

## **Appendix N**

### **Water Demand Verification and Backcast**





## Draft Technical Memorandum

*To: Don Wright, Forum Project Manager*

*From: Dan Rodrigo, CDM Project Manager  
Bill Davis*

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Task 13 –Water Demand Model Verification and Backcast*

### Introduction

This technical memorandum describes the results, methodology and assumptions used in verification of the Central Puget Sound Water Suppliers Forum Water Demand Forecast Model (Model) results under Task 13, and the use of the Model to backcast historical water use. Task 13 was an addition to the original scope of work. The purpose of the model verification and backcast procedures is to (a) increase confidence in the model by demonstrating the reliability and accuracy of its estimated water use, and (b) diagnostically test the model for systematic problems.

The model verification process uses model inputs for the year 2005 and compares the resulting model estimated water demand with recorded water demand in 2005. Similarly, the backcast process uses model inputs for a historical year (in this case the year 2000) and compares the model results with recorded water use in 2000.

In accordance with the memo received from Forum Project Manager on March 3, 2008, model validation and backcast are performed for the retail service areas of the three large water systems, Seattle, Tacoma, and Everett, for the year 2005. The verification and backcast comparisons exclude the wholesale water sales of these three providers. In addition, since the computation of non-revenue water (NRW) losses for each provider is based upon total consumption (including wholesale deliveries), the verification and backcast comparisons are conducted with the *retail* water demand only, excluding wholesale and NRW water.

It is important to recall that the Water Demand Model is not a utility-level forecast model, but rather a regional planning model. This point was emphasized that the forecast is not being developed at the utility level. However, there is no information available regarding the total regional water demand for comparative and verification purposes. Thus the verification and back cast “tests” of the model are limited to utility-level comparisons. In other words, the verification process is comparing the water demand forecast estimated by the model for specifically defined planning sub-regions with actual utility water use data. For the Seattle

Retail sub-region and the Tacoma Retail sub-region, the comparison with utility data is a reasonable comparison. However, the Everett sub-region is defined as being limited to only the Everett retail service area. Thus, the model water use factors and demographic data developed for the Everett sub-region reflect water use patterns for more than the Everett retail area.

Typically, model verification can be performed as a mathematical check for a utility level model. However, since the Water Demand Model is a regional model of aggregate utility-level data, such mathematical precision may not be possible. Differences in the model forecast and observed data may exist due to: (a) different definitions and classification of sectors (e.g., PSRC definition of single-family versus each utility's classification of single-family customers), (b) delineation of service area boundaries as applied to PSRC demographic data versus actual customer counts by each utility, and (c) averaging of water use factors representing water use in each sector from available data. Generalized regional assumptions were input into the water demand forecast model to re-create the forecasts for the verification and backcast. In order to achieve the level of accuracy of a utility-level forecast, all model inputs would need to be utility specific and historically accurate.

The intent of the verification and backcast exercise was to test the performance of the regional model, not to replicate utility-level demand. For long-range regional planning, a model error of five percent or less is deemed acceptable. A *utility-level* water demand model developed by CDM for the City of San Diego Water Department was within one-half of a percent of estimating actual water demand in the base year *after* having been calibrated. Similarly a utility-level water demand model developed for the Miami-Dade Water and Sewer Department was within one percent of reported water use in the base year. In both of these examples, the utility-level models are based upon utility billing information and utility-specific demographic data. For a regional demand model such as the CPS Demand Model, which is based upon generalized information and regional assumptions, a model error of five percent can be anticipated.

## **Model Verification**

In theory, model verification should provide an exact replication of actual water use in the base year. That is, if the model consists of a water use factor, which is actual water use divided by the number of users, that is multiplied by the number of users, then the result should be the actual water use. Again, the water use factor consists of a "numerator", which is base year water use, and a "denominator", which is the number of users. The model "demographic driver" is the number of users in a given year, such as the base year and each forecast year. The estimated water use is the water use factor times the demographic driver.

The CPS Forum Water Demand Model is more complex than this simple example in that (a) the water use factor is a weighted average factor given the purveyors within each sub-region, although the Seattle and Tacoma sub-regions are defined

as single utility retail areas, and (b) the water use factor is adjusted for income and price change, as well as weather in the summer months and conservation savings from the base year.

The validation model run utilized the reported weather data for 2005 from the SeaTac, Buckley, and Everett weather stations for the three provider service areas (Seattle, Tacoma and Everett), respectively.

No adjustments were made for conservation or price of water default settings of the model.

Retail water demand in 2005 was obtained from the Forum utility survey for the Seattle service area. However, 2005 retail water demands for the Tacoma and Everett service areas were obtained from their respective Comprehensive Water Plans (Comp Plan) in order to incorporate non-potable large water use into the comparison.

Results of the validation comparison are shown in **Table 1**. The verification run of the Water Demand Model over-estimates aggregate water demand of the three utilities by 3.2 percent. However, for individual utilities and sectors the model estimates exceed actual water use from 0 to 12 percent. Most of the difference occurs in the single-family sector comparison. As noted above, the verification procedure should be able to reproduce actual water use when the water use factor is multiplied by the number of users because the number of users is the denominator of the water use factor. However, this is not the case in the single-family sector.

The single-family water use factor is derived by dividing the base period water use by the number of single-family accounts reported by utilities in the purveyor surveys. The Model generates the water demand forecast by multiplying the single-family water use factor by the number of single-family households as determined by PSRC data. The model verification for the single-family sector is not exact because of this difference between the “denominator of the water use factor” and the “demographic driver”.

In addition, the number of households used in the verification forecast is an interpolated value from the PSRC demographic data. PSRC provided housing data for the year 2000 and at 10 year intervals out into the future. Thus, the number of households in the base year is an interpolated value between 2000 and 2010, and may not be exact for the base year in each of the three validation service areas. Furthermore, the GIS processing of PSRC demographic data by Traffic Analysis Zone (TAZ) level into the respective purveyor service area boundaries may not accurately reflect the exact service area of each purveyor in the base year.

It should also be noted that the water use for the base period used to derive the water use factor is an average of water use in the years 2004-2006 as reported in

the purveyor survey. Thus, the “numerator of the water use factor” is not exact to the base year in each of the validation service areas.

The differences are most pronounced in the Everett retail area. This may be due to more pronounced differences between the PSRC demographic data and actual customer data as just described. Again, the Everett sub-region is not synonymous with the Everett retail area. Furthermore, it may be that the regional weather elasticities used in the Model are a “better fit” for Seattle and Tacoma than for Everett. This discrepancy again emphasizes that the Forum Model was designed to be, and performs well as, a regional model and is not a utility level forecasting model.

<b>Table 1 - CPS Model Validation: Comparison of Model Predicted Demand and Actual Demand in 2005</b>							
		<b>SF</b>	<b>MF</b>	<b>NR***</b>	<b>Large User</b>	<b>Total NR</b>	<b>Total Retail</b>
Seattle*	Model	23.3	12.4	20.1	3.6	23.6	59.4
	Actual	22.6	12.2	23.2	0.0	23.2	58.1
	Model Difference	3.1%	1.7%			1.8%	2.3%
Tacoma**	Model	18.1	5.7	9.0	15.8	24.8	48.6
	Actual	17.6	5.7	24.8	0.0	24.8	48.1
	Model Difference	2.7%	0.9%			0.0%	1.1%
Everett**	Model	4.5	2.8	1.4	29.8	31.3	38.6
	Actual	4.0	2.6	29.1	0.0	29.1	35.7
	Model Difference	12.2%	8.3%			7.4%	8.0%
Total of 3	Sum of Models	45.9	20.9	30.5	49.2	79.7	146.6
	Sum of Actual	44.2	20.5	77.1	0	77.1	141.9
	Difference of Sums	3.7%	1.9%			3.3%	3.2%

\*Seattle's 2005 actual water use is from utility survey

\*\*Tacoma and Everett's 2005 actual water use is from their utility comprehensive water plans

\*\*\*Nonresidential actual water use includes large user demand for all three utilities

## Model Backcast

Model backcasting is a procedure in which actual historical data from a year prior to the model base year are input into the model to see how well the model estimates the observed water use in that historical year. The purpose of the backcast is to demonstrate the model's reliability and identify possible problems with the model.

CPS Forum Model input values were determined for the year 2000 and entered into the Model as input for a “forecast” year. Thus, the Model was used to estimate water demand in a year prior to the base period of the model. This *backcast* was

performed for the same three retail water service areas as the verification (i.e., Seattle, Tacoma and Everett). Given the time and budget constraints of producing the verification and backcast, *CDM developed estimates of year 2000 input data, rather than obtain actual 2000 data for each of the three areas.*

As with the verification input data, the demographic data (i.e., housing, employment and population) for 2000 for the three service areas were obtained from PSRC data. As described in the verification section above, there may be differences between PSRC data by TAZ and actual service area demographics for the three areas, as well as differences between the PSRC number of households and actual number of residential accounts.

In addition, since single-family household data are adjusted within the model to reflect the percent of households served, assumptions had to be made about the percent of households served by the three providers in the year 2000. Seattle service area percent of households served in 2000 was assumed to be 100 percent, as in 2005. Tacoma service area percent of households served in 2000 was assumed to be 100 percent, as in 2005 for the King County portion of the service area, but only 98 percent in 2000 for the Pierce County portion of the service area. Everett service area percent of households served in 2000 was assumed to be 88 percent, as in 2005. *Some differences between the demographic data delineated for provider service areas for the Water Demand Model and actual service area customer base are anticipated.*

Water use factors “beyond” the base year are adjusted for changes in the real price of water, household income, and mix of employment among employment groups. The single-family and multifamily water use factors are adjusted for the growth in both price and income, while the nonresidential water use factor is adjusted for the growth in price and the change in employment mix.

The change in employment mix for each service area is calculated within the Model from employment data entered into the Model for the base year and 2000. There are minor shifts in employment by employment group within each service area. The most noticeable change is a shift in manufacturing employment within the Everett service area.

The assumed growth rate in real income of one percent per year from 2005 to 2010 was regressively applied to obtain the income adjustment for the year 2000. Thus, the real income in 2000 is only 96 percent of 2005 income. This generalization may lead to some inaccuracy in the water demand backcast. In fact, actual income growth between 2000 and 2005 was much less than the assumed rate of growth as the economy was in recession for much of that time period.

Water rates in 2000 from the three providers were compared with the rates in 2005. Everett rates remained the same. This means that the *real* (inflation-adjusted) price of water changed in proportion to the Consumer Price Index (CPI) between 2000 and 2005. Since inflation decreased the purchasing power of the

dollar by 11.7 percent from 2000 to 2005, Everett's rate for water was 11.7 percent higher in 2000 than in 2005 in real dollars. Seattle and Tacoma had rate changes between 2000 and 2005. Thus, the *nominal* price of water changed for these two providers. The change in the nominal water bill was calculated given the average water use (i.e., water use factor) for each provider, and then adjusted for the change in CPI to derive the change in real dollars for each provider.

Water use among the large-use customers was assumed to remain constant at the 2005 level due to a lack of information on large user water use and employment in 2000. *This assumption may lead to inaccuracy of the water demand backcast if water use among large users has changed between 2000 and 2005.*

The reported weather data for 2000 from the SeaTac, Buckley, and Everett weather stations for the three provider service areas (Seattle, Tacoma and Everett), respectively.

The impact of conservation programs are estimated region-wide within the Model. Thus, a regional percent increase (reverse savings impact) was estimated and applied equally to all three providers to correct for the change in average water use from 2000 to 2005 due to conservation effects. *This regional assumption will likely generate some miss-estimation of actual water demand at the utility or sub-regional level.* It was assumed that passive conservation (i.e., plumbing codes and standards) had a two percent effect from 2000 to 2005, while active conservation measures implemented as part of the Utility Goals from 2000 to 2005 had a five percent impact.

Results of the water demand backcast for Seattle, Tacoma and Everett are summarized in **Table 2**. As with the Model Validation, the comparison with actual 2000 water use is for retail water demand only. This comparison does *not* include wholesale water demands or estimated Non-Revenue Water losses.

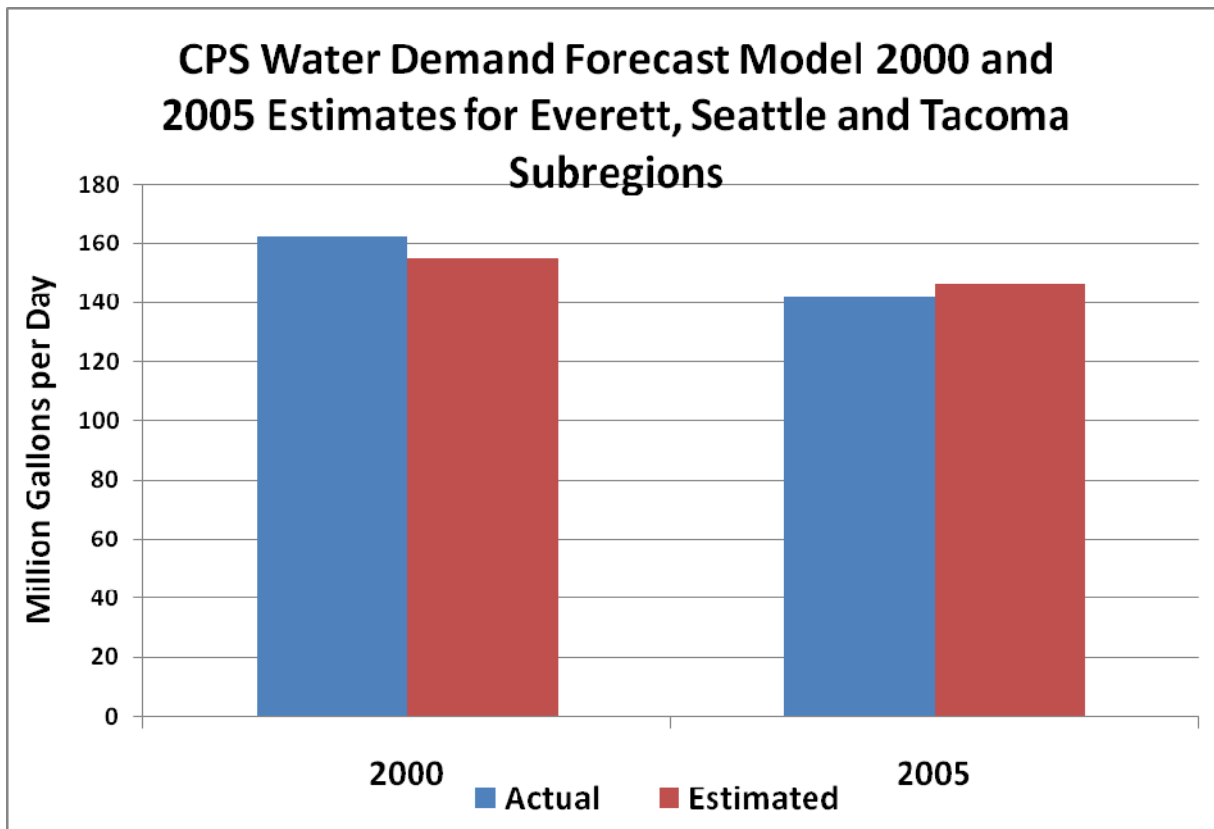
Table 2. CPS Model Backcast for Year 2000 (MGD)							
		SF	MF	NR	Lg User	Total NR	Total Retail
Seattle	Model	25.3	12.2	22.2	3.7	25.9	63.4
	Actual	27.0	14.5	27.7		27.7	69.3
	Model Difference	-6.4%	-15.7%			-6.5%	-8.4%
Tacoma	Model	18.1	5.6	10.2	16.4	26.6	50.3
	Actual	19.6	3.9	31.5		31.5	55.0
	Model Difference	-7.3%	42.5%			-15.7%	-8.6%
Everett	Model	4.3	2.6	2.9	31.2	34.1	41.0
	Actual	4.2	3.0	31.4		31.4	38.5
	Model Difference	4.0%	-13.6%			8.7%	6.5%
Total of 3	Sum of Models	47.7	20.4	35.3	51.3	86.6	154.8
	Sum of Actual	50.7	21.4	90.6	0.0	90.6	162.8
	Difference of Sums	-5.9%	-4.8%			-4.4%	-4.9%

Overall, the Water Demand Forecast Model under-estimates 2000 water use among the three providers by 4.9 percent. Water use among all sectors (single-family, multifamily and nonresidential) is under-estimated for Seattle. Single-family and nonresidential use is under-estimated for Tacoma, while over-estimated in Everett. However, it is important to recall that the Water Demand Forecast Model is not designed to estimate *short-term* changes in demand at the utility level, or sector level.

The model estimates are a function of the data inputs for 2000, which include regional generalizations rather than utility-specific data as noted above. Water use by sector is estimated within the model as the sector demographic driver times the water use factor for each sector. The resulting estimate of water use by sector, relative to total demand which includes large water users and non-revenue water estimates is used later in the model to redistribute demand to sector level estimates after making weather adjustments to seasonal water demand and conservation adjustments to total water demand. Thus, the resulting estimate of water use by sector is not likely to replicate actual demand by sector in a given year.

## Conclusions

Use of the CPS Forum Water Demand Forecast Model to estimate observed 2000 and 2005 water use show that the Model estimates under-estimate 2000 actual water use by 4.9 percent and over-estimate 2005 actual water use by 3.2 percent, as shown in **Figure 1**. The under-estimation of the 2000 demand and over-estimation of 2005 demand suggest that the *model inputs used for those two time periods do not accurately reflect actual conditions* in those specific years.



Differences between regional modeling and utility-level modeling must be considered when comparing regional model estimates with utility-level consumption. The CPS water demand sub-region for Everett is not synonymous with the Everett retail service area with which the demands are being compared.

The verification and backcast input data are *estimated* data rather than *actual* historical values for each of the three service areas. Specifically, while the 2000 housing and employment data for the three sub-regions are PSRC data, the 2005 housing and employment values are interpolated and may not reflect actual conditions, but nonetheless serve to represent the base demographic conditions of the forecast.

The 2000 model inputs for income and conservation were determined from a 'reverse-trending' of data from the 2005 base period. That is, the assumed future growth rate for income used in the forecast model was applied in reverse to estimate the median household income in 2000. While this may be consistent with the forecast methodology, the resulting estimate of 2000 income is off the mark because the regional economy was in recession during much of that 5-year period when actual income growth was not the one percent per year assumed in the Model. Similarly, a percent reduction in demand due to conservation was reversed to account for conservation savings between 2000 and 2005 (i.e., conservation

savings had to be added back into the 2000 water demand estimate). This generalization of conservation effects on the forecast applied equally to each of the three sub-regions does not present an accurate reflection of water conservation savings in each of the three service areas from 2000 to 2005.

Water use among large water users in the three sub-regions is not accurately reflected in the 2000 backcast estimate. The 2005 level of water use among large customers was held constant in the 2000 backcast, and may under-estimate usage by these users if indeed these users were using water more efficiently in 2005 than in 2000.

A final conclusion from the verification and backcast process is that the regional Water Demand Forecast Model was designed to be, and performs well as, a regional model but is not a utility level forecasting model. The Model is acceptable for regional long-range planning purposes. A more precise verification and backcast estimate could be developed with more precise historical model inputs for each of the three service areas. Elements of the Model, such as water use factors, weather elasticities, growth rates, and regional conservation assumptions should be refined before the Model is used for utility-level planning.

## **Recommendations**

The purpose of the water demand forecast verification and backcast is to provide confidence that the water demand model is producing reasonable estimates of water demand for regional planning purposes. The water demand model verification process can be improved upon. Sufficient time and budget should be anticipated in the development of the next Outlook for model verification and development of a backcast. Selection of a few major utility service areas for comparative purposes should consider the alignment of geographic area boundaries with demand forecasting areas. In addition, utilities should be selected for which readily available historical data can be obtained both as model input, and for comparative purposes. The backcast process should use model inputs that reflect actual conditions, rather than estimated data. Regional assumptions used in the forecast model should be corrected, or validated for utility-specific conditions. The utility specific data and assumptions should be incorporated into the forecast model for both the model verification and backcast. That is, the backcast procedure should not be implemented until the model verification procedure is complete and differences between the base year model estimates and base year actual demand are corrected or understood.