professional judgment when planning information was not available. It is strongly recommended that these data inputs be revisited at least every 5 years in order to evaluate the short and long term trends of demographics, income and price of water. In addition, as future water conservation programs are implemented in the region, water usage may change (possibly dramatically). Therefore, Cascade should continue to monitor water demand trends in the service area.