EXHIBIT NO. JAD-1T
DOCKET NOS. UE-090704/UG-090705
2009 PSE GENERAL RATE CASE
WITNESS: DR. JEFFREY A. DUBIN

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY, INC.,** **Respondent.**	**Docket No. UE-090704** **Docket No. UG-090705**

PREFILED REBUTTAL TESTIMONY (NONCONFIDENTIAL) OF
DR. JEFFREY A. DUBIN
ON BEHALF OF PUGET SOUND ENERGY, INC.

DECEMBER 17, 2009

PUGET SOUND ENERGY, INC.

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I. INTRODUCTION AND QUALIFICATIONS

Q. Please state your name, business and address.

A. My name is Jeffrey Alan Dubin. My address is Pacific Economics Group, L.L.C. ("PEG"), 300 South Grand Avenue, Los Angeles, California, 90071.

Q. Who retained you for this testimony?

A. Puget Sound Energy, Inc. ("PSE") retained me to provide this testimony.

Q. What is your position with PEG?

A. I am a Co-Founding Member of PEG.

Q. Do you hold any other positions?

A. I am an Adjunct Full Professor of Economics at the University of California, Los Angeles Anderson School of Management

Q. Have you prepared an exhibit describing your education, relevant employment experience, and other professional qualifications?

A. Yes, I have. It is Exhibit No. JAD-2. Please also see Exhibit No. JAD-3, which contains a list publications I have authored and a list proceedings in which I have provided expert testimony, including before the Washington Utilities and Transportation Commission.

Q. What has PSE asked you to examine in this proceeding?

A. PSE has asked that I review the Joint Testimony of Alan Buckley and Donald W. Schoenbeck filed on behalf of Commission Staff and the Industrial Customers of Northwest Utilities ("ICNU") hereafter ("Joint Testimony"), and specifically the proposal in the Joint Testimony to filter the Mid Columbia (“Mid C”) hydro generation series by eliminating certain hydro years that Commission Staff and ICNU consider to be outliers. Commission Staff and ICNU use the resulting sub-sample of hydro-generation data and its corresponding power costs to estimate the rate year (April 2010 through March 2011) average AURORA model power costs. The proposed methodology of Commission Staff and ICNU eliminates both high and low hydro generation years but removes more years that are associated with large estimated AURORA power costs. Thus, Commission Staff’s and ICNU's methodology results in a downward adjustment to the PSE’s baseline power costs.

Additionally, PSE asked that I review Public Counsel's proposal to use the average Mid C hydro generation for the 50-year period 1949-1998 as the basis for the rate year forecast in this case, rather than using the average Mid C hydro generation for the 50-year period 1929-1978, which the Commission previously approved in PSE's 2004 general rate case. Public Counsel's proposal also results in a downward adjustment to the baseline power costs.

Q. Please summarize your conclusions.

A. Commission Staff and ICNU propose a methodology to truncate or trim the hydro data used to set power costs for PSE. There exists no statistical or intuitive reason to filter the hydro-generation in the manner suggested by Commission Staff and ICNU--it is neither appropriate nor statistically sound to eliminate twenty of the fifty data points (40 percent) to force data to be "normal". In short, the proposed hydro filtering methodology is inappropriate, and the Commission should reject this adjustment.

Regarding Public Counsel's proposal to use a more recent 50-year period, it is problematic for several reasons. Public Counsel incorrectly finds that hydro levels are larger in the more recent 50-year hydro period. Additionally, there is no sound basis for using a rolling average or limiting the time period to 50 years.

Q. How is your testimony organized?

A. Section II discusses my previous testimony before this Commission on hydro issues and the various methodologies that can be used to filter data. Section III critiques Commission Staff's and ICNU's methodology. Section IV discusses my conclusions and recommendations with respect to hydro filtering. Section V discusses Public Counsel proposal to adopt a more recent 50-year period for determining PSE's expected hydro generation level. Section VI summarizes this testimony.

II. TECHNIQUES FOR FILTERING DATA

Q. What conclusions did you reach in PSE's 2004 GRC with respect to the appropriate hydro record to examine for forecasting the likely future levels of hydro-generation?

A. In PSE's 2004 GRC, I concluded that PSE's hydro generation and hydro flow are actually quite simple--the data are trendless and normally distributed. Consequently, I concluded that the best estimate of future water flow generation is a simple, long-run average that uses all available data. For these reasons, I advocated using the long-run average value based on the full information available.[1] It was--and is still--my opinion that forecasts of future water flow and generation should be made on a fifty-year or longer hydrological record. There was--and currently is--no reason to exclude any data, including those from low-water years. Further, there was no evidence of outliers in the data I reviewed for the 2004 GRC.

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[1] *See WUTC v. Puget Sound Energy, Inc.*, Order No. 6, Docket Nos. UE-040640, *et al.*, ¶¶ 124, 128 & 131.

Q. Commission Staff and ICNU have proposed to use a "water filter". What is a water filter?

A. Commission Staff and ICNU jointly propose to limit the water years used to establish hydro generation and the resulting AURORA modeled power costs. To accomplish this, Commission Staff and ICNU have proposed a methodology termed "water filtering". *See* Exhibit No. JT-1CT, at page 11 lines 4-15. Water filtering is a technique that censors certain water years before calculation of the historical average water generation and corresponding rate year power costs.

Q. Please describe the water filtering proposed by Commission Staff and ICNU.

A. Commission Staff and ICNU propose to utilize an annual hydro filter that combines monthly hydro generation for all months in a year to form annual hydro generation. For the fifty-year period from 1929 through 1978, Commission Staff and ICNU propose to estimate the standard deviation of only Mid Columbia fifty annual water generating years and then exclude any water year (and the power costs for such year) that exceeds more than one standard deviation from the average of the original fifty years. Commission Staff and ICNU regard these excluded observations as "extreme" or "outliers". Commission Staff and ICNU use the resulting sub-sample of observations to determine and reduce the AURORA modeled power costs for the corresponding years. *See* Exhibit No. JT-1CT, at page 11, lines 17-23 and page 12, lines 1-5.

Q. Is ICNU and Commission Staff's methodology consistent with how hydro filtering has been used in other proceedings?

A. No. To my knowledge, the power costs included in the general rate case of Avista Corporation ("Avista") in Docket No. UE-070804 were settled and included a *monthly* hydro filtering adjustment. Again, in Docket No. UE-090134, Avista Corporation, Commission Staff, ICNU and other parties have filed a partial settlement stipulation which includes a *monthly* hydro filter.

Q. Please describe the monthly hydro filtering used in the Avista rate cases.

A. The monthly hydro filtering methodology used in the Avista rate cases considered each month separately (*e.g.*, all January periods) for fifty years--from 1928 through 1977. One then calculates the standard deviation of monthly hydro-generation for all such January periods and retains any monthly period with generation within one standard deviation of the mean January generation. Any generation for a monthly period that is larger than one standard deviation is discarded. The resulting subset of January periods is used to calculate a new average for January. Under this methodology, only the associated power costs from the AURORA model that correspond to the subset of January periods is retained to form average power costs for January. The sum of each of the twelve months' average power costs corresponding to the standard deviation of the monthly hydro generation is then considered to be the AURORA power costs for the rate year.

Q. Have Commission Staff and ICNU proposed a *monthly* hydro filtering in this case?

A. No.

Q. Have there been proposed alternatives to the hydro filtering methods described above?

A. Yes. In the general rate case for PacifiCorp in Docket No. UE-061546, page 24, paragraph 93, PacifiCorp proposed to remove extreme or outlying hydro generation events based on rank-ordering techniques. In such a method, hydro-generation would be sorted from lowest to highest, and a certain percentage of the low and high hydro generation would be eliminated before forming the average (by month).

III. DISCUSSION AND CRITIQUE OF FILTERING METHODS

Q. Please provide a high-level summary of your testimony regarding the hydro filtering proposal of Commission Staff and ICNU.

A. PSE witness Mr. David Mills discusses the pricing aspect of this proposal, and why it is flawed, in his prefiled rebuttal testimony. However, I testify that even ignoring the pricing aspect, the proposed methodology Commission Staff and

ICNU use to adjust for theoretical pricing error is in effect, creating bias in the analysis needed to determine normal hydro on the Mid-C. Despite the Commission's instructions for the use of more, rather than less, data regarding hydro, this proposal eliminates hydro years by introducing an erroneous pricing argument and biases an otherwise statistically sound input into the AURORA model.

Q. Do the proposed hydro filtering methods have an analog in statistical theory?

A. The proposed hydro filter methods are statistical estimation techniques that trim the sample data observations in order to remove outliers. Techniques for dealing with outliers are well known in statistics and have been extensively studied.

Q. Please define outliers, extremes, and contaminants?

A. An *outlier* is defined as an observation (or subset of observations) that appears to be inconsistent with the remainder of the data. *Extreme* observations are those at the lower or upper tail of the data ranked from lowest to highest. *Contaminant* observations are those that come from another distribution, but that are occasionally mixed into the main population of interest. Extreme observations or contaminant observations may or may not be outliers.

Q. What should be done with outliers if they are detected?

A. Outliers should always be examined to understand whether they are part of natural variation or due to execution errors (*e.g.*, the recording of a person's height in inches when all other observations were in meters). Modern statistical methodology rarely rejects information unless, upon inspection, an observation is subject to an uncorrectable execution in its recording. When we reject data, we no longer have a random sample but a censored sample.

Q. Can outliers provide valuable insights?

A. Yes. Outlying observations may provide the *most* useful scientific information and indeed have been the basis of many scientific discoveries. Outliers, even if present, should be accommodated and not simply rejected. The disaster of the space shuttle Challenger is good case in point. Engineers had limited experience with cold temperatures in Florida and the effect of cold on the rubber O-rings that sealed the solid rocket boosters. With cold temperatures, the Shuttle O-rings became rigid, and hot gases were able to escape and ignite the solid fuel booster. Tragically, and as a consequence, the space shuttle Challenger exploded shortly after lift-off. Engineers based their forecasts about the behavior of the O-rings on the experience they had, which unfortunately, did not include very cold temperatures. In any analysis of the effect of cold weather on O-rings, it would have been derelict to eliminate data points about cold temperatures in Florida simply because these data points were considered "outliers." Extreme events provide valuable information that would have been lost had the engineers made the population of data analyzed somehow “more normal” by eliminating these data.

Q. Are certain statistical estimators sensitive to or influenced by outliers?

A. Yes. Statistical methods may be sensitive to outliers so that the presence of an outlier may have a significant effect on a statistical estimate. In this case, the outlier is termed influential. Statistical techniques have been developed to be robust or resistant to the presence of outliers, and attempt to accommodate their presence. For example, the median is a technique that is resistant to outliers because the estimate of central tendency is not influenced by outliers with the median (the presence of a large outlier would not change the result that 50 percent of the data is above the median). In contrast, an outlier would significantly affect the mean estimate. Statistical methods (*e.g.,* discordance tests) have also been proposed to detect outliers.

Q. Are there any statistical methods that reject outliers?

A. Yes. Most rejection schemes for treating outliers involve some form of trimming. The hydro filter methodology proposed by Commission Staff and ICNU (annual or monthly, using a one standard deviation cutoff) and hydro filter methodology proposed by PacifiCorp (removing the low and high observations from a ranked order set) are both trimmed-mean estimators.

Q. What is a trimmed-mean estimator?

A. In statistics, a trimmed-mean is the mean of a population after a certain (typically very small) fraction of the largest and smallest observations are removed.[2] This technique can produce a more efficient estimate of a population's mean when there are outliers or contaminant observations that are judged to be outliers. Trimmed mean estimators are unbiased for symmetric distributions (*i.e.,* they produce estimates of the center of symmetry that are, on average, correct).

Q. How does the hydro filtering methodology proposed by Commission Staff and ICNU relate to the trimmed-mean?

A. For normal distributions, hydro filtering techniques that employ one standard deviation trim 15.87 percent of both the upper and lower tails of the distribution. Thus, for a normal distribution, the hydro filtering technique relying on one standard deviation would be expected to retain only the center 68.3 percent of the distribution and discards 15.87 percent in each tail, or about 32 percent of the observations. This would be termed a 15.87 percent trimmed mean. A 5 percent trimmed mean would retain the center 90 percent of a distribution and a 2.5 percent trimmed mean would retain the center 95 percent of a distribution.

[2] *See e.g.*, "Comparing Location Estimators: Trimmed Means, Medians and Trimean" by James Rosenberger and Miriam Gasko in Understanding Robust and Exploratory Data Analysis, David Hoaglin, F. Mosteller, and J. Tukey, eds. John Wiley & Sons, New York: New York, 1983, pp. 297-338.

Q. Normal populations are symmetrically distributed. How does the hydro filtering methodology proposed by Commission Staff and ICNU apply in asymmetric distributions?

A. This is not completely known, but distributions with skewness in one direction or another will have asymmetric trimming when the analyst employs a plus or minus standard deviation threshold.

Q. When does one usually employ trimmed means?

A. A trimmed mean is usually employed when a population is presumed to be contaminated by very large or very small outliers. The trimmed mean estimator is meant to be robust to these outlying observations (*i.e.*, it is not sensitive to their values). Abundant literature in statistics is devoted to understanding robust statistical inference. This literature demonstrates that if a population is normally distributed, the mean is fully efficient and produces an estimate with the smallest degree of uncertainty. For such a normal population, however, the trimmed mean becomes less efficient the more it is trimmed.

Q. Please discuss the efficiency of trimmed means and untrimmed means.

A. In moderate size samples, the 20 percent trimmed mean is only 88 percent as efficient as the untrimmed mean. In other words, one would become more uncertain about the range of values that possibly would contain the true value with a given level of certainty (*i.e.*, the 95 percent confidence interval would be larger). On the other hand, in the presence of contaminants, the simple average is only 82.5 percent as efficient as the 5 percent trimmed mean, which itself is nearly fully efficient. Hence, in some cases, the trimmed mean may be more efficient and robust to outlying observations than the sample average. With respect to the trimmed-mean, however, it is also well known that the resulting estimate of the population may be quite sensitive (both in terms of bias and efficiency) to the amount of trimming. This is particularly true when the populations at issue are skewed.[3]

Q. Do Commission Staff and ICNU advocate trimming certain hydro years?

A. Yes. Commission Staff and ICNU have advocated trimming certain hydro years. Consequently, it is important to recognize whether some hydro years are extreme or outliers and, if they are, it is crucial to handle them appropriately.

Q. Can you summarize?

A. For normal distributions, the moral of the story is quite simple--use all the data. For non-normal populations with some degree of wild contamination, a 5 percent trimmed mean is often fully efficient. In my experience, no one has ever advocated throwing out or trimming 40 percent of the available information as Commission Staff and ICNU have done by removing 20 of the 50 years of data.

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[3] For additional discussions about the properties of the trimmed-mean estimator, when a population is skewed, see Carroll, R.J. (1979), “On Estimating Variances of Robust Estimates When Errors are Asymmetric,” Journal of the American Statistical Association, Volume 74, pp. 674-679, and

Moreover, whether any trimming should be done at all depends on whether the hydro generation data is contaminated and whether certain hydro years are outliers and should be excluded in determining the average. The stated goal of Commission Staff and ICNU that hydro filtering will result in power costs that are "more normally expected to occur" and will "not be biased one way or the other"[4] will not be accomplished by trimming 40 percent of the data.

IV. CONCLUSIONS

Q. What conclusions did you reach in your testimony in PSE's 2004 GRC with respect to hydro generation and the presence of outliers?

A. In my testimony from PSE's 2004 GRC, I examined the historical water record for the sixty-year period, from 1928 through 1987. After an extensive statistical examination, I concluded that the process for water generation in the Pacific Northwest was rather simple--natural water flow (and water generation) was trendless, normally distributed, and random (not able to forecast). I also concluded that the best estimate of future water flow is a simple long-run average using all available data. Both Commission Staff witness Dr. Yohannes Mariam and the Commission agreed with my conclusion.

D'Agostino, R. and Lee, A., "Robustness of Location Estimators Under Changes of Population Kurtosis," Journal of the American Statistical *Association*, Volume 72 (1977), pp. 393-396.

[4] Exhibit No. JT-1CT at 8:20-23.

In the 2004 GRC I also tested the water data for outliers and did not detect any statistically significant outliers. Importantly, the early periods of low water flow were not outlying or extreme but perfectly consistent with a normal distribution. I have repeated this statistical analysis, and I still do not detect any outliers in the fifty-year hydro generation data.

Q. Is the proposal to censor part of the hydro record sensible in this case?

A. No. The proposal of Commission Staff and ICNU to trim 40 percent of the available data is unnecessary and likely to lead to bias and inefficiency. Without determining that some observations are outliers, it would be unwise to remove any data from the fifty-year samples being studied.

In short, the proposal of Commission Staff and ICNU reduces power costs by asymmetrically trimming away more low water (high cost) years than high water (low cost) years, which circumvents the Commission finding that the fifty-year water record is appropriate for rate setting.

Q. Have Commission Staff and ICNU demonstrated that the hydro years they propose to exclude are outliers?

A. No. Commission Staff provides no evidence that data points greater than one standard deviation away from the mean are outliers. In fact, the hydro filtering methodology proposed by Commission Staff and ICNU (*i.e.*, detect and eliminate outliers based on a one standard deviation cutoff) is, to my knowledge, unique in the literature of statistics.[5]

Q. Is a one standard deviation standard common in statistics for detecting or rejecting outliers?

A. No. Proposals to detect outliers are usually based on two or more standard deviations from the mean. For instance, Belsley, Kuh, and Welsch[6] discuss the "studentized residual" method to detect outliers based on the comparison of an observation's residual (prediction error) as compared to its estimated standard error. This technique assists in identifying outliers in the regression model. According to Belsley, Kuh, and Welsch, a studentized residual identifies a *potential* outlier if the deviation around the mean is larger than two standard deviations.

Similarly, in standard significance testing, t-statistics must be larger than two before they are considered to be statistically significant. In teaching and in practice, I would not regard a data point as a potential outlier unless its studentized residual was three or more, which corresponds to a deviation three times greater than the standard error. However, these techniques vary from the methodology proposed by Commission Staff and ICNU in this proceeding.

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[5] *See, e.g.,* Barnett, V. and T. Lewis, Outliers in Statistical Data, John Wiley & Sons, Great Britain: Chichester (1978).

[6] Belsley, D., E. Kuh, and R. Welsch, Regression Diagnostics: Identifying Influential Data and Sources of Collinearity, Wiley-Interscience, 2004.

Q. Please explain your contention with respect to the methodology proposed by Commission Staff and ICNU.

A. Commission Staff and ICNU arbitrarily use the one standard deviation level for eliminating a data point as an outlier. When analysts identify a data point as a potential outlier, they must then decide whether that data point should be accommodated with a new understanding of the process that was used to generate the data or whether the data point should be eliminated. Commission Staff's and ICNU's approach, however, simply eliminates 40 percent of the available water generation data. In doing so, Commission Staff and ICNU change the underlying distribution that is found in nature and replaces it with something that they think is more normal.

Q. If the Commission were to adopt some level of trimming, what would you suggest?

A. The Commission should not trim *any* data from the hydro generation record even if it has previously determined that water filtering may be appropriate <u>only</u> in the context of a Power Cost Adjustment ("PCA") type mechanism. *See WUTC v. PacifiCorp*, Dockets UE-061546, et al., Order 08 at ¶¶ 88-89 (June 21, 2007). In the *PacifiCorp* case, the Commission did not reach any conclusion regarding how much filtering might be appropriate in such a case. Importantly, there exists no statistical or intuitive reason to filter the hydro-generation in the manner suggested by Commission Staff and ICNU.

If the Commission were to adopt some level of trimming, however, I would recommend employing, at most, a 5 percent trimmed-mean. As discussed above, the 5 percent trimmed-mean is nearly fully efficient in the face of outlier contamination. Trimming the lowest 5 percent and highest 5 percent of the water generation years, although unnecessary, would result in the least statistical harm.[7]

Q. How should PSE forecast likely future hydro generation?

A. The best value of a point forecast depends on the criterion against which alternatives can be judged. To weigh the costs of being wrong, analysts rely on a cost function that describes the penalty or cost of the forecast errors that are virtually certain to occur in connection with the random process being forecast. No matter what point forecast we make, it is likely that actual water generation will differ from the baseline forecast. In classic statistics, the expected costs are minimized (a procedure also known as minimum risk). When the cost function depends on the squared error made by the forecast, it is well known that the optimal forecast is the mathematical expectation of the variable being forecast, given information available at the time the forecast is made.[8]

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[7] Applying the 5% trimmed mean to either the 50-year period from 1929-1978 or to the 70-year period from 1929-1998 results in an insignificant change in expected hydro generation and a trivial change in estimated power costs.

[8] *See* Granger, C.W.J. and P. Newbold, Forecasting Economic Time Series, Chapter 4, Academic Press, New York: New York (1977).

As discussed in my testimony in PSE's 2004 GRC, the optimal forecast for water generation is simply the historical average because hydro generation is trendless and normally distributed. *See* Exhibit No. 111 (JAD-1T), at page 24, lines 5-10, in PSE's 2004 GRC.

Q. How do statisticians compare the accuracy of forecasts and estimates?

A. Any estimation method raises the question of how close the true value will be to the estimate. To answer this question, statisticians rely on confidence intervals. A forecast or an estimate will rarely be exact. However, statisticians like some way of bounding the range of possibility so that we can say that there is a high probability that the true value will fall within the confidence band around the estimate. For a specified probability, the estimator with the tightest confidence is best because it provides confidence that the estimate and the true value will not be too far apart.

Q. Are some estimators better than others?

A. Some estimation methods are better than others because they have superior accuracy (*i.e.*, tighter confidence intervals). For instance, an average based on more observations from a population will be more accurate than an average based on fewer observations. In fact, the Gauss-Markov theorem states that among all unbiased linear estimators (*i.e.*, correct on average), the sample average using all of the data is best (*i.e.*, the confidence band around this estimate is most precise) because the variance of this estimate is smallest. A corollary to this result (and under its same conditions) is that the estimator is less accurate if he or she uses an alternative to the sample average. Using any estimator other than the sample average must necessarily result in a larger variance and wider confidence interval.

Commission Staff’s and ICNU's proposal to eliminate a full 40 percent of the available water generation history is without merit because replacing the historical average with an average based on a significant subset of the data will lead to much less accurate estimates.

Q. Does excluding some years of information potentially bias the estimated mean hydro generation?

A. Yes. As discussed in my testimony in PSE's 2004 GRC, the persistence of low-water or high-water flow periods in hydrological observations is an empirical regularity. Sampling only some of the available information has every potential to bias estimates of mean flow or to erroneously “find” trends in the data that are, in fact, *not* present.

Q. Can you explain that further?

A. Yes. If, hypothetically, one were to conclude that the first ten-year period (*e.g.,* the low-water period of 1929-1938) comes from a different geological process than the last forty-year period (*e.g.,* the normal-water period of 1939-1978), we would be left with the inference that in a fifty-year period, 20 percent of that time period was subject to a different geological process. In statistics, this is termed a mixture model. In this case, we might say that there is a 20 percent chance that we are in a "low-water" period and an 80 percent chance of being in a "normal-water" period. In future years, we might expect to see the "low-water" period 20 percent of the time and the "normal-water" period 80 percent of the time.

Q. What is the net result of mixing these two states of nature?

A. The net result for forecasting purposes is that one should combine, 20 percent of the time, the average level of water from the "low-water" period (first ten years) with the average level of water in "normal-water" period (subsequent forty years). The resulting forecast would simply equal the full time period forecast. This is the approach I recommend. The fact that water generation in certain historical period is very low or very high proves that this has occurred in the past and can likely occur again. Such information should *not* be rejected.

Q. Do Commission Staff and ICNU rely on scientific arguments for their proposed technique?

A. Commission Staff and ICNU eschew scientific analysis: "The choice of a one standard deviation filter was not based on a scientific study of any kind." S*ee* Exhibit No. JT-1CT at page 11, lines 19-20. But in discussing the hydro filtering adjustment, the Joint Testimony uses terms like "normally distributed", "outlier", and "extreme", which are terms of science and have particular meaning. More importantly, the proposal to censor data above one standard deviation *is* a scientific and statistical technique. It is a matter of statistical science whether such a procedure is "reasonable" or meritorious simply because it lacks "computational controversy". *See* Exhibit No. JT-1CT at page 11, lines 19-21. Therefore, the Commission should be cognizant of the statistical arguments against the proposed hydro filtering methodology.

Q. What is the basis for the hydro filtering methodology that Commission Staff and ICNU propose?

A. Commission Staff and ICNU assert without support that in situations where a PCA mechanism is in place, there is no need to consider extreme circumstances because "[i]n the event extraordinary costs, or benefits, occur as a result of extreme water conditions, customers will pay a portion of these costs and receive a portion of the benefits, when and if they actually occur under the PCA mechanism." *See* Exhibit No. JT-1CT at page 12, lines 11-14. This unsupported assertion erroneously suggests that the PCA mechanism allows PSE the opportunity for "double recovery" to recover power costs first through base rates and then again if extreme hydro conditions occur. *See* Exhibit No.JT-1CT at page 9, lines 20-23 continuing at page 10, lines 1-3.

Q. Do you agree with this unsupported assertion?

A. No. The PCA mechanism works in conjunction with the hydro conditions that are expected to occur. For example, this Commission, in PSE's 2004 GRC, came to the:

> …practical conclusion that power costs determined in general rate proceedings and in PCORC proceedings should be set as closely as possible to costs that are reasonably expected to be actually incurred during short and intermediate periods following the conclusion of such proceedings.

WUTC v. Puget Sound Energy, Inc., Docket Nos. UE-040640, *et al*., Order 06 at ¶ 108 (Feb. 18, 2005).

Similarly, in PSE's 2006 GRC, this Commission reiterated its determinations to set baseline rates at what is expected in the rate year:

> The Commission has reset the Power Cost Baseline Rate on several occasions and each time it has done so on the basis of a fully developed record. The Commission's goal has been to set the baseline as close as practicable to what is likely to be experienced during the rate year. We expect that practice to continue and we also expect the parties to continue to refine the method and improve the data upon which we act.

WUTC v. Puget Sound Energy, Inc., Docket Nos. UG-060266 & UE-060267, Order 08 at ¶ 22 (Jan. 5, 2007).

These orders echo sound statistical practice to provide forecasts based on what can be expected in the rate year. As discussed above, optimal forecasts are precisely the mathematical expectation of what will occur. In this instance, hydro forecasting must be based on the complete hydro generation record in order that the forecast be as accurate as possible.

Q. In the 2006 GRC order quoted above, the Commission sets the expectation that the parties would continue to refine and improve how the baseline rate is set. Do you believe the proposed hydro filtering methodology meets this expectation?

A. No. Setting baseline power costs based on expected levels using the fifty-year or longer hydro record will produce the most accurate forecast and will subject PSE and its customers to the least variance. When Commission Staff and ICNU censor some hydro-generation years as outliers, they acknowledge that these extreme conditions will be handled by the PCA mechanism. Commission Staff and ICNU fail to acknowledge, however, that PSE and its customers will experience low water years with significant probability. In such low water years, non-hydro-generation costs will be high, and the actual deviation from baseline power costs will be larger than it would have been had the baseline been properly centered from the outset. Similarly, PSE's customers will under-recover benefits in high water periods because benefit deviations will be smaller under the hydro filtering methodology than if the baseline has been properly set.

In addition to not meeting the Commission's expectation, customers are not necessarily better off under the proposed hydro filtering methodology.

Q. Does the proposed hydro filtering methodology attempt to fix something that is not broken?

A. Yes. The proposal to filter hydro generation is an attempt to correct an estimate that is not currently influenced by outliers or extremes.

V. PUBLIC COUNSEL'S HYDRO PROPOSAL

Q. Could you summarize the testimony of Mr. Scott Norwood filed on behalf of Public Counsel as it pertains to PSE's hydro generation forecast?

A. Yes. Mr. Norwood observes that PSE used the average hydro generation for the 50-year period 1929-1978 as the basis for the rate year forecast in this case. Mr. Norwood observes that Mid C hydro generation for the most recent 50-year period 1949-1998 is "significantly" higher than the level experienced in during 1929-1978. He therefore recommends that the forecast period be based on the most recent 50-year period.

Q. Have you examined Mr. Norwood's argument?

A. Yes. Mr. Norwood's suggestion is problematic for at least three reasons. First, Mr. Norwood incorrectly finds that hydro levels are larger in the most recent 50-year period. Second, a suggestion to replace one 50-year period of data with a more recent 50-year period implies that forecasts of hydro levels should be done using a rolling average with newer data replacing older data. Finally, Mr. Norwood's suggestion implicitly recommends that average hydro levels be determined using 50-year periods. I discuss these problems in turn.

Q. Did you examine the hydro data for the period 1929 through 1998 in this proceeding?

A. Yes. I examined the hydro data for the 70-year period from 1929 through 1998. I examined the hydro generation for PSE's combined ownership of Mid-C and its Westside projects. I determined the total hydro power historically available to PSE by combining the megawatt hours generated from their Mid-C and Westside projects. I then divide by the number of hours in a year to obtain the annual average megawatts of hydroelectric generation (aMW). These figures differ somewhat from those I analyzed in 2004 since there have been changes in PSE's ownership shares and in hydro regulation. However, I reach identical conclusions with respect to the hydro generation as I did in 2004. The picture that emerges for hydro generation remains the same and is quite simple. The data are trendless. The data are normally distributed. The data are not forecastable nor do they reflect a very short-lived persistence. The best estimate of future hydro generation is consequently a simple long-run average using all available data. Commission Staff reviewed my analyses during the 2004 GRC and performed their own analyses of the statistical properties of the hydro generation record and reached identical conclusions. These findings were adopted in the Commission's final order in PSE's 2004 GRC.

Q. Did Mr. Norwood present evidence for a "significant" difference in the

hydro levels in the most recent 50-year period versus the period employed by PSE?

A. No, he did not provide such evidence. In response to his testimony, I undertook this analysis. I determined that the average hydro generation for the period 1929 through 1978 was 735 aMW. The average hydro generation for the period 1949 through 1998 was 750 aMW. I performed a test for the difference in these levels by comparing the 20-year period from 1929 through 1948 to the 20-year period from 1979 to 1998. The difference in the average hydro generation in these two 20-year periods (723 aMW in 1978-1998 versus 684 aMW in 1929-1948) was not statistically significant. The test I performed recognizes that the period from 1949 through 1978 is present in both 50-year periods and must be removed in order to obtain a correct equality of means. Mr. Norwood is not correct that there is any "significant" difference in these estimates using one 50-year period versus another.

Q. Did Mr. Norwood examine whether the recent 20-year period of data from 1979 through 1998 was significantly different from the 50-year period from 1929 through 1978?

A. No. Had Mr. Norwood performed such a test he would have found that the difference of 735 aMW (1929-1978) and 723 aMW (1979-1998) was not significantly different. More generally there is simply no evidence that the 70-year hydro data is anything but a normally distributed random process so that while it is comforting that these estimation periods produce statistically similar results, it remains my opinion that the long-run average using all of the hydro record should be used to determine the likely future level of hydro generation.

Q. Is it proper to define the estimation period by testing for changes in the average or mean?

A. No. As I discussed in 2004, I am aware that witnesses in other proceedings have testified that this is appropriate with regard to the hydro issue. In one such approach, one starts at the most recent period, say a ten-year period, and asks whether the next most recent ten years has the same average level as the initial ten years. If it does, these data are included in this approach and if it does not, one stops. Based on such a procedure, some have concluded that the 1929 through 1948 period has a significantly different average level than later periods and, therefore, is a biased addition to the estimates of the future. Based on my statistical analysis in 2004 and my recent analysis of the revised hydro generation data there is no statistical or logical basis to conclude that earlier data should be excluded, as Mr. Norwood recommends when he suggests eliminating the period 1929 through 1948 from the data record.

Q. Does Mr. Norwood recommendation advocate a rolling average?

A. Yes. Mr. Norwood would replace an older 50-year period of data with a later 50-year period of data for estimating the likely hydro generation level. This is in fact a "rolling average" or "moving average" procedure.

Q. Are there problems with using moving averages to determine expected levels of future hydro flows?

A. Yes. There are several problems. First, a moving average with fixed window (e.g. 50-year period) generally cannot be an optimal forecast because it arbitrarily ignores earlier information. It is highly unlikely that it could ever be optimal to give zero weight to the information from previous observations of hydro generation simply due to the passage of time. For instance, the optimal forecast in a first-order autoregressive model leads to the classic adaptive expectation forecast that applies geometrically declining weights to prior observations but does not set the weight given to any historical observation arbritraliy to zero. Second, the stochastic properties of hydro generation imply that forecasts should be made using all the data and hence a moving or rolling average cannot be an efficient or optimal forecast and conversely must be an inferior forecast to using all of the data.

Q. Did you discuss the issue of moving average forecasts at hearing in the 2004 GRC?

A. Yes. I rejected the application of moving averages because they can lead to cycles in data that are not present in nature. The Commission discussed this testimony in their order and Commission Staff agreed with me at hearing that there were statistical problems with moving averages. The Commission rejected the use of rolling averages in that case:

> Dr. Dubin testified to the well-recognized statistical theorem that use of rolling averages may produce cycles that are not actually present. Dr. Mariam agreed that this problem is inherent to models that rely on rolling averages and is one reason to move away from the 40-year rolling average approach to hydro normalization.
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> . . . .
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> We find on the basis of the current record and the clear and convincing argument by Staff and PSE that the method presented by Dr. Mariam, based on 50 years of data, is a superior alternative to the 40-year rolling average.[9]

Q. Could you explain further?

A. Yes. As I explained at hearing in the 2004 GRC, the moving average has been known to induce cycles or patterns in otherwise random data since Professor Slutsky presented this phenomenon in his classic 1937 study.[10] A more recent analysis is Howrey's 1968 analysis of moving average transformation performed by Simon Kuznets (1971 Nobel Prize winner in Economics) in his investigation of "long business cycles" in economic activity.[11] Howrey shows that Kuznets subjected his data to moving average transformations. These transformations in fact introduce large peaks at low frequency in the spectrum of the economic time series. Kuznet's conclusions that economic activity seem to be characterized by

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9 *See WUTC v. Puget Sound Energy, Inc.*, Order No. 6, Docket Nos. UE-040640, *et al.*, ¶¶ 128, 130.

10 *See e.g.* Slutsky, E. (1937), "The Summation of Random Causes as the Source of Cyclic Processes," *Econometrica*, Vol. 5, pp. 105-146.

11 *See e.g.* Howrey, E. (1968), "A Spectrum Analysis of the Long-Swing Hypothesis," *International Economic Review*, Vol. 9, pp. 228-260.

long swings was a statistical artifact of the data transformations applied (the moving average) and not really characteristic of the data itself. As I explained at hearing in the 2004 GRC, the moving average should be avoided in this instance for similar reasons. It can very easily introduce swings and variability in the hydro forecast that are not in fact present causing hydro forecasts, power costs and ultimately rates to be subject to swings that are artifacts of the method and not present in the hydrological historical record.

Q. Is Mr. Norwood's reliance on a 50-year period arbitrary?

A. Yes. There is no basis for a 50-year period to determine the expected level of hydro generation. In the 2004 GRC I strongly advocated for the use a 60-year period to determine hydro generation as that was all that was available at the time. However, I reported that I did examine a 70-year period from 1928 through 1998 of raw water flows measured at the Grand Coulee dam. My prior analysis of this data suggested that the full 70-year period could and should be used for hydro forecasting. Mr. Norwood now raises the use of the period of the hydro record from 1979 through 1998 in place of the 1929-1948 hydro record. I reiterate my opinion that a longer record is better.

Q. Are there longer hydrological records beyond 70 years available and suitable for study that might be applied in this proceding?

A. No. This was a point I discussed at hearing in the 2004 GRC. While there are some older hydrological records they do not pertain to the hydro flows at issue for PSE and methods have not been developed to apply regulation and rules to this data to yield a consistent hydro generation data series for analysis.

Q. Could you summarize your opinions regarding Mr. Norwood's proposal?

A. Yes. As I said in my testimony in the 2004 GRC, the 60-year record would be better to use than the 50-year record and similarly the full 70-year record is preferred to the 60-year record or the 50-year record. I strongly advocate the use of the available 70-year hydro record to determine likely future levels of hydro generation and recommend strongly against the use of a rolling average whether the motivation is that 50 is somehow special (it is not) or whether earlier periods reflect significantly lower mean hydro flows (properly tested they do not). Mr. Norwood's suggestion is another form of filtering wherein he ignores the data and arbitrarily drops the first 20 years of the historical hydro record with no basis other than his "concern" that it is different.

VI. SUMMARY

Q. Please summarize your conclusions.

A. The hydro filtering proposal in the Joint Testimony and Public Counsel's proposal to use a rolling 50-year average of hydro data are unscientific and not supported by the evidence. Each is a form of filtering designed to eliminate normal events of low water that occurred in nature. There is no scientific basis to conclude that these events were extreme or outliers in nature. The Commission did not find in PSE's 2004 GRC that such low water years were extraordinary nor should the Commission be seduced by such misguided arguments now. Filtering is a scientific method subject to scientific scrutiny and, under scrutiny, filtering the hydro record has no scientific support.

Q. Does this conclude your prefiled rebuttal testimony?

A. Yes, it does.