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BEFORE THE WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

DIRECT TESTIMONY OF THOMAS D. DUKICH
REPRESENTING AVISTA CORPORATION

Exhibit T____(TDD-T)

1 I. INTRODUCTION

2 Q. Please state your name, position, and business address.

3 A. My name is Thomas D. Dukich and my business address is S. 7222
4 Brookshire Court, Spokane, Washington, 99223. For 20 years I held various management
5 positions in the Rates and Regulatory Affairs Department at Avista including the position
6 of Director. Prior to that, I was the Supervisor of Research and Forecasting for the
7 Company. In that position, I conducted and directed numerous studies involving statistical
8 sampling and statistical analysis as well as producing the Company's short-term load
9 forecast. My last day of full time employment for Avista was November 1, 2001.

10 I joined Avista in 1978 after having been previously employed for seven years as an
11 Assistant and then an Associate Professor at Gonzaga University where I taught courses on
12 research methodology. I have also taught Market Research at Eastern Washington
13 University. I am now an independent consultant testifying on behalf of Avista.

14 Q. Would you describe your educational background?

15 A. I graduated from the University of Minnesota in 1967 with a B.A. in
16 Psychology and Business and from the University of Montana in 1972 with M.A. and
17 Ph.D. degrees in Experimental Psychology and Statistics. Both my undergraduate and
18 graduate training included numerous courses in statistics and I have subsequently attended
19 courses and seminars on strategic planning, Box-Jenkins forecasting, finance, accounting,
20 rate design and pricing.

21 Q. Have you previously testified before this Commission?

22 A. Yes. I have appeared before this Commission on numerous occasions.

23 Q. Would you briefly describe your assignment for Avista?

24 A. I was asked to examine what historical period of streamflows would likely
best reflect pro forma power costs for Avista.

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SUMMARY OF TESTIMONY

Q. Would you please summarize your testimony?

A. I first examined the kinds of questions we try to answer when we look to the historical water year record during the rate setting process. After formulating what I believe to be the most relevant questions, I then follow with four different approaches that I feel are responsive to those questions. All four approaches lead me to the same conclusion: the most appropriate course of action is to use all the available data applicable to Avista's resources. In this, case 60 years of streamflow record.

I also reviewed the 1985 testimony of Commission Staff witness Mr. Winterfeld in Cause No. U-85-36 ("Winterfeld testimony"). I did so because the Commission relied extensively on his testimony when it ordered the use of the rolling 40-year average in that fully litigated Avista rate case. Much subsequent discussion has centered on Mr. Winterfeld's conclusions. After a detailed examination of Mr. Winterfeld testimony, I concluded that his results are largely driven by the mechanics of the way he set up his analysis. I don't believe they have much merit when it comes to actual streamflow data.

INTRODUCTION

15 Q. What is needed by the rate making process with regard to hydro generation.

16 A. Pro forma, normalized power supply cost should reflect the expected cost of
17 serving customer loads. If they do not, the Company will chronically under recover or
18 chronically over recover costs. Put another way, customers will either chronically underpay
19 or overpay.

20 Q. How is this cost determined?

A. As Mr. Norwood and others Company witnesses cover in detail in their
21 testimonies, a period of historical water years, each one separately run through the power
22 supply model, are used to determine what Avista expects costs to be in the future. For

1 ratemaking purposes we should also ask: 1) what period of future cost are we trying to
2 reflect in rates, and 2) how many historical water years should we run through the model to
3 best reflect a given future time period?

4 Regardless of ones view on how much of the historical record should be used, we
5 ought to determine as best we can the answer to the question regarding what period of
6 future costs we are trying to reflect in rates. The answer to this question is important
7 because it determines the “dependent variable” in any analysis. Our success should be
8 measured against this variable. If we are interested in only next year’s costs, then that is the
9 benchmark. If we are interested in the average cost over the next five years, then that’s the
10 benchmark, and so on. If we decide we are estimating cost to some indeterminate length of
11 time, that may demand a different analytical approach.

12 Q. What is your opinion as to what period of future costs should be reflected in
13 rates?

14 A. Based on my analysis here and on my experience with the rate making
15 process, I believe an average of a five-year or longer period is reasonable.

16 Q. What about the question regarding what historical record should be used to
17 estimate these future costs?

18 A. No matter what period of future costs we choose to use as the criterion, I
19 conclude that using 60 years of record is the best overall approach.

20 Q. Why did you draw that conclusion?

21 A. My reasons fall into four different categories and represent four somewhat
22 different approaches to the problem: one approach might be called theoretical, one
23 empirical, one traditional, and one anecdotal. I’d like to begin with the theoretical.

1 THEORETICAL

2 I realize that there is a risk of eyes glazing over when a theoretical discussion is
3 presented in testimony. However, I believe in the current instance a theoretical discussion
4 is extremely relevant and should not be ignored. Over the years, it has been interesting to
5 me to observe how during the rate making process we often struggle to make sure that
6 decisions are consistent with the rule of law and the principles of accounting. I believe that
7 we should do no less when it comes to the principles of statistical analysis as they apply to
8 decisions regarding the selection of the number of water years.

9 There is a mathematical theorem that has been gaining more exposure in the
10 statistical literature over the past several years even though this theorem was proven true in
11 1933. It goes by the name of the Glivenko-Cantelli Theorem, after the two mathematicians
12 who first published the proof of the theorem. How various experts have described the
13 Glivenko-Cantelli Theorem reflects its importance. It has been called the existence theorem
14 for statistics as a branch of applied mathematics. It has also been called the fundamental
15 theorem of statistics. It has been said that, in effect, without the Glivenko-Cantelli Theorem
16 modern statistics would not exist, as we know it today. It is the central truth of modern
17 statistics. It is even more fundamental than the Central Limit Theorem, which is the
18 foundation of much inferential or sampling statistics.

19 Q. What is the essence of the Glivenko-Cantelli Theorem?

20 A. What Glivenko-Cantelli says is that as you build your observed or empirical
21 distribution function by collecting more and more data points, this empirical distribution
22 will converge to the true distribution. In other words, more data is better if you wish to
23 reflect the true distribution function, or as statisticians frequently say, if you wish to reflect
24 the true state of nature. And, as you collect more and more information, you get closer and
closer to the true distribution, how close you get is a direct function of how much

1 information you have collected.¹ This seems intuitively obvious, but until Glivenko-
2 Cantelli, convergence to the true distribution was not mathematically proven.

3 In my opinion, the analysis of how many historical water years to use really needs
4 to go no further than Glivenko-Cantelli. It is clear to me that the Glivenko-Cantelli
5 Theorem indicates we should use as much reliable data as we have. Sixty (60) years is
6 preferable to 40, if we are interested in most accurately reflecting how water years are truly
7 distributed across different values. And as Mr. Norwood and others testify, it is 60
8 individual years, not the average of the 60 that are modeled to reflect pro forma power
supply costs.

9 In sum, more data is better if you wish to reflect the true state of a distribution.
10 This fact is the foundation of modern statistics. I hope that it can also become one of the
11 foundations of utility regulation, along with the rule of law and the principles of accounting.

12 EMPIRICAL APPROACH

13 Q. Would you now describe what you have called the empirical approach to the
water year issue?

14 A. Yes. The empirical approach follows from the theoretical discussion of
15 Glivenko-Cantelli. It is the practical application side. In this approach, I have used what
16 has come to be called “computer intensive” or “resampling” methods to answer questions
17 regarding water years.

18 Q. Would you explain the term “resampling”.

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20 _____
21 ¹ A little more formally, the Glivenko-Cantelli Theorem can be stated as follows. The
22 empirical distribution function f_n estimates F to any desired degree of precision uniformly in
23 x for sufficiently large sample size n . The true distribution function F can be rediscovered
24 from the data; or the empirical distribution function f_n can be said to look like the true
distribution function F for large sample size n .

1 A. Yes. The resampling method repeatedly draws random samples from the
2 existing data in order to gain insights into the “true” distribution. The sample is said to
3 bootstrap itself into the true distribution following the logic of the Glivenko-Cantelli
4 Theorem. As a result, resampling is also called “bootstrapping” in the statistical literature.

5 Q. Is resampling the same as what is called a Monte Carlo method?

6 A. Not really. In Monte Carlo, samples are usually drawn according to some
7 assumed probability distribution to reflect the range of possible outcomes. In resampling,
8 no assumption is made about the underlying distribution and no a priori distribution is used
9 to determine the sampling plan. In fact, the goal of resampling is to rediscover the true
10 distribution from the empirical data on hand through the resample methodology.

11 Q. Is resampling a proven technique in common use?

12 A. Yes. One author, David Salsburg, had this to say about resampling: “The
13 implications of this method have been so extensive that almost every issue of the
14 mathematical statistical journals since 1982 has contained one or more articles involving
15 bootstrap.” (The Lady Tasting Tea: How Statistics Revolutionized Science in the
16 Twentieth Century, Freeman, 2001.)

17 Q. How did you apply the resampling methodology to the water year question?

18 A. I started with 60 years of natural inflow data measured at the Dalles in cubic
19 feet per second. In my testimony I refer to this as simply streamflow. As Mr. Norwood
20 testifies, this is all the streamflow data we have that is directly applicable to Avista’s
21 unique configuration of hydro generation.

22 However, just because we start with a 60-year database does not mean that fewer
23 years might not in some way be proven to be a better reflection of the average streamflows
24 or power supply expenses. But of course, it follows from Glivenko-Cantelli that 60 years
are best if we are interested in working toward approximating the true state of nature.

1 samples is estimating the same “true” mean. It’s also quite clear that as sample size
2 increases, the average deviation around the grand mean decreases significantly. Exhibit
3 ___(TDD-2) shows this same average deviation information but with a chart that is
4 purposely scaled to focus attention on just the changes in the average deviation as a function
5 of sample size.

6 One way to interpret these results is to conclude that as sample size increases, the
7 reliability or accuracy of the estimate increases, i.e., the error of the estimate decreases. We
8 may be tempted to compute traditional “confidence intervals” around our estimates in order
9 to quantify this decrease in estimating error. Recall however that this is a resampling
10 experiment. We make no assumption about the parameters of the underlying distribution.
11 So we probably should not, for example, use plus or minus 1.68 times the standard
12 deviation of the means to calculate the 90% confidence limit. But I have saved that
13 calculation for the discussion of the traditional approach.

14 We can, however, express the improvement in our estimate in a similar way. It has
15 become traditional in resampling experiments to use percentiles instead of
16 standard deviation or standard error units. So for the result in Exhibit ___(TDD-3), I show
17 the 5th and the 95th percentile ranks. One way to verbalize these results is to say that 90
18 times out of a 100, the mean will be included in this range. It has also been common to say
19 that we are 90% confident that the true population mean is between these values. I will
20 return to Exhibit ___(TDD-3) again later on in my testimony when I address the question of
21 how well the current 40-year rolling average represents the average streamflows.

22 In sum, it is very clear from these results that using more water years clearly
23 produces a more reliable estimate of the average streamflow, i.e., 60 years is better than 50
24 which is better than 40 which is better than 30.

1 Q. Would you now turn to the next questions. What might we expect if we try
2 to predict streamflow for a single year versus what we might expect if we try to predict it
3 for an average of a 5-year period or for an average of a 10-year period of streamflows?

4 A. It takes some effort to describe how this analysis was accomplished. Let me
5 start by explaining what I did for the question regarding what best predicts the streamflow
6 for a single year? Starting with the 60 historical water years, I randomly selected, with
7 replacement, 100 different individual single years.² Then for each one of those single years I
8 examined what kind of estimating errors would occur using 30, 40, 50, or 60 years of history
9 to forecast that fixed single year. I did this 100 times. The end result is that for each
10 randomly selected single year, there are 400 attempts to forecast that year, 100 using 30
11 years of history, 100 using 40 years, 100 using 50, and 100 using 60 years of history. The
12 single year question involves 1,800,100 data points.

13 The same process was repeated for the question of what best predicts a five-year
14 period. I again begin with the 60 historical years of water but this time randomly select,
15 again with replacement, 100, five-year periods and took the mean of each of those five-year
16 periods. For the mean of each five-year period, I again examined what kind of estimating
17 errors occurred using 30, 40, 50, or 60 years of history to forecast that particular five-year
18 forecast period. I did this 100 times, once for each five-year period. Again, the end result is
19 that for each randomly selected five-year period, there are 400 attempts to forecast that

20 ² It is possible to select 100 years out of 60 because we are sampling with replacement.
21 This means that a single year may be selected more than once. We could sample without
22 replacement which would, of course, limit the total number of single samples to 60. But
23 sampling without replacement leads to dependencies that are difficult to evaluate even with
24 a resampling methodology. It is reasonable to sample with replacement because there are no
dependencies in the streamflow data and the same level of streamflow does in fact occur
more than once in the actual 60-year history. For example, in 1950 and 1983 and again in
1942 and 1963 streamflows were within two, one-one hundredths of a percent (0.02%) of
each other. If we round the data to the nearest 100 cubic feet per second, there are 21
“repeats” in the actual 60-year record.

1 period, 100 using 30 years of history, 100 using 40 years, 100 using 50, and 100 using 60
2 years of history. The five-year question involves 1,800,500 data points.

3 An analogous procedure was followed for the question of what historical period best
4 predicts the average of a 10-year period of streamflows. There were 1,801,000 data points
5 are involved in evaluating the 10-year average.

6 For the three periods, a total of 5,401,600 data points were analyzed. Of
7 course this helps explain why resampling is classified as a “computer intensive” endeavor.

8 Q. What did you conclude as a result of this resampling experiment?

9 A. Attempting to forecast a single year is very difficult no matter how many
10 prior years are used to do it. Forecasting five-year and ten-year averages is much easier in
11 the sense that the possible variation in a five and in a ten-year average is much smaller than
12 the variation in a single year. In fact, the single year average deviation is over two times the
13 deviation of the 5-year and the 10-year averages.

14 The results are further summarized in Exhibit ___(TDD-4) and Exhibit ___(TDD-5).
15 Exhibit ___(TDD-4) shows the 90% confidence interval for the average deviation and
16 Exhibit ___(TDD-5) shows the shape of the distributions for the single year, for the 5-year
17 averages, and for the 10-year averages.

18 Q. What about trends and cycles in the historical data? Wouldn't that justify
19 using a continuous record of just the most recent data rather than examining various non-
20 continuous periods?

21 A. There is no evidence that I am aware of that indicates that there are trends or
22 cycles in the adjusted streamflow data. Mr. Winterfeld also concluded that there are no
23 such trends in streamflows. It is reasonable to conclude that streamflow is a “continuous
24 random variable” in statistical terms, meaning that knowing what happened in any one year
does not significantly improve the chance of forecasting what will happen in any other year.

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TRADITIONAL

Q. The third area you mentioned is the traditional approach. How is that different from the empirical approach you just discussed?

A. The empirical approach assumes nothing about the shape of the underlying distribution or the true state of nature. The traditional approach usually assumes that the underlying distribution is normally distributed or at least that the sampling statistic that is used is normally distributed. For example, because of the Central Limit Theorem, it can be safely assumed that the distribution of sample means drawn from the historical water data is normally distributed even though the distribution of individual data points themselves may not be normally distributed.

The traditional approach is dependent upon picking the correct formula for calculating the sample statistic, the standard error of the means, etc. This may not be a problem when we ask questions such as: what is the 90% confidence interval around the mean of a sample of 40 water years? However, when we ask more complicated and unique questions, like just discussed in the prior section, finding the correct formula may involve some very clever mathematics.

However, even without the advanced mathematics, I believe it is still valuable to examine the more traditional approach to see what insights it may offer. It is also an approach that many of us are more comfortable with. I suspect that will change, as the resampling approach becomes better known.

Q. What analysis did you conduct?

A. To begin, it should be pointed out that we can view this problem two different ways. One way is to treat the flows that have occurred so far as the total population. In that case, there is no need to use inferential statistics since we already know the true state of nature. The other and more traditional way is to assume that the flows that

1 have occurred so far are a sample of all flows that have or will ever occur. In this latter case,
2 we don't know the true state of nature. This distinction can matter.

3 For example, since we can't assume that the historical mean to date is the true state
4 of nature, we really must be careful about using that mean as a criterion to make definitive
5 judgements about one method or the other. We don't really know the true state of nature.
6 However, the historical mean to date is the only estimate we have so we can, with some
7 caution, use it as a guideline for making necessary judgements.

8 I treated the historical record as a sample of the unknown true state of nature. I
9 looked at what we might expect to conclude about the reliability of estimating the mean
10 streamflow given sample sizes of 30, 40, 50, and 60 years. The results are shown in Exhibit
11 ___(TDD-6) and in Exhibit ___(TDD-6).

12 Q. What did you conclude?

13 A. As we might expect, the larger the sample size, the narrower the confidence
14 interval around the mean, and the more reliable the estimate of the mean streamflow. Mr.
15 Winterfeld drew the same conclusions in his testimony. This comes about because the
16 formula for the standard error of the mean, the variance of the sample means from the
17 estimated grand population mean, has sample size in the denominator.³

18 Each of the samples makes an estimate of the very same true population mean, a
19 major difference being that ones with smaller sample size produce less reliable or accurate
20 estimates. In other words, the variance of the estimates is greater for smaller sample sizes.
21 Since it is no more expensive to use 60 years than it is 40 years for our sample, the data
22 having already been collected, it is most reasonable to use as large a sample as we can,

23 ³ The formula for the standard error of the mean is the standard deviation of the sample
24 observations divided by the square root of the sample size. So as sample size increases, we
would expect the standard error of the mean to decrease and, at the same time, confidence
limits to narrow, all things being equal.

1 namely 60 years. And we should continue to add to the sample size, as the data become
2 available. Again, 60 years is preferable to 50, to 40, to 30, and so on.

3 Q. Are these results consistent with the empirical approach you discussed
4 earlier?

5 A. Yes. If we compare at Exhibit ___(TDD-) and Exhibit ___(TDD-) we see
6 the same pattern. For both the resampling methodology and for the traditional approach,
7 estimates of the mean are more reliable as sample size, in this case the number of historical
8 water years, increases.

9 ANECDOTAL APPROACH

10 Q. Would you turn now to the fourth area you mentioned, or the anecdotal
11 approach.

12 A. The term anecdotal is sometimes used to reflect an unscientific report.
13 However, in this instance what I mean to reflect by this term is that with very little analysis
14 or basically just simple observation, certain conclusions could be drawn regarding the
15 historical water year record.

16 I believe that we are all aware that Avista and the region are in the midst of record
17 low streamflows. For Avista in particular, this is one of the very lowest recorded
18 streamflow in the last 75 years. Mr. Norwood and Mr. Kalich both discuss the streamflow
19 record in their respective testimonies. Prior to the 2001 water year, there had been
20 speculation that the record lowest water year was a very rare event that we may never
21 experience in our lifetimes. There was even the suggestion that perhaps it was reasonable to
22 ignore very low water years since these were unlikely to ever occur again. As Mr. Norwood

1 discusses, that is just what the use of the adjusted 40 water-year record accomplishes. It
2 ignores the very lowest water years.

3 Q. What is your opinion of omitting certain years from the historical record
4 because they appear to be unlikely to occur again?

5 A. It is interesting to note history behind this approach. It developed because it
6 was assumed that extreme highs and lows were in fact “errors” indicating that something had
7 gone wrong with the observation or experimental technique. Modern approaches to
8 analysis which focus more on distributions have come to recognize that extremes likely
9 reflect the underlying true distribution.

10 We may be tempted in the current situation to exclude the two highs and the two
11 lows, for instance, because they may influence the mean of the streamflows more than we
12 would like or because they produce rate impacts that are not pleasant to contemplate. As a
13 rationale, we may even note that the mean streamflow is not significantly influenced by
14 excluding these data points.

15 There are several problems with this approach. First, there is no indication that the
16 extreme values in the streamflow data are the result of a failure or errors in the methodology
17 used to measure the flows. Consequently, excluding these legitimate values biases the
18 estimate of the true distribution. Secondly, the fact that the historical mean values is not
19 significantly influenced by excluding some values is somewhat misleading since it is only an
20 estimate of the true mean. In addition, it is quite possible to select any number of
21 combinations of less than 60 values from the historical record that produce the same mean
22 as the 60-year historical record.

1 data series he created, as he himself admits. In addition, it is difficult for me to determine
2 exactly how he did the Monte Carlo.

3 In his analysis Mr. Winterfeld eliminates the sign of the errors in order to guard
4 against large positive and negative errors canceling each other out. Then he calculates an
5 average deviation score. Normally, this same end is accomplished by calculating a
6 traditional variance and standard deviation. Because of the non-standard way that Mr.
7 Winterfeld calculated his deviations, it is difficult to interpret his results and put them the
8 context of traditional analysis.

9 Toward the end of his testimony, just when I thought he would test the efficacy of
10 his "model" on the actual 50 years of streamflow record that then existed, he switches to a
11 112 year interpolated streamflow series. This series was apparently created by converting
12 the 50-year record to a 112-year record through a weighting scheme. He then ran additional
13 simulations on this 112 years series but not on streamflows. Rather, he ran his 1-year
14 rolling average simulations on the revenues produced by these data after they had been run
15 through Avista's 1984 power supply model.

16 Q. Besides being confusing is there anything wrong with what Mr. Winterfeld
17 did?

18 A. In my opinion, there is. Mr. Winterfeld "loses the data" as he progresses
19 through his analysis. In fact, he never actually does any analysis on streamflows as far as I
20 can tell. He did his analysis on a coin flip experiment, on the output of the power supply
21 model, and on the prices as they existed or were forecasted in 1984. He also created a 112-
22 year water record rather than using the 50-year record more relevant to Avista's resource
23 mix and dam locations.

24 Q. But don't all these problems cancel each other out in the Monte Carlo
simulation?

1 A. I don't believe so, partly because the various comparisons he does are so
2 confounded with different levels of data. In addition, nothing is added by treating
3 streamflow as a binary variable, i.e., as either good or poor. In fact, much is lost and
4 misleading conclusions likely have been drawn.

5 Q. Would you please give some detailed examples of the problems you found in
6 Mr. Winterfeld's methodology?

7 A. Yes. First of all, recall that Mr. Winterfeld concludes that the most recent
8 continuous 40 "water years" of history are preferable to using 50 water years because the
9 "cumulative error" is greater for 50 "water years" than for 40 water years.⁵ Recall again
10 that his analysis did not include real water years but rather 0s and 1s with no defined
11 reference to any actual streamflow parameter.

12 In addition, I believe that Mr. Winterfeld's conclusion favoring 40 years of historical
13 water is largely driven by an artifact in his methodology. In other words, the arithmetic
14 necessarily follows merely from the mechanics of the way he set up his comparisons even
15 though Mr. Winterfeld himself may not have been aware of it. And because so much has
16 been made of Mr. Winterfeld conclusions, it is worth while to examine his methodology in
17 some detail.

18 I have recreated a portion of Mr. Winterfeld's Exhibit T-76 in my Exhibit ___ (TDD-
19 9). In Exhibit T-76, Mr. Winterfeld examined only a single future water year. Later he
20 studies only continuous running averages even though he acknowledges that there are no

21 ⁵ We now have 60 years of adjusted water data available that further complicates the re-
22 examination of comparisons done in Mr. Winterfeld's original simulation. In a few years we
23 will have 70 years. For the purposes of my discussion, I usually compare the rolling 40-
24 year rolling method to using the full 60 years worth of data. Unfortunately, some 20 years
25 ago, these data were not available to Mr. Winterfeld. He also did not have available the
26 computing power nor the software that we have today. In 1984, the newest Macintosh had
27 an 8-Megahertz clock speed. I ran these resampling experiments on a desktop computer
28 with a 1.7-Gigahertz clock speed. Over 200 times faster.

1 dependencies in streamflows. If there are no dependencies, any 40-year record could have
2 been examined, including a non-continuous 40-year record. This should have been done in
3 order to avoid, as I discuss later, the real possibility that his results were merely a
4 coincidence resulting from the particular pattern of streamflows that has historically
5 occurred already. His Monte Carlo method does not correct for this possibility because, as
6 far as I could tell, it sampled only from the immediately prior 40-year period so in a sense it
7 preserved the uniqueness of the immediately prior 40 years.

8 In addition, when Mr. Winterfeld created the scenario to test the one-year rolling
9 average, he built in a dependency that constrains or limits the kind of errors that can be
10 made in the one year rolling data. He did this by “backcasting” or creating an after the fact
11 scenario. The estimate for the year forecasted is always what happened in the immediately
12 prior year. This creates a dependency that does not exist in actual streamflow data. If we
13 use the immediately prior year to forecast the next year, in the real world that next year
14 could be any year at random because actual streamflow data have no dependencies, unlike
15 Mr. Winterfeld simulation.

16 Mr. Winterfeld’s method produces an error that is always a type of inverse of the
17 original estimate. Note in Exhibit ___(TDD-9) the places where the state changes from 0 to
18 1 or 1 to 0. If the data goes from 1 to 0, you can predict the error by simply putting a 1 in
19 the immediately preceding line of the error column. These occurrences are marked with a
20 symbol that looks like a check mark with an arrow on one end of it. If it goes from 0 to a 1, a
21 minus 1 will appear. If there is no change, 1 to 1 or 0 to 0, a 0 will be in the immediately
22 preceding line of the error column.

23 Q. What about how Mr. Winterfeld sets up the continuous records method.

24 A. The way this is calculated appears to produce a bias against the continuous
records method. I believe I can explain why this occurs by discussing how the variance of a

1 series of 1s and 0s like Mr. Winterfeld used (a discrete random variable) is influenced by the
2 length of the period of 1s and 0s and by discussing some “memory” characteristics of
3 statistical models.

4 We need to begin by reviewing how the continuous records approach and the rolling
5 average method created their respective estimates. If we refer again to Exhibit ___(TDD-9),
6 the very last estimate in the continuous records column (0.564), we see that this estimate is
7 made up of an average of the prior 39-conditions in the “streamflow” condition column.
8 Now in the same continuous records column, go to line 7 to the estimate of 0.667. This
9 estimate is an average of the six prior “streamflows” in the streamflow condition column.

10 When we examine the estimates in the 1-year rolling average column, we note that
11 they are not an average of prior conditions at all, but as I just discussed, simply the
12 immediately prior condition. In other words, the estimate is just what happened last time.
13 Examples of this are indicated on Exhibit ___(TDD-9) by a long line with an offset at the
14 end.

15 Q. You referred to reasons related to a discussion of statistical modeling. How
16 are those related?

17 A. A model that changes as a result of the feedback it gets from its environment
18 can be said to have a “memory”. Though they do so in different ways, both the continuous
19 records model and the 1-year rolling average model change as a result of feedback from their
20 environments. However, the continuous records model takes into account the entire past
21 history, whereas the 1-year rolling average model considers only the just prior single year.
22 The continuous records model can be said to have an infinite memory and the 1-year rolling
23 average model only a single-year memory.

24 Exhibit ___(TDD-10) through Exhibit ___(TDD-23) are a related series of exhibits
that show step-by-step what happens to the estimates as years are added to the 1 and 0

1 data series. It is important to understand this “estimate--error--new estimate” cycle so that
2 we can fully realize the consequences of the simulation Mr. Winterfeld set up.

3 Exhibit ___(TDD-10) shows what happens when a long series of sixteen 1s
4 abruptly changes to a long series of eighteen 0s. The rolling average model, shown with
5 filled squares, had been going along simply estimating that the next year will be what
6 happened last year, that is, a one (1). And because early on the 1s continue, it did not make
7 any errors until things changed abruptly. This is shown on Exhibit ___(TDD-11).

8 What are the consequences of this error? The rolling average model then
9 immediately changes its estimate to a 0, or what happen the last time. The single error
10 causes the model to changes its estimate from a 1 to a 0 and it suffers an error of only 1 unit
11 and continues on estimating 0s.

12 Exhibit ___(TDD-10) also shows how the continuous records model operates under
13 the identical pattern of 1s and 0s. First, note that the continuous records model (open
14 circles) has been estimating a value between 0.5 and 1.0 even though only 1s have been
15 occurring. It does so because it has a memory longer that 1 year and because Mr. Winterfeld
16 started the example in his Exhibit T-76 at year seven. Why, I’m not exactly sure. In any
17 event, because the continuous records models has an infinite memory, it uses the average of
18 the first six years, rather than just year six alone, to estimate year seven. So the estimate for
19 year seven is the average of what has happened so far: $1+0+1+0+1+1$ divided by 6 equals
20 0.667. This is shown as the first open circle in Exhibit ___(TDD-10).

21 The next estimate is the average of the first seven years (six plus the 1 that just
22 occurred) or $1+0+1+0+1+1+1$ divided by 7 or 0.714. Estimates proceed in this fashion,
23 each taking into account all the information to date. In a sense this is a changing rolling
24 average of “N”, where N is the number of years that have already occurred.

1 When the series abruptly changes from a long run of 1s, the continuous records
2 model does not drastically change its estimate. Instead, a 0 just gets added to the calculation
3 of the average. The pattern of estimates as the 0s continue is shown in Exhibit ___(TDD-
4 10).

5 The error pattern suffered by the continuous records model is shown in Exhibit
6 ___(TDD-12). It is considerably more complicated than the error pattern produced by the
7 1-yr rolling average model. Exhibit ___(TDD-13) shows the two error patterns on the same
8 chart.

9 Without going into further detail, one can begin to get a sense of what happens when
10 these two models are compared. When the world flip-flops, goes from all 1s to all 0s, the 1-
11 year rolling average model adjusts after making just one error. However, the continuous
12 records model is penalized because it is forced to have an infinite memory. It continues to
13 factor in all the past 1s even though the world has changed to all 0s and as a result it
14 accumulates a large error total. This is shown graphically in Exhibit ___(TDD-14), which
15 compares the cumulative absolute error made by the two models.

16 Different patterns of 1s and 0s produce different estimating and error patterns.
17 Exhibit ___(TDD-15) shows the estimating pattern for the two models when there are eight
18 1s in a row, followed by nine 0s in a row, followed again by eight 1s in a row, followed once
19 more by nine 0s in a row. Exhibit ___(TDD-16) shows the error pattern for the two models
20 and Exhibit ___(TDD-17) shows the cumulative absolute error. Once again, the 1-year
21 rolling average model accumulates a lower error total than the continuous records model.

22 Things get more complicated as the 1 and 0 pattern changes and the value of a
23 memory in a more complicated world begins to show. Exhibit ___(TDD-18) shows the
24 resulting estimating pattern when two 0s in a row alternate with two 1s in a row, i.e.,
00110011, and so on. Exhibit ___(TDD-19) shows the error pattern. Exhibit ___(TDD-

1 20) shows the cumulative error for the two methods. The cumulative error is the same in
2 this case.

3 Following along the same logic, Exhibit ___(TDD-21) shows the estimating pattern
4 for the two models when 1s and 0s alternate, i.e., 0101010101. Exhibit ___(TDD-22)
5 shows the resulting error pattern. Exhibit ___(TDD-23) compares the cumulative error for
6 the two models. The 1-year rolling average model now has a much greater error total than
7 the continuous records model. In a sense, we might say memory is most valuable when the
8 world is constantly changing.

9 Depending on the pattern of 1s and 0s, sometimes the continuous records approach
10 leads to a lower cumulative error and sometimes it is the 1-year rolling average. I will
11 discuss this further a little later in my testimony.

12 Q. How do all these factors you have discussed so far relate to your statement
13 that there is an artifact in Mr. Winterfeld method that drives his conclusions?

14 A. Putting together all that I've discussed so far, it is possible to demonstrate
15 that his results appear to simply follow from the mathematics of the way the comparisons
16 are set up. Rather than running a Monte Carlo simulation as Mr. Winterfeld did, I calculate
17 the expected result of the comparison between the two models.

18 To calculate the variance of a binomial distribution such as a series of 1s and 0s, we
19 can take the expected probability of 1 (usually called "p"), times the expected probability of
20 0 (usually called "q"), time the series length (usually designated as "N"). So the formula for
21 the variance is: $p \cdot q \cdot N$.

22 The two methods, continuous records versus 1-year rolling average, are structured
23 such that for the continuous records approach, on average, the error (variance) is calculated
24 each time a new year is added. So in year one, the variance is 0.25 (.5x.5x1); in year five it is

1 1.25 (.5x.5x5); in year ten it is 2.5 (.5x.5x10); in year twenty-five it is 6.25 (.5x.5x25), and
2 so on.⁶

3 If we do the same for the 1-year rolling average approach, the flaw in Mr. Winterfeld
4 method begins to shows up. In year one the variance is 0.25 (.5x.5x1). The same as in the
5 continuous records approach. However, in year two, the variance is again 0.25 (.5x.5x1)
6 because the rolling one-year approach does not take into account anything more than a
7 single immediately prior year. For each added year the variance is the same: 0.25. To get
8 the “cumulative error” we would again add up all these individual, identical variances each
9 based on an N of only one. So for the 1-year rolling average model we have constant
10 variance (error) and for the continuous records model we have a variance that increases as N
increases.

11 The end result is that the rolling 1-year average produces a lower cumulative error
12 simply because of the mechanics of the way the comparison was set up. **Necessarily, the**
13 **sum of $p \cdot q \cdot N$ (the continuous records method) will always be greater than sum of**
14 **$p \cdot q \cdot 1$ (the 1-year rolling method), where N is greater than 1.**

15 This result follows from probability theory. So I conclude that Mr. Winterfeld’s
16 results appear to be based on the mechanics of the way he set up his comparisons. They
17 say little about the merits of one method compared to the other with regard to streamflows.

18 ⁶ Mr. Winterfeld transformed all the “errors” at this stage into absolute values and summed
19 them up to get what he called his “cumulative error” metric. He did not calculate the
20 variance or standard deviation at this point. Mr. Winterfeld created absolute deviations and
21 then took the standard deviation of those values, the standard deviation of average
22 deviations. The interpretation of the average deviation is much different than the standard
23 deviation. The standard deviation from the mean has very convenient mathematical
24 properties; one of the most important is that it is one of the two parameters of a normal
distribution. This cannot be said of the average deviation. Hence, it is more difficult to
interpret. I discuss these issues with regard to resampling and note that traditional
inferential statistics are not always appropriate for resampling experiments.

1 Q. Does this flaw happen for cases where the expected probability of 1s and 0s
2 is different than 0.5.

3 A. Yes. For any p and q, this will always happen.

4 Q. Why does the continuous records approach ever turn out better than the 1-
5 year rolling average method?

6 A. Because at any point in the series and for any particular unique series, the p
7 and q values don't remain constant. Remember that the continuous records method has a
8 memory. Wherever it is, it looks back to the start of the series and calculates an average to
9 predict the next outcome. So, if six 1s in a row have just occurred in the middle of a series,
10 it will base its estimate for the next outcome on the average it saw since the beginning of the
11 series rather than the long term expected value of p or q. When the errors are summed up,
12 they are summed over different p and q combinations. However, for the 1-year rolling
13 average method, the p and q values are always very close to the expected long run values
14 because it has a very short memory—one year in fact. And because it always and only
15 predicts the same as just last year, it stays very close to the developing probabilities of p
16 and q whereas the continuous records methods can get further away because it is averaging
17 more and more history.⁷

18 At 30 years for example, the continuous records model has built up a reserve of
19 knowledge of the past. If all prior 30 years were 1s, it would take 30 years of 0s to equal
20 the number of 1s and the prediction for the next occurrence would still not be a 0. But
21 rather, it would be 0.5, the long-term or expected value. The continuous records approach

22 ⁷ It could be argued that what Mr. Winterfeld has done is to set up a process where we are
23 allowed to witness the unfolding of an estimate of the variance for a binomial distribution
24 (continuous records) vs. just the estimate of the probability of a 1 (the 1-year rolling average
model) as N increases. In this case it is not clear what comparing the cumulative errors
between these two estimating processes really means.

1 minimizes its maximum error by hedging its bets, so to speak. The 1-year rolling average
2 will predict 0s after just one mistake. The continuous records method never clears its
3 memory. It assumes all the past is equally valid so it does not discard it. On the other
4 hand, the 1-year rolling average method remembers only yesterday. All else is irrelevant.
5 Remind anyone of some teenagers?

6 Of course, as the rolling average length increases to 5, 10, or a 40-year rolling
7 average, memory gets longer. The length of the memory is equivalent to a judgement
8 regarding the relevance of historical data. A 40-year rolling average says that no data over
9 40 years old is worthwhile or relevant. If new data is added, older data is discarded as a
10 result of the, "over 40 years is irrelevant rule", set up by this approach. In contrast, the
11 continuous records approach keeps all data and gives it equal relevance.

12 All these factors combine to produce somewhat unpredictable results as several of
13 my prior exhibits show. An example of how these factors combine can be demonstrated by
14 turning to Exhibit ___(TDD-24).

15 This exhibit shows that depending upon the unique series of 1s and 0s that have
16 occurred, and depending upon the series length we focus on, either method may produce the
17 lower cumulative error. The series of 1s and 0s that are shown in my Exhibit ___(TDD-24)
18 are the same as the series Mr. Winterfeld chose for his Exhibit T-76. At the 35th year, the
19 continuous records approach is lower; at the 30th year the rolling average approach is lower;
20 at the 25th year the methods are essentially identical with regard to cumulative error.

21 In the same vein, as Exhibit ___(TDD-23) shows what happens to cumulative error
22 when two 0s alternate with two 1s: 00110011001100110011. The result is that in this
23 instance cumulative error is essentially identical for the two methods.

24 Q. Mr. Winterfeld looks at more than a 1-year rolling average. Doesn't that
correct the deficiencies you discussed?

1 A. No, it just incrementally waters them down until at exactly 40 years the two
2 methods are essentially the same, each with a 40-year memory. Then as the continuous
3 records methods adds years beyond 40, the differences again reappear.

4 Q. In light of all this, are you implying that a continuous record approach is
5 better in all situations? Should we always use all the data that is available?

6 A. What method is better depends on a detailed analysis of the data series in
7 question.⁸ If there are trends or cycles in the data, it may indeed be better to use a rolling
8 average approach, the exact length being uncertain. Of course, even a simple rolling average
9 approach gives equal weight to all the data within its length. For a 40-year rolling average,
10 the second year in the 40-year period is given the same weight as the thirty-ninth year.
11 There are methods that differentially weight the age of the data in the period so that older
12 data may have less weight or so that each tenth year is given more weight if there is a 10-
13 year cycle in the series, etc.

14 There is, however, no indication that such a model is appropriate for the streamflow
15 data we are discussing here. In fact, it has been mentioned already that there is widespread
16 agreement that there are no dependencies or cycles in the streamflow history. Absent a
17 reason to say that older data is irrelevant or should be given less weight, there is no
18 statistical reason to prefer a model, such as a 40-year rolling average, that uses less than all
19 the applicable data. In fact, as I have already testified, I believe that to discard any data
20 reduces the accuracy of our estimates and is contrary to theory in mathematical statistics,

21 ⁸ The one-year rolling average method may be effective in a 1 and 0 world where simply the
22 raw number of exact, correct “hits” is what is important, as opposed to minimizing its
23 maximum error. For example, betting maroon (a combination of black and red that may well
24 perfectly represent the relative frequency of red and black) on a roulette wheel will always
produce more losses than betting red all the time, or black for that matter. However, if I am
interested in forecasting blended or continuous values, and want to be closest most often, a
1 and 0 model probably will not be my choice. In fact it may always be wrong.

1 especially the Glivenko-Cantelli Theorem. And of course, the 2001 record low streamflow
2 demonstrates quit convincingly that the low streamflows that occurred some 60 years ago
3 during the 1930s are not irrelevant, contrary to the way the 40-year rolling average model
4 treats the same data.

5 Q. Do you have an opinion on Mr. Winterfeld use of only a single forecasted
6 year as the criterion for deciding on how many historical water years to use?

7 A. Mr. Winterfeld does base his conclusions on the premise that we are most
8 interested in only yearly estimates of streamflows and power supply costs (pages 3 and 5
9 of his testimony). My experience has been that when we construct a pro forma test period
10 for rate making, we attempt to make that pro forma reflect a period longer than one year.
11 We average out injuries and damages for example. When we evaluate surplus sales, we don't
12 just use the next year's prices but also examine a longer period.

13 If fact, the first full year that rates are in effect (the "rate year") is typically over a
14 year past the pro forma period. This occurs simply because of the time it takes to litigate a
15 case and because it is very difficult to file a case with the newest possible pro forma test
16 year. It is also prudent to plan on not coming in to adjust rates each year so, as long a
17 period as is practically possible, should be reflected by the pro forma.

18 As I discussed earlier, we ought to ask what period we are trying to forecast for the
19 pro forma, since that may become the criterion we use to evaluate various approaches. I
20 believe it is more reasonable to think about a five-year period, not only because it fits better
21 with what has been done in the past but also because it is easier to forecast an average
22 period than a single year, as Exhibit ___(TDD-4) Exhibit ___(TDD-5) and reflect. Mr.
23 Winterfeld never evaluated anything but a single forecasted year in any of his comparisons.

24 Q. Did you do any analysis with regard to the type of bias a continuous 40-year
method may introduce?

1 A. Yes I did. I compared the distribution of individual streamflow years for all
2 60 years of the record as well as for the last 40 years. I created histograms or frequency
3 polygons, as they are sometimes called, for both the 60-year series and the 40-year series. I
4 standardized these series to adjust for the fact that the 60-year series obviously has more
5 data points than the 40-year series. The results are shown in Exhibit ___(TDD-25).

6 The darker line in the exhibit is the 60 year series, the lighter line the 40. The shaded
7 areas show the significant bias in the 40-year series compared to the 60 years of streamflow
8 record. The rolling 40-year average very clearly produces a distribution that significantly
9 under represents low water years and over represents the high water years.

10 Avista witnesses have discussed this bias in prior cases and they discuss it again in
11 this case. The continuous last 40-year of record not only produces a change in the estimate
12 of the mean of streamflows but it also produces a different shaped distribution of yearly
13 flows, one that is skewed away from values below the mean value.

14 Q. Did you do any other analysis on the differences between the 40-year rolling
15 average method and the 60 year water record?

16 A: Yes. My results are shown in Exhibit ___(TDD-26) and Exhibit ___(TDD-
17 27). These two exhibits are a recast of my Exhibit ___(TDD-2) and Exhibit ___(TDD-3)
18 with data added to enable a comparison of how the series of unique water years represented
19 by the existing continuous 40-year rolling average compares with many other outcomes that
20 may well have occurred. In fact, resampling theory implies that these possible outcomes are
21 a better estimate of the true state of nature than the single unique 40-year series
22 recommended by Mr. Winterfeld.

23 Exhibit ___(TDD-27) shows that the 40-year continuous rolling average is just
24 barely within the 90% confidence interval for a sample size of 40 years and is clearly
outside the 90% confidence interval for sample sizes of 50 or 60 water years. What this

1 indicates is that the 40-year rolling average is one of the very least representative series that
2 should be used to reflect the true state of streamflows.

3 Q. You demonstrated that the continuous record approach sometimes produces
4 a lower cumulative error than the rolling average approach. Did you conduct any resampling
5 experiments comparing the two methods?

6 A. Yes. This resampling experiment is an element of my critique of Mr.
7 Winterfeld's method. It involved using the resampling technology to directly compare Mr.
8 Winterfeld's rolling average method to the continuous records approach for actual
9 streamflow data. I believe the outcome of the resampling experiment better reflects the
10 efficacy of the two models because it avoids the use of 1s and 0s and because it does not
11 limit the data range to simply the immediately prior 40 year period, although that period
12 was allowed as a possible selection.

13 Q. Would you outline the experiment you did?

14 A. I randomly selected, with replacement, 60 years of streamflows. I then
15 compared the continuous records approach and the 1-year rolling average approach with
16 regard to cumulative, absolute error, calculated the way Mr. Winterfeld did in his testimony.

17 I ran 1,000 iterations of the experiment with the streamflow data, taking a new
18 random sample each time. I found that the continuous records approach produced a lower
19 cumulative, absolute error 993 times out of the 1,000, or 99.3% of the time. In other words,
20 in only 7 times out of 1,000 did Mr. Winterfeld's rolling average approach do better than
21 the continuous records approach when actual streamflow data were used. The other 993
22 times the continuous records approach was better. I would be happy to run additional
23 iterations during my cross-examination since the model can be demonstrated on a laptop
24 computer with a projection screen.

1 are significant and fatal flaws in his methodology. Finally, duplicating his method and using
2 actual streamflow data led me to a conclusion just the opposite of the one he drew.

3 Compared to the entire 60-year streamflow record, the continuous 40-year rolling
4 average under represents poor water years and over represents good water years. This not
5 only biases the estimate of the mean streamflows, but also distorts the distribution of
6 streamflows that are used to determine power supply costs. In fact, the 40-year rolling
7 average method produces one of the very least representative streamflow periods.

8 All applicable data should be used; 60 years of streamflow data is preferable to 40,
9 rolling or otherwise. This conclusion is consistent with statistical theory. More data is
10 better.

11 Q. Does this conclude your testimony?

12 A. Yes it does.

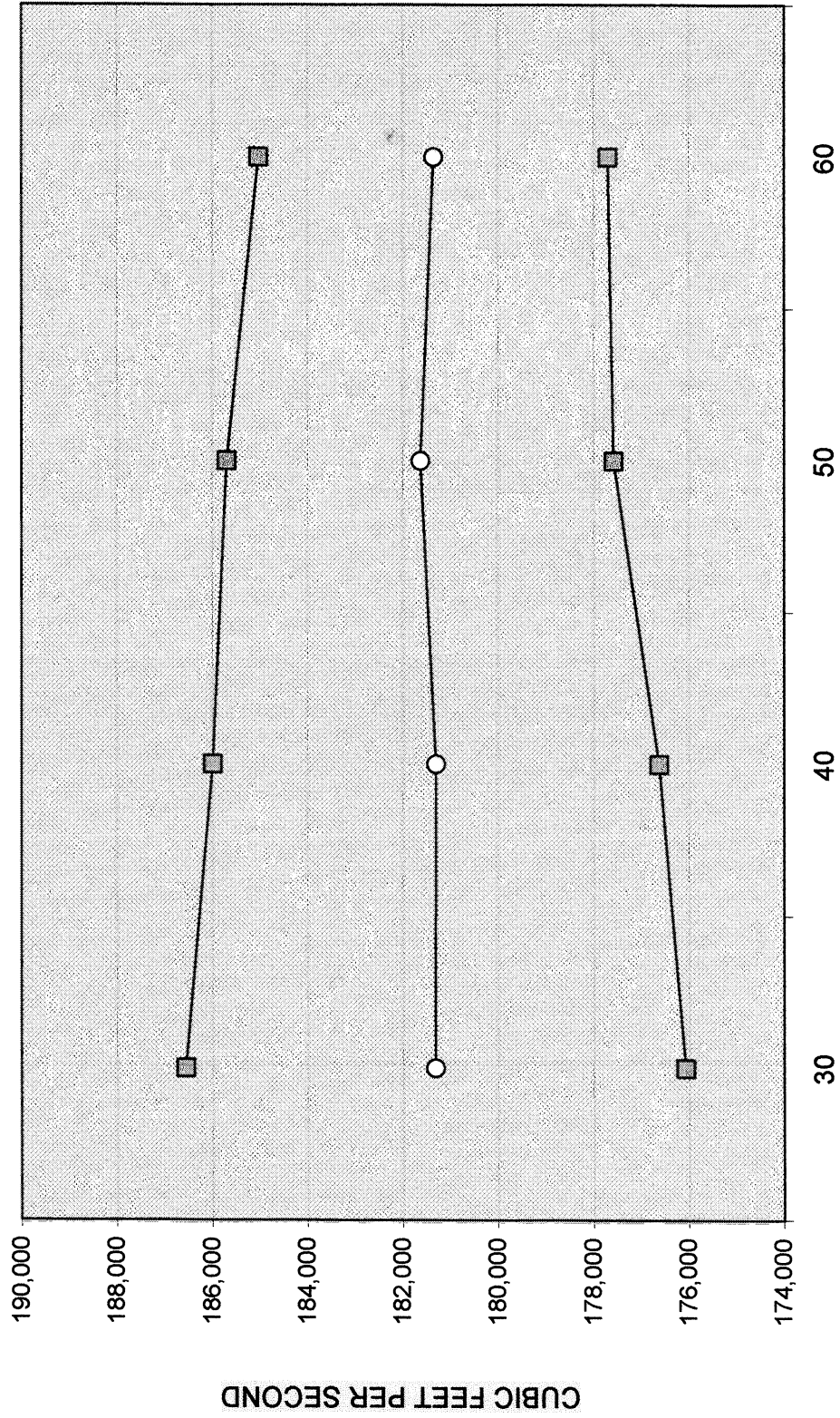
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-1)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

GRAND MEAN AND THE AVERAGE DEVIATION (PLUS OR MINUS) OF
 SAMPLE MEANS FROM THE GRAND MEAN FOR VARIOUS SAMPLE
 SIZES BASED ON 1,000 MEANS FOR EACH SAMPLE SIZE



1,000 SAMPLES OF A GIVEN SIZE X (=30, 40, 50 AND 60)

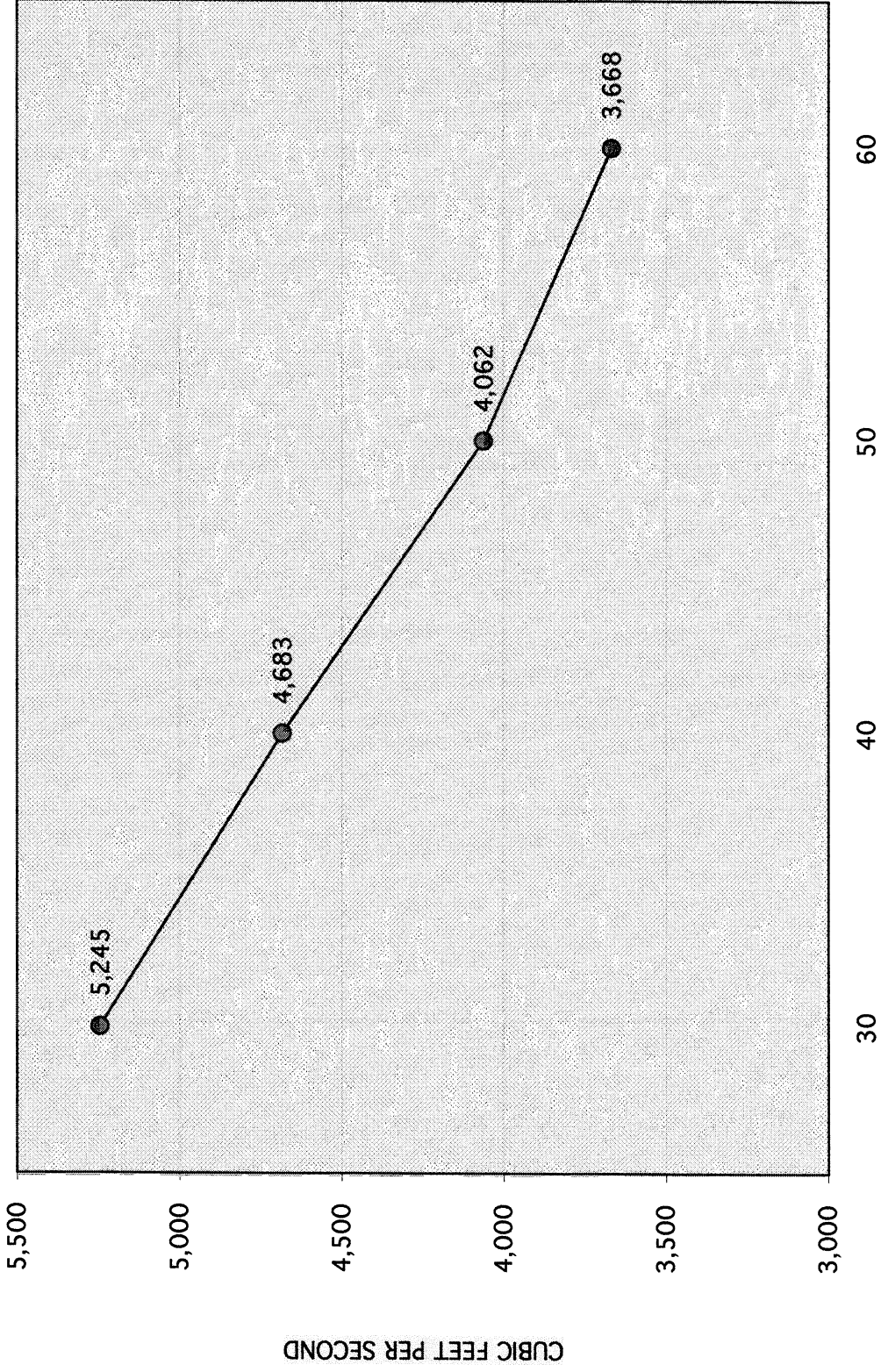
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-2)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

AVERAGE DEVIATION FOR THE MEAN FROM THE GRAND MEAN FOR
VARIOUS SAMPLE SIZES BASED ON 1,000 MEANS FOR EACH SAMPLE



1,000 SAMPLES OF A GIVEN X (X=30, 40, 50 AND 60)

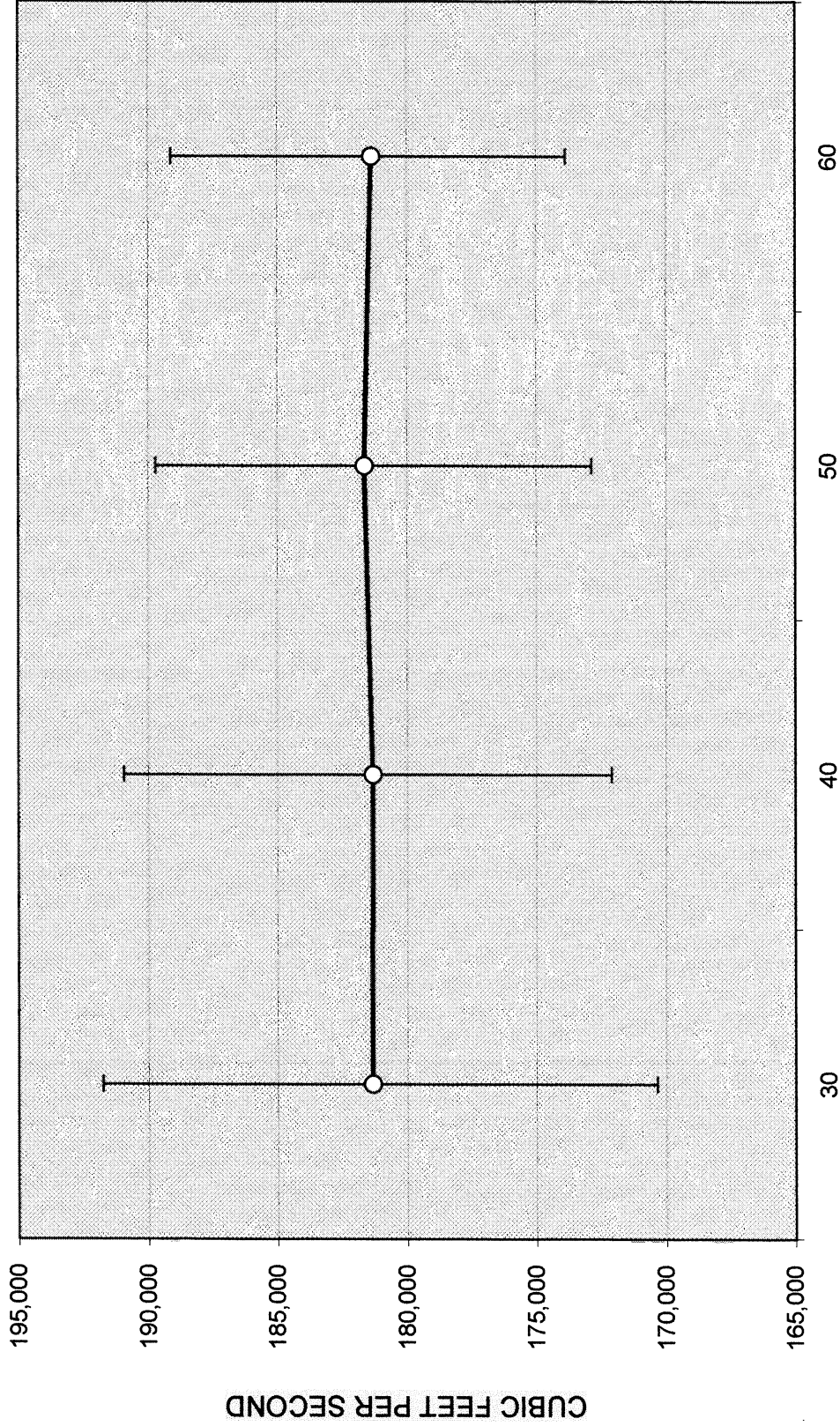
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____(TDD-3)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

RESAMPLING 90% CONFIDENCE LIMITS FOR THE MEAN
AROUND THE GRAND MEAN FOR VARIOUS SAMPLE SIZES
BASED ON 1,000 MEANS FOR EACH SAMPLE SIZE



1,000 SAMPLES OF A GIVEN SIZE X (X=30, 40, 50, and 60)

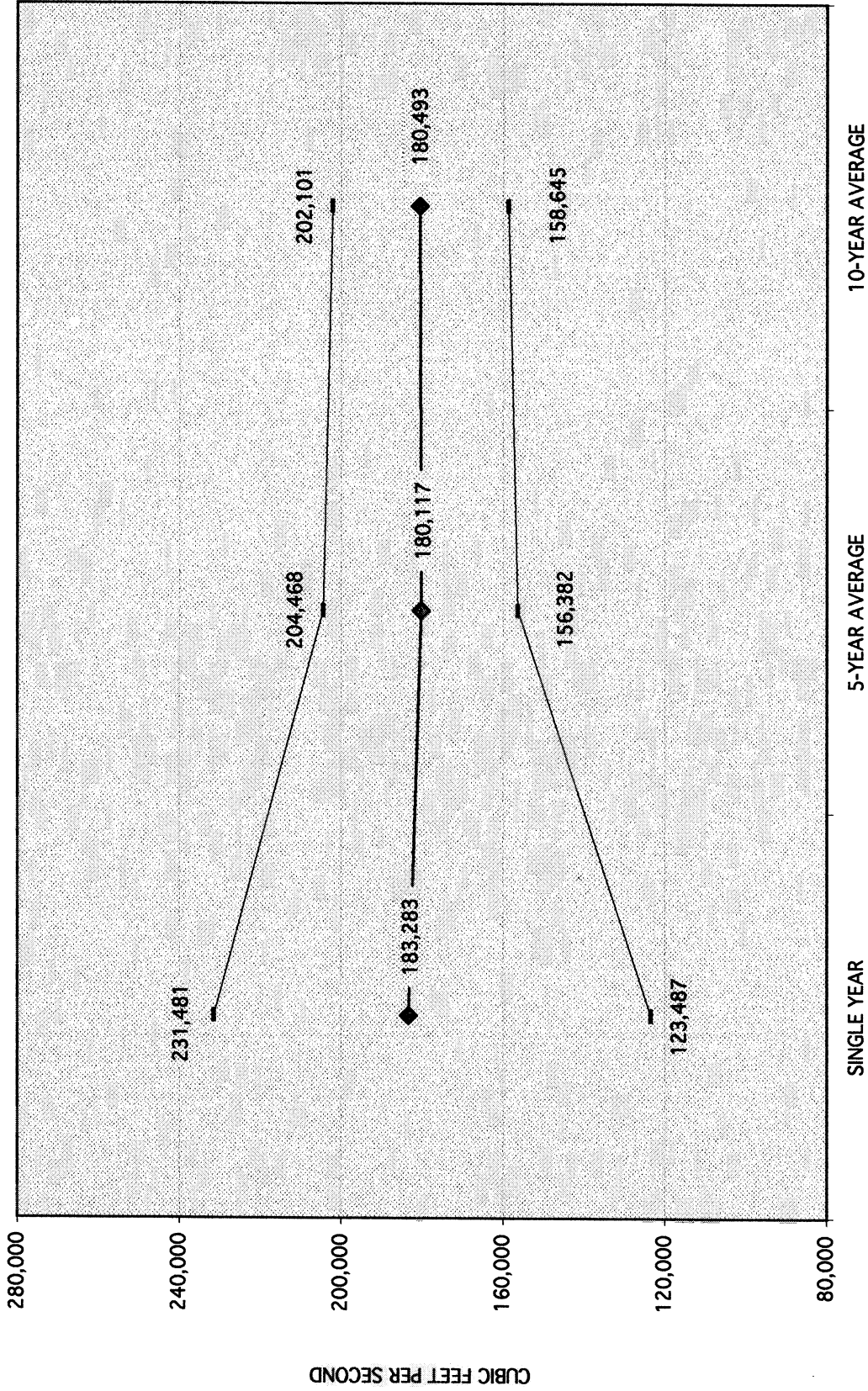
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-4)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

90% CONFIDENCE AROUND THE AVERAGE DEVIATION FOR 100 RANDOMLY SELECTED SINGLE YEARS AND FOR 100 RANDOMLY SELECTED 5-YEAR AVERAGES AND 10-YEAR AVERAGES



FORECAST PERIOD POSSIBILITIES

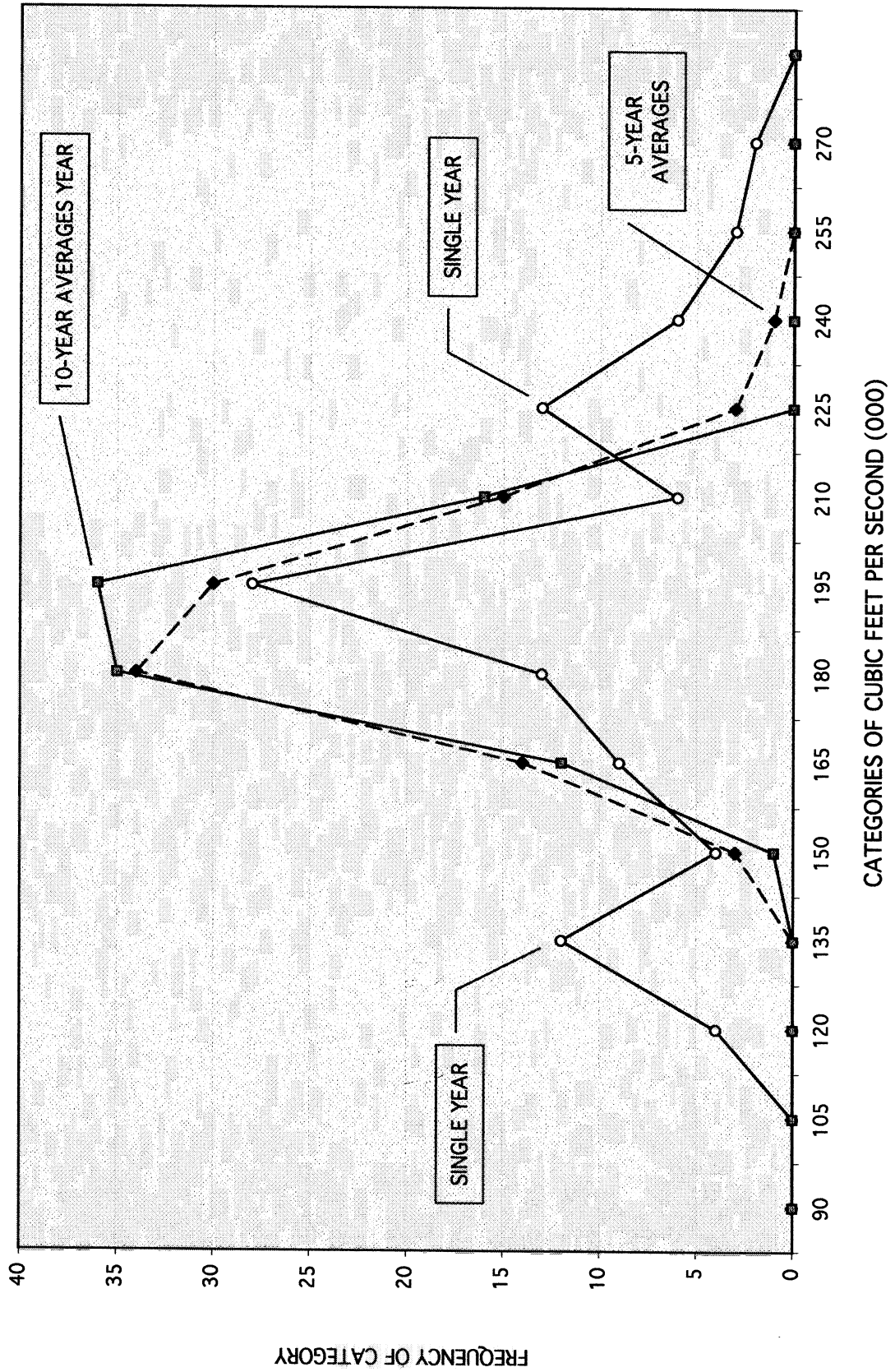
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____(TDD-5)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

DISTRIBUTION OF 100 RANDOMLY SELECTED SINGLE
 WATER YEARS, 100 RANDOMLY SELECTED 5-YEAR AVERAGES,
 AND 100 RANDOMLY SELECTED 10-YEAR AVERAGES



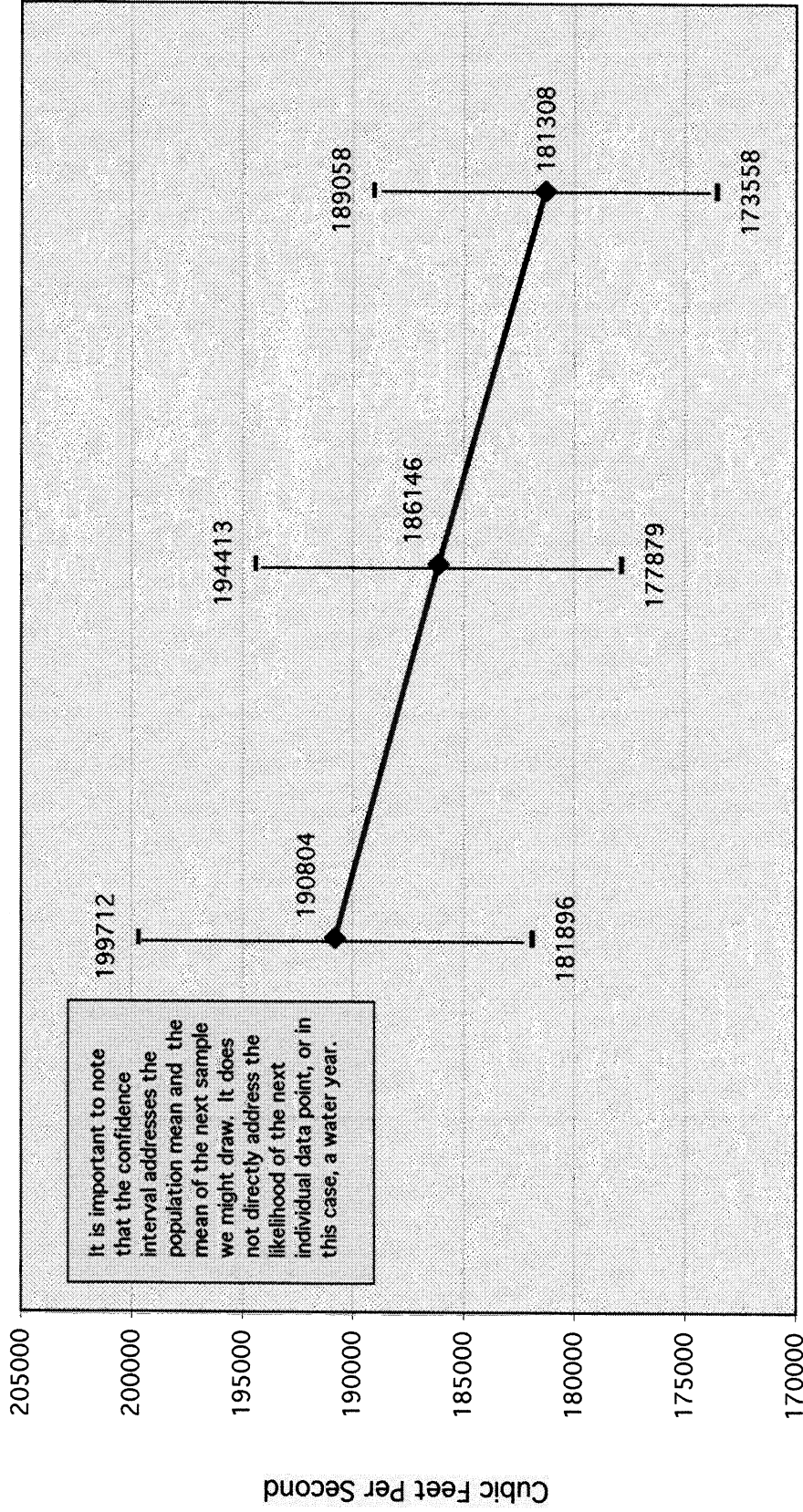
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-6)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

STANDARD ERROR OF THE MEANS AND CONFIDENCE INTERVALS AT 90% FOR THE LAST 40, 50 AND 60 YEARS OF STREAM FLOWS



Last 40 Years Last 50 Years Last 60 Years

Sample Size (Number of Water Years)

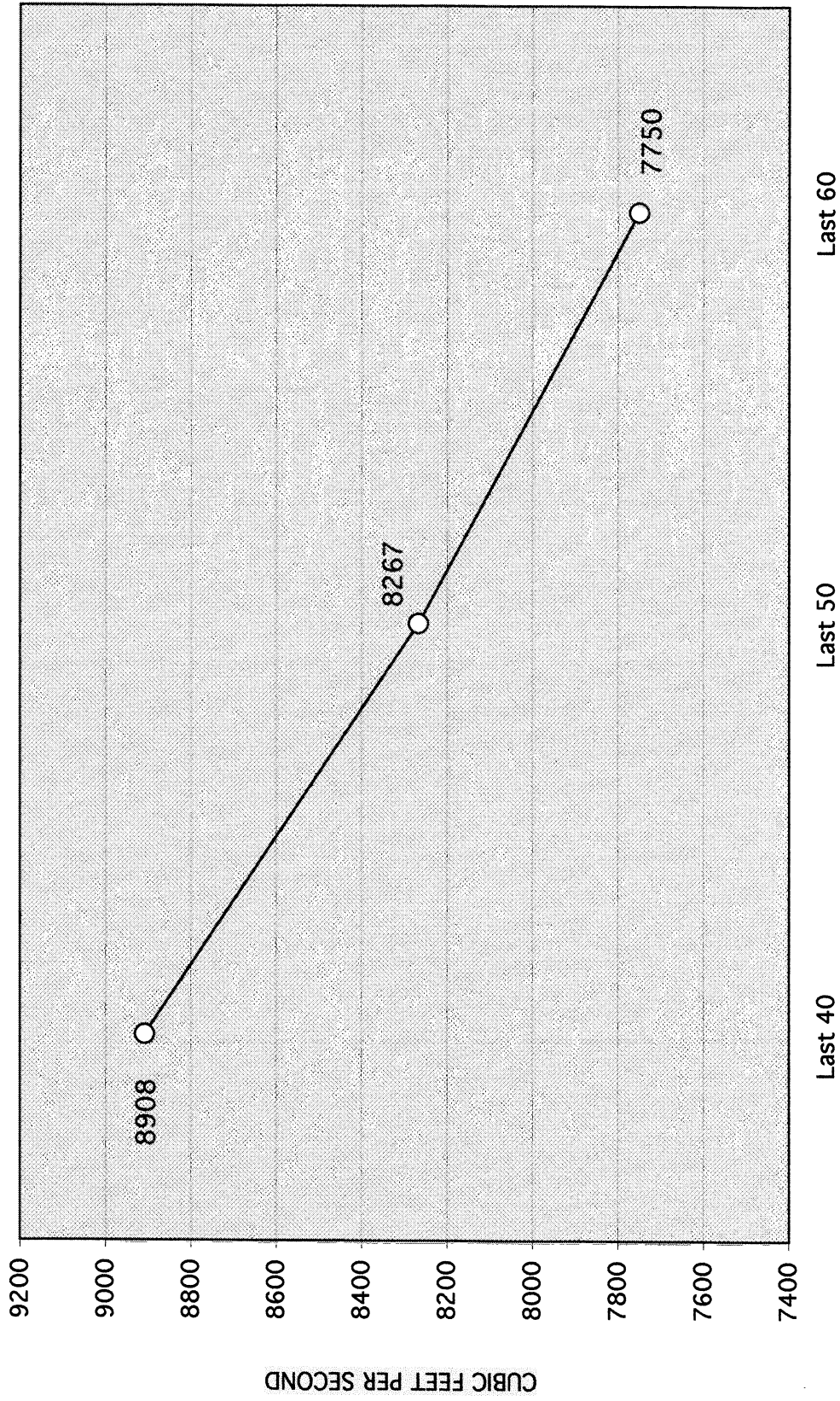
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-7)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

90% CONFIDENCE INTERVAL FOR 40, 50, AND 60 YEAR STREAM FLOW SERIES



YEARS OF DATA

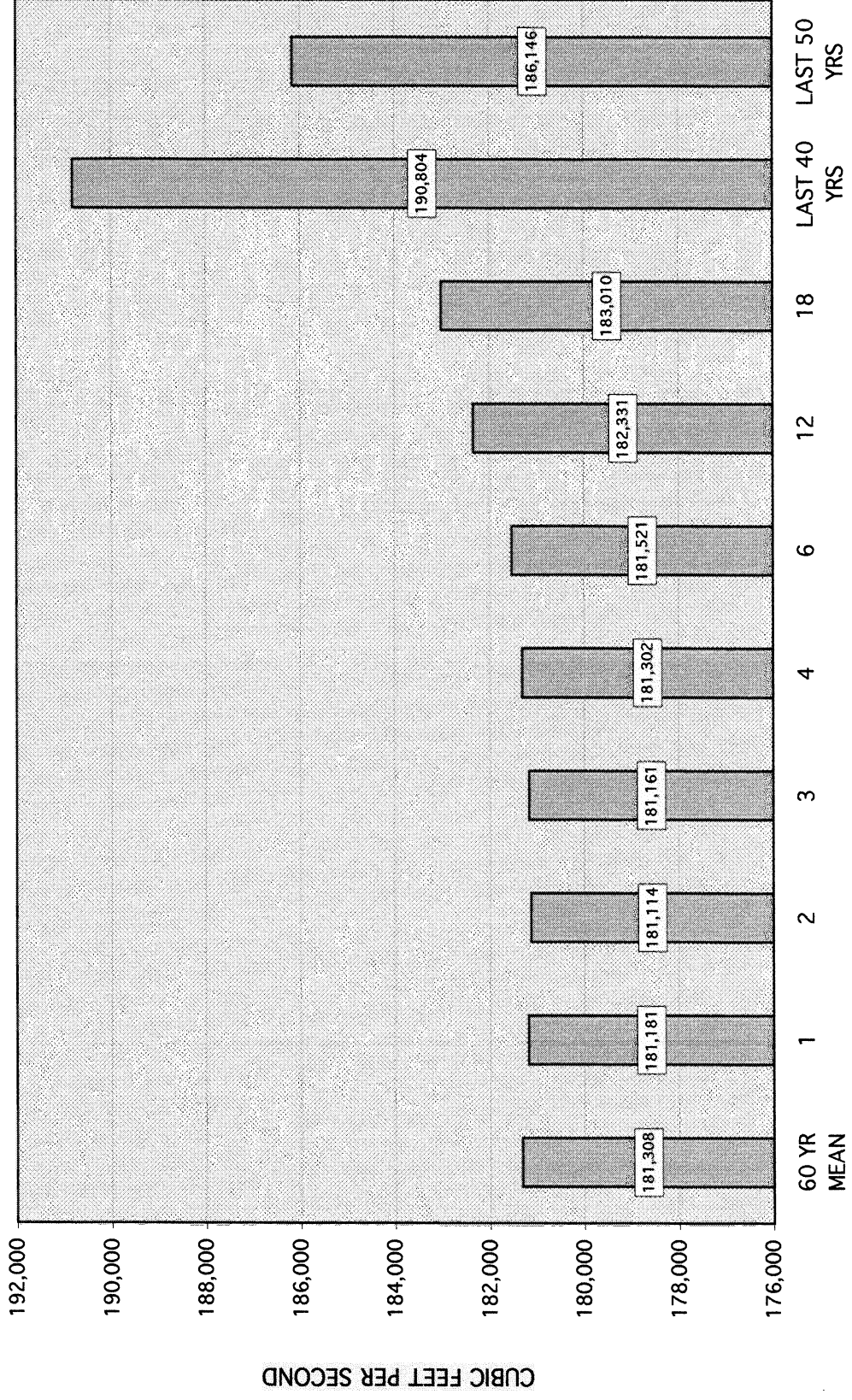
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-8)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

EFFECT ON THE 60 YEAR MEAN OF EXCLUDING HIGH AND LOW VALUES AND COMPARISON TO 40 AND 50 YEAR SERIES AVERAGES



NUMBER OF HIGH AND LOW VALUES EXCLUDED AND SERIES MEANS

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-9)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

Year	Streamflow Condition	CONTINUOUS RECORDS		1 YR ROLLING AVERAGE	
		Estimate	Error	Estimate	Error
[a]	[b]	[c]	[d]	[e]	[f]
1	1				
2	0				
3	1				
4	0				
5	1				
6	1				
7 ✓	0	✓ 0.667	0.667	1.000	1.000
8	0	0.571	0.571	0.000	0.000
9	0	0.500	0.500	0.000	0.000
10	0	0.444	0.444	0.000	0.000
11	0	0.400	0.400	0.000	0.000
12	1	0.364	-0.636	0.000	-1.000
13	1	0.417	-0.583	1.000	0.000
14	1	0.462	-0.538	1.000	0.000
15	1	0.500	-0.500	1.000	0.000
16	0	0.533	0.533	1.000	1.000
17	0	0.500	0.500	0.000	0.000
18	1	0.471	-0.529	0.000	-1.000
19	0	0.500	0.500	1.000	1.000
20	1	0.474	-0.526	0.000	-1.000
21	0	0.500	0.500	1.000	1.000
22	1	0.476	-0.524	0.000	-1.000
23	1	0.500	-0.500	1.000	0.000
24	0	0.522	0.522	1.000	1.000
25	1	0.500	-0.500	0.000	-1.000
26	0	0.520	0.520	1.000	1.000
27	0	0.500	0.500	0.000	0.000
28	1	0.481	-0.519	0.000	-1.000
29	1	0.500	-0.500	1.000	0.000
30	1	0.517	-0.483	1.000	0.000
31	0	0.533	0.533	1.000	1.000
32	1	0.516	-0.484	0.000	-1.000
33	0	0.531	0.531	1.000	1.000
34	0	0.515	0.515	0.000	0.000
35	1	0.500	-0.500	0.000	-1.000
36	1	0.514	-0.486	1.000	0.000
37	1	0.528	-0.472	1.000	0.000
38	1	0.541	-0.459	1.000	0.000
39	1	0.553	-0.447	1.000	0.000
40 ✓	1	✓ 0.564	-0.436	1.000	0.000
Cumulative Error		=	-1.886		0.000

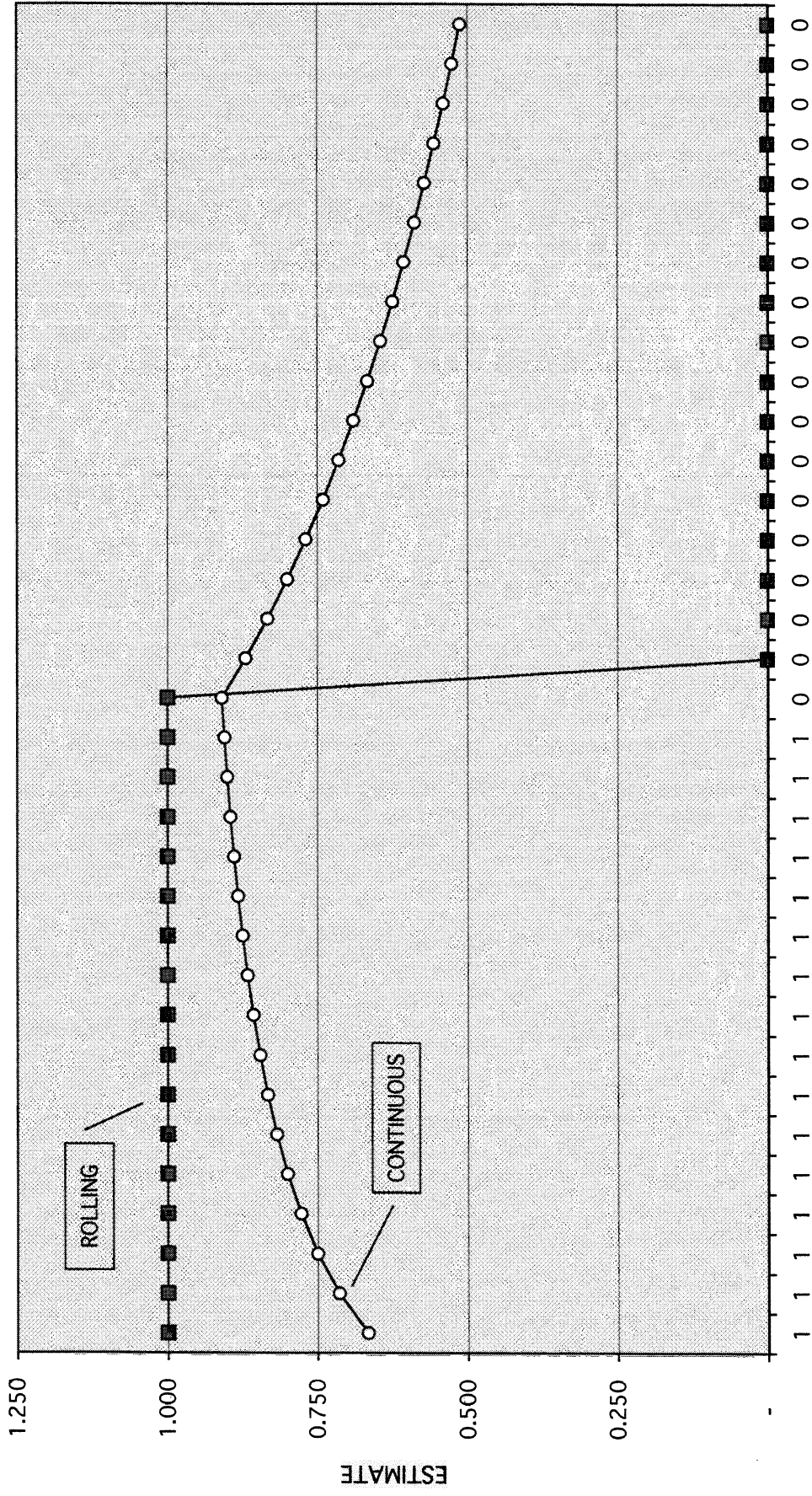
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____(TDD-10)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ESTIMATES WITH 16 STRAIGHT ONES AND 18 STRAIGHT ZEROS
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY=1)



TRUE VALUE

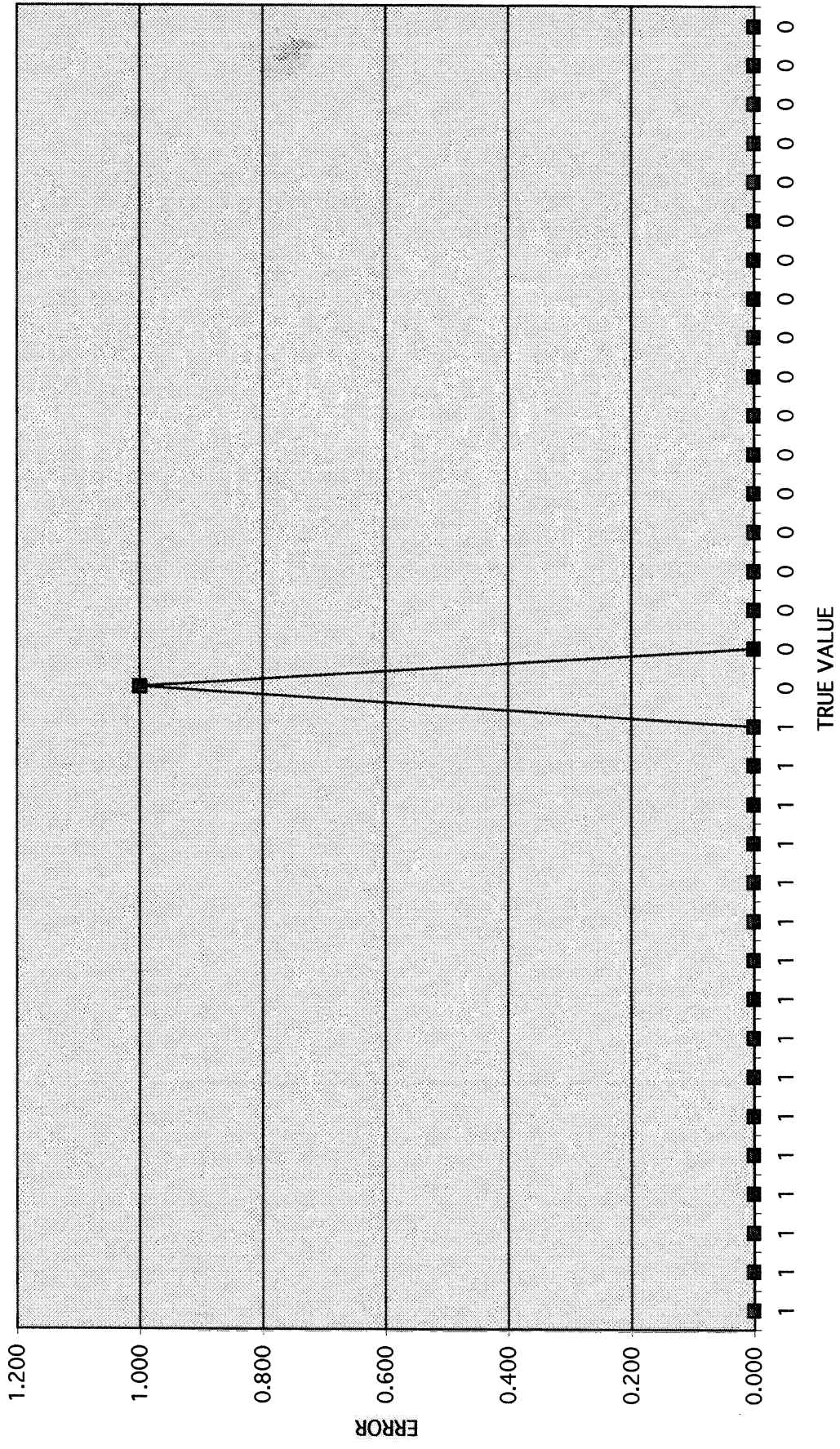
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-11)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ERRORS WITH 16 STRAIGHT ONES AND 18 STRAIGHT ZEROS
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 1-YR ROLLING AVERAGE (MEMORY =1)



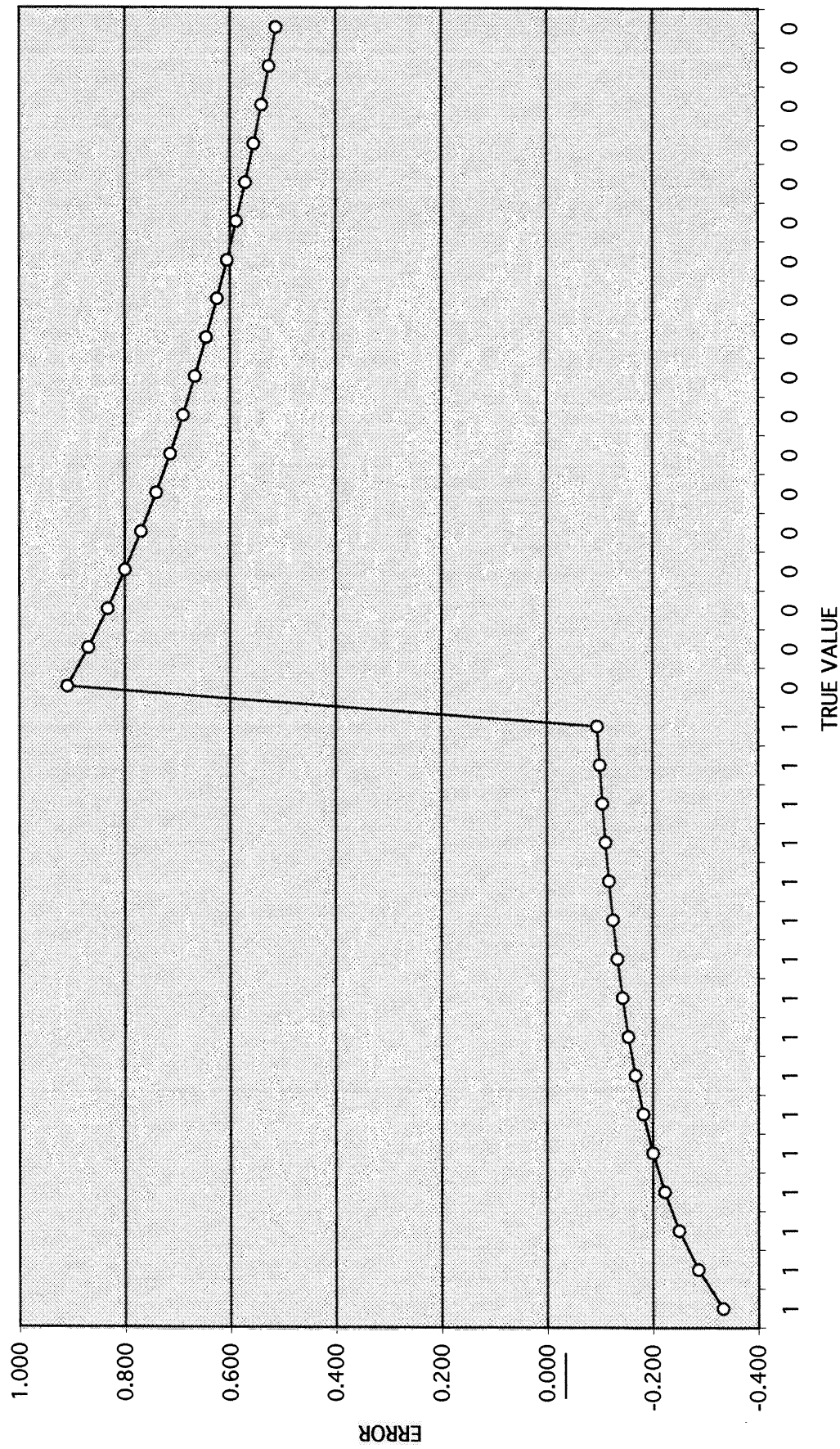
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-12)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ERRORS WITH 16 STRAIGHT ONES AND 18 STRAIGHT ZEROS
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40)



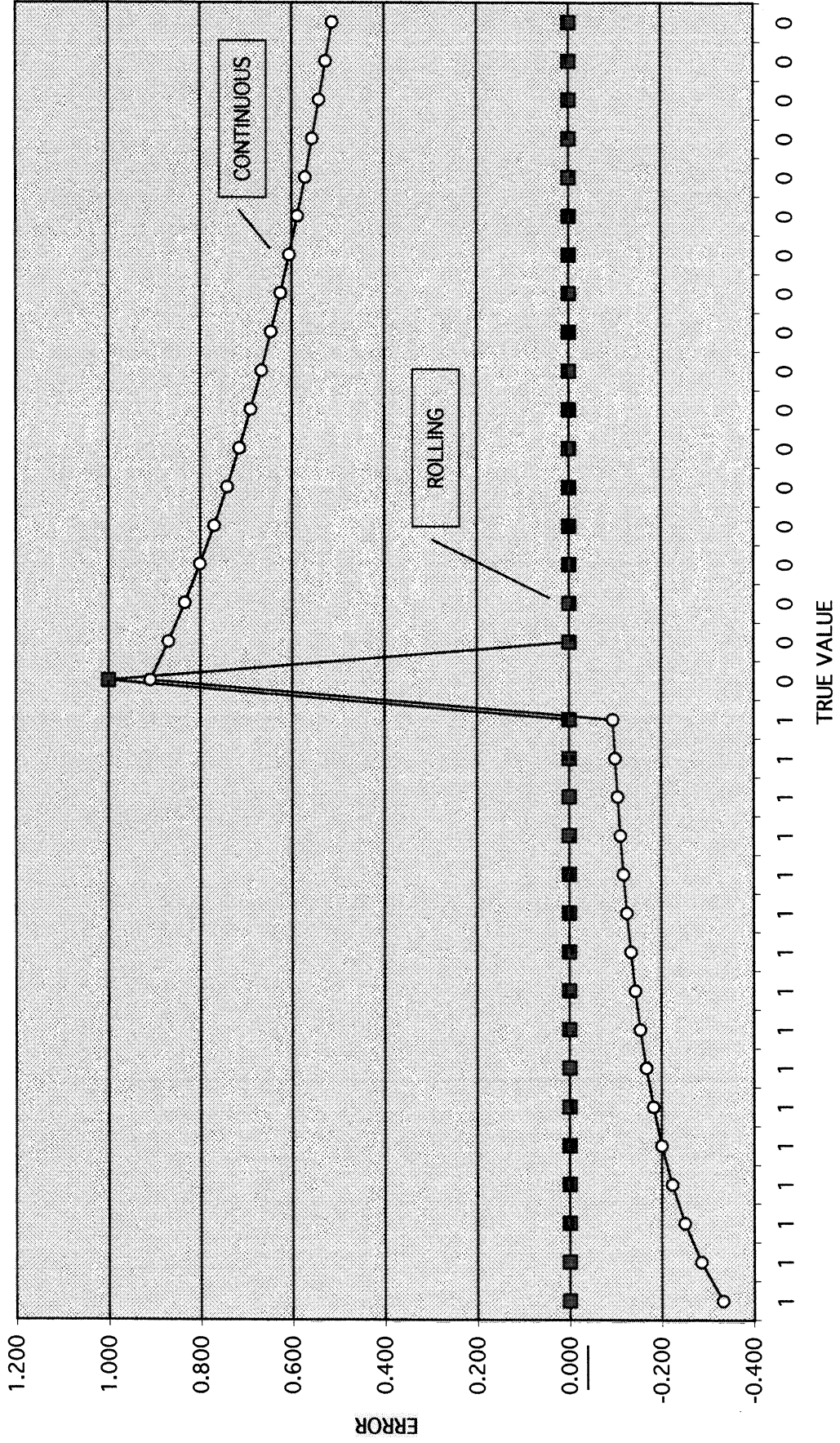
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-13)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ERRORS WITH 16 STRAIGHT ONES AND 18 STRAIGHT ZEROS
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY =1)



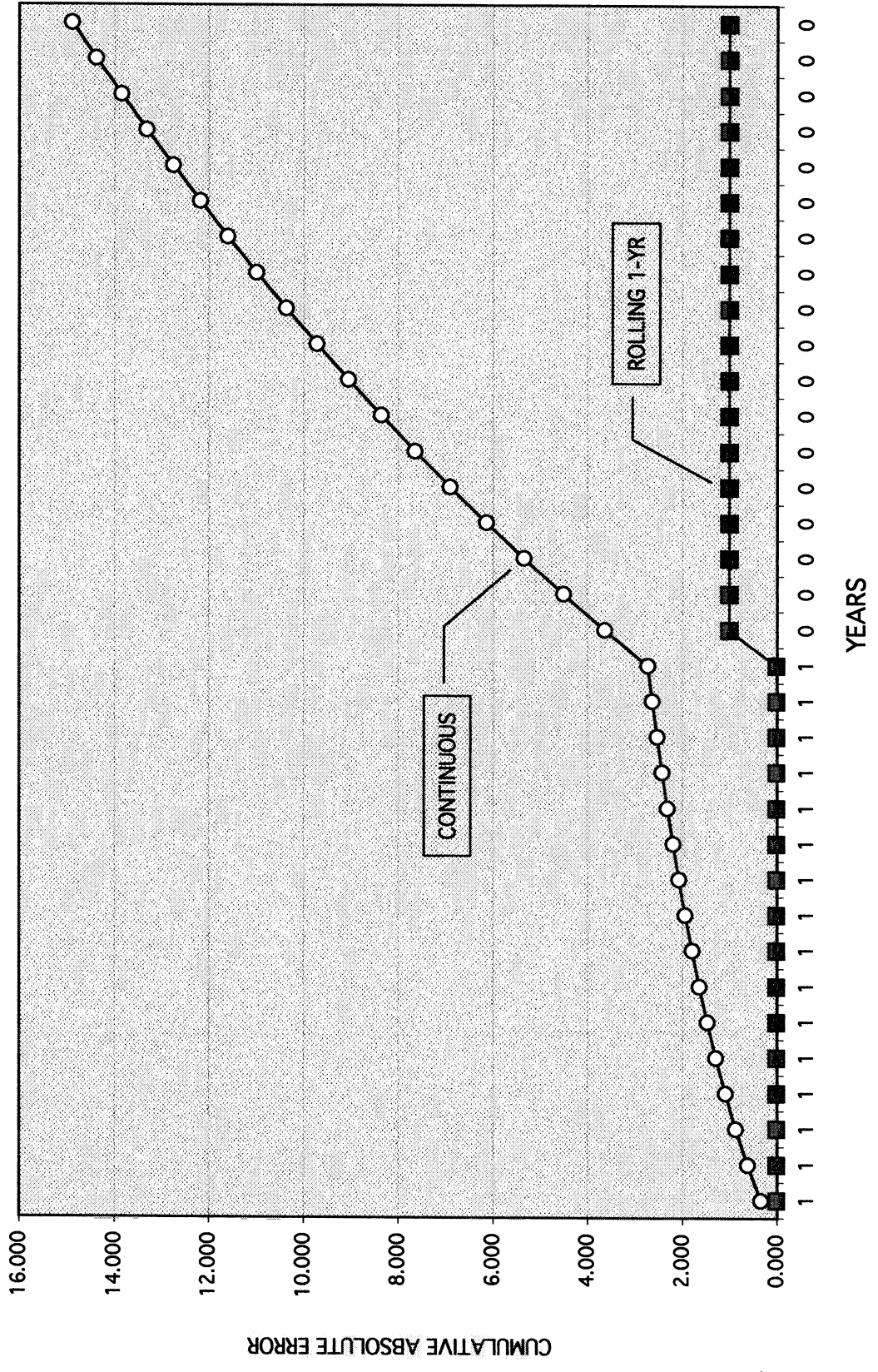
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-14)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

CUMULATIVE ABSOLUTE ERROR WITH 16 STRAIGHT ONES AND 18 STRAIGHT ZEROS
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY =1)



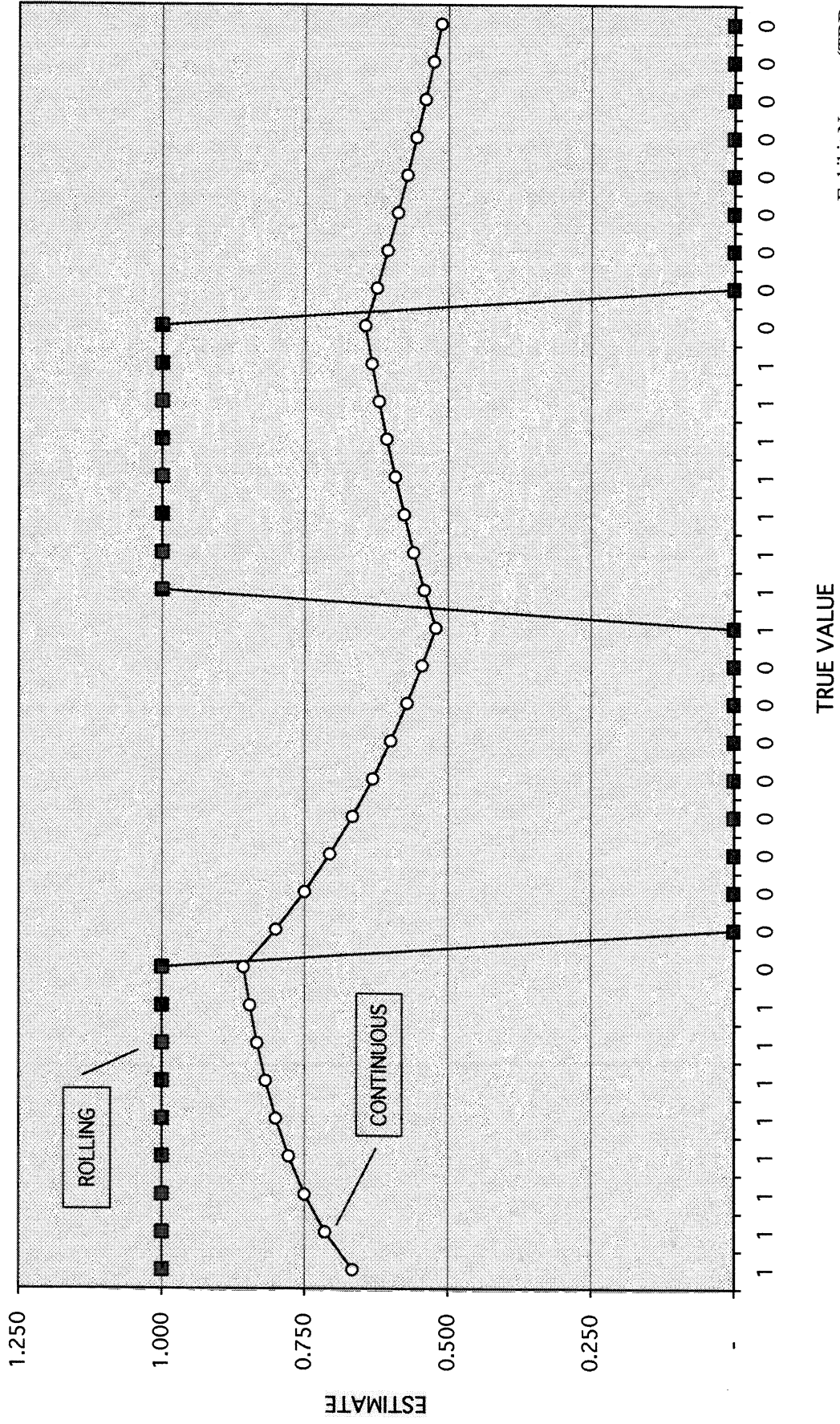
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-15)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ESTIMATES WITH 8 STRAIGHT ONES AND 9 STRAIGHT ZEROS REPEATED
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY=1)



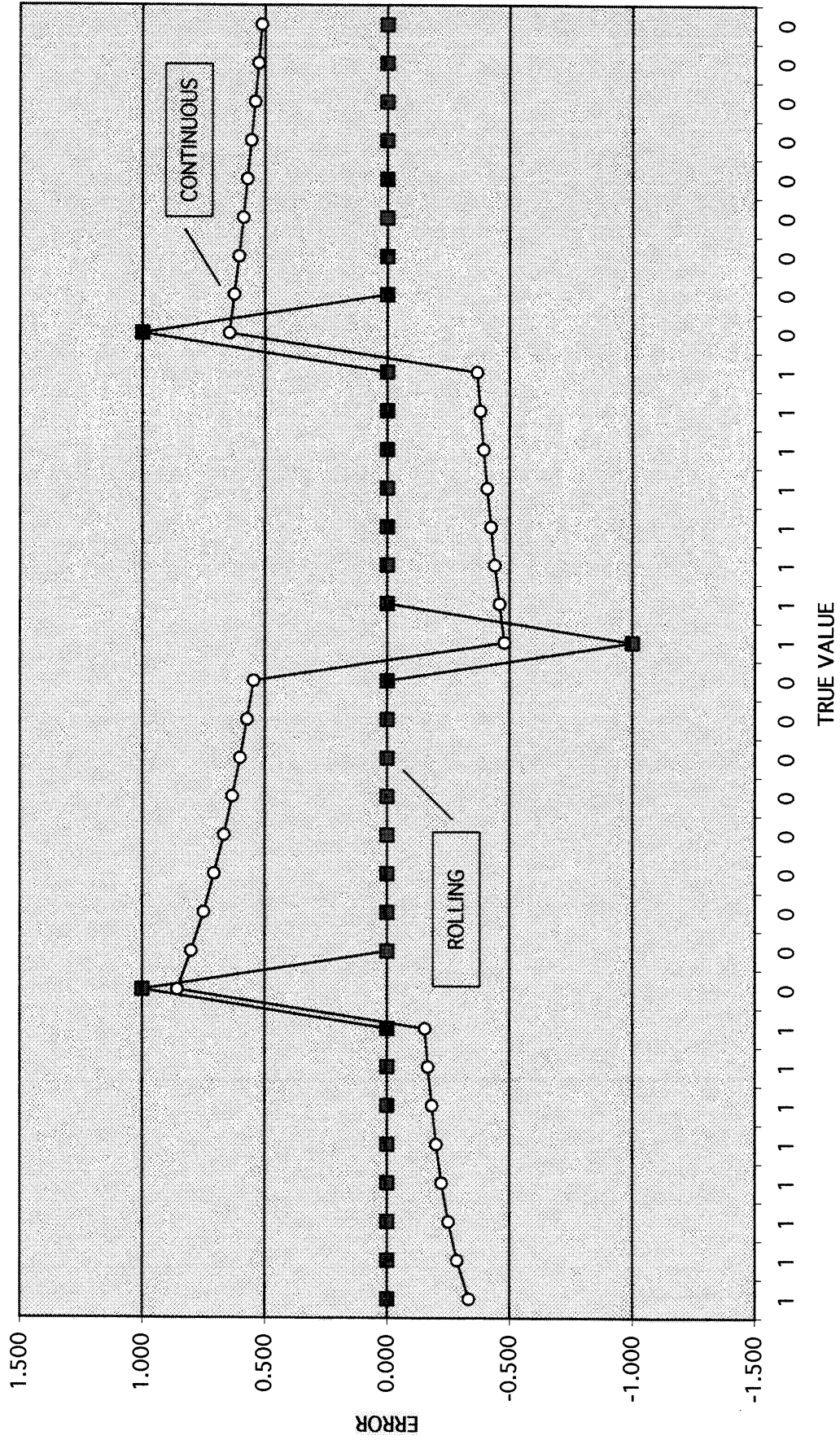
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-16)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ERRORS WITH 8 STRAIGHT ONES AND 9 STRAIGHT ZEROS REPEATED
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY =1)



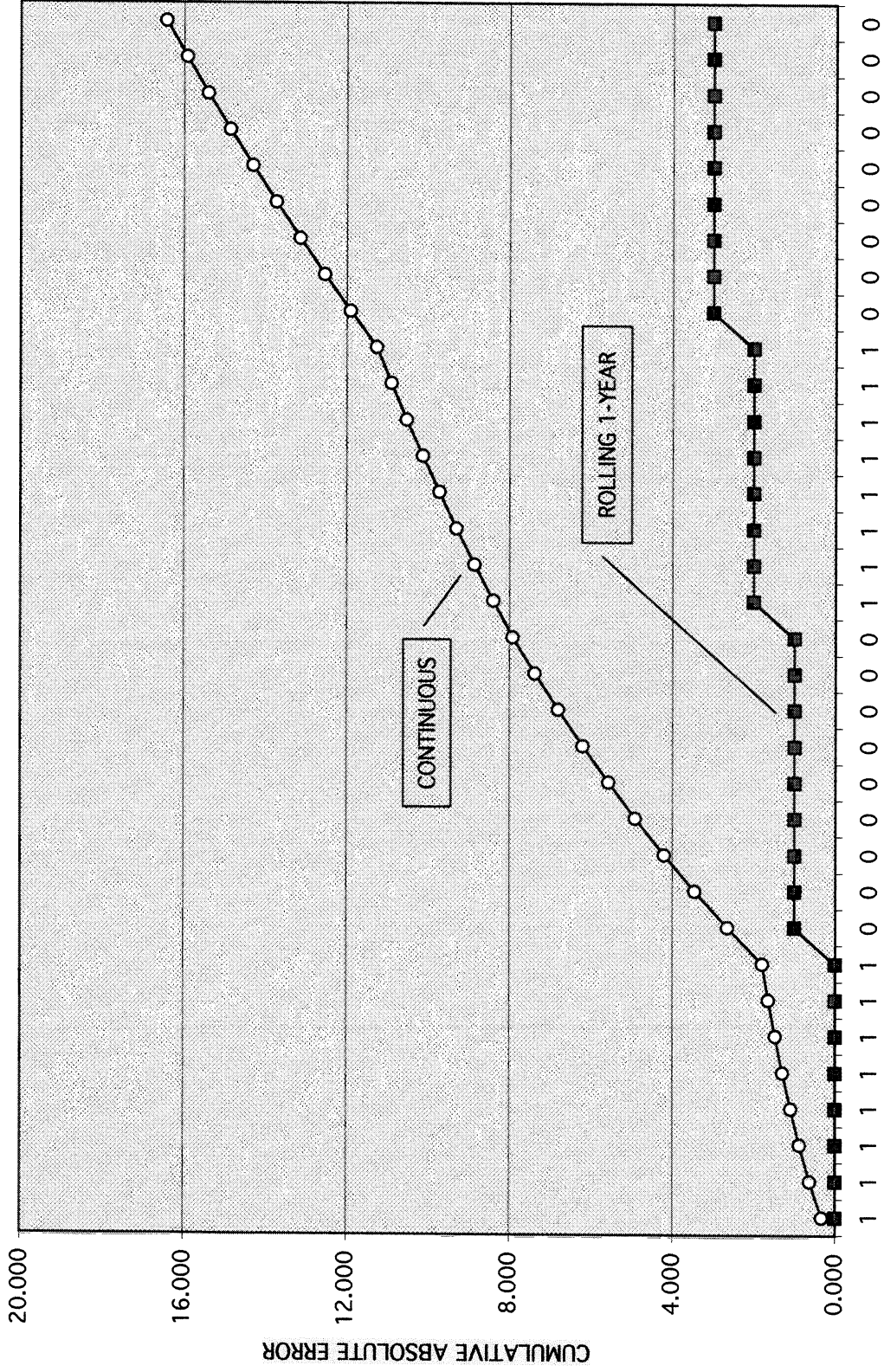
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-17)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

CUMULATIVE ERROR WITH 8 STRAIGHT ONES AND 9 STRAIGHT ZEROS REPEATED
 CONTINUOUS RECORDS (MEMORY=40) VS I-YR ROLLING AVERAGE (MEMORY=1)



TRUE VALUE OF GOOD (1) OR POOR (0)

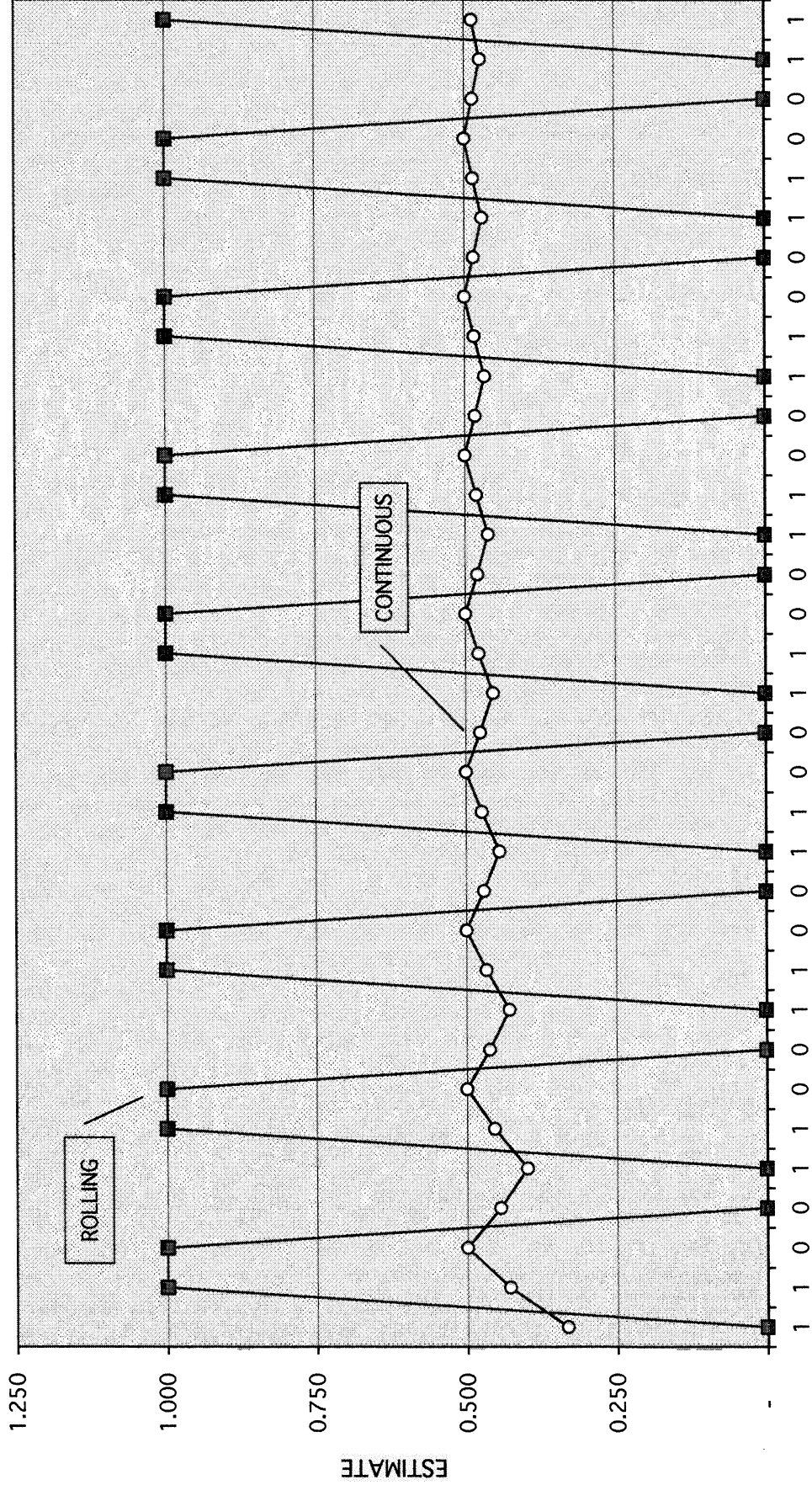
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-18)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ESTIMATES WITH 2 ONES ALTERNATING WITH 2 ZEROS REPEATED
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY=1)



TRUE VALUE

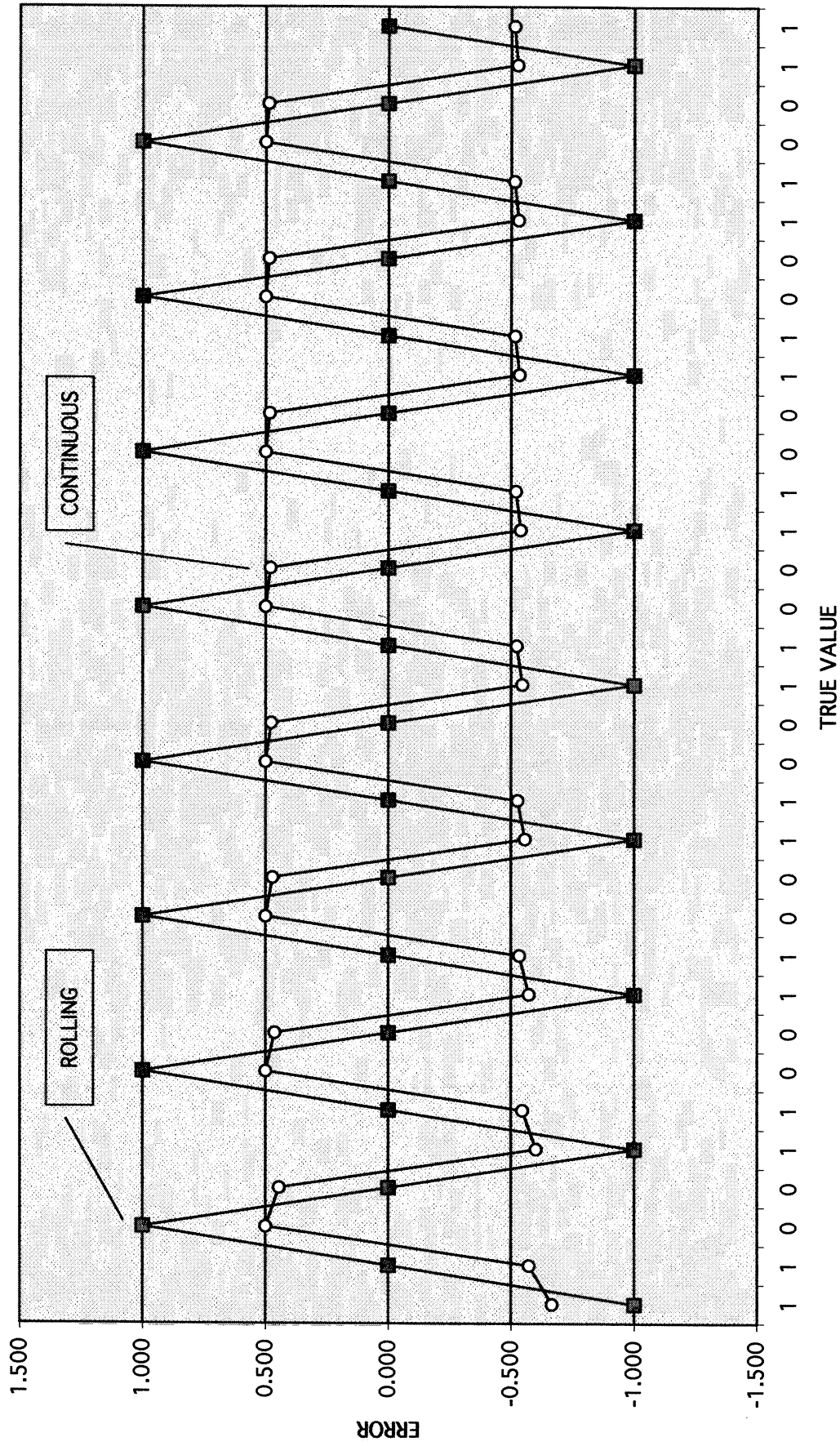
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____(TDD-19)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ERRORS WITH 2 ONES ALTERNATING WITH 2 ZEROS REPEATED
 EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY =1)



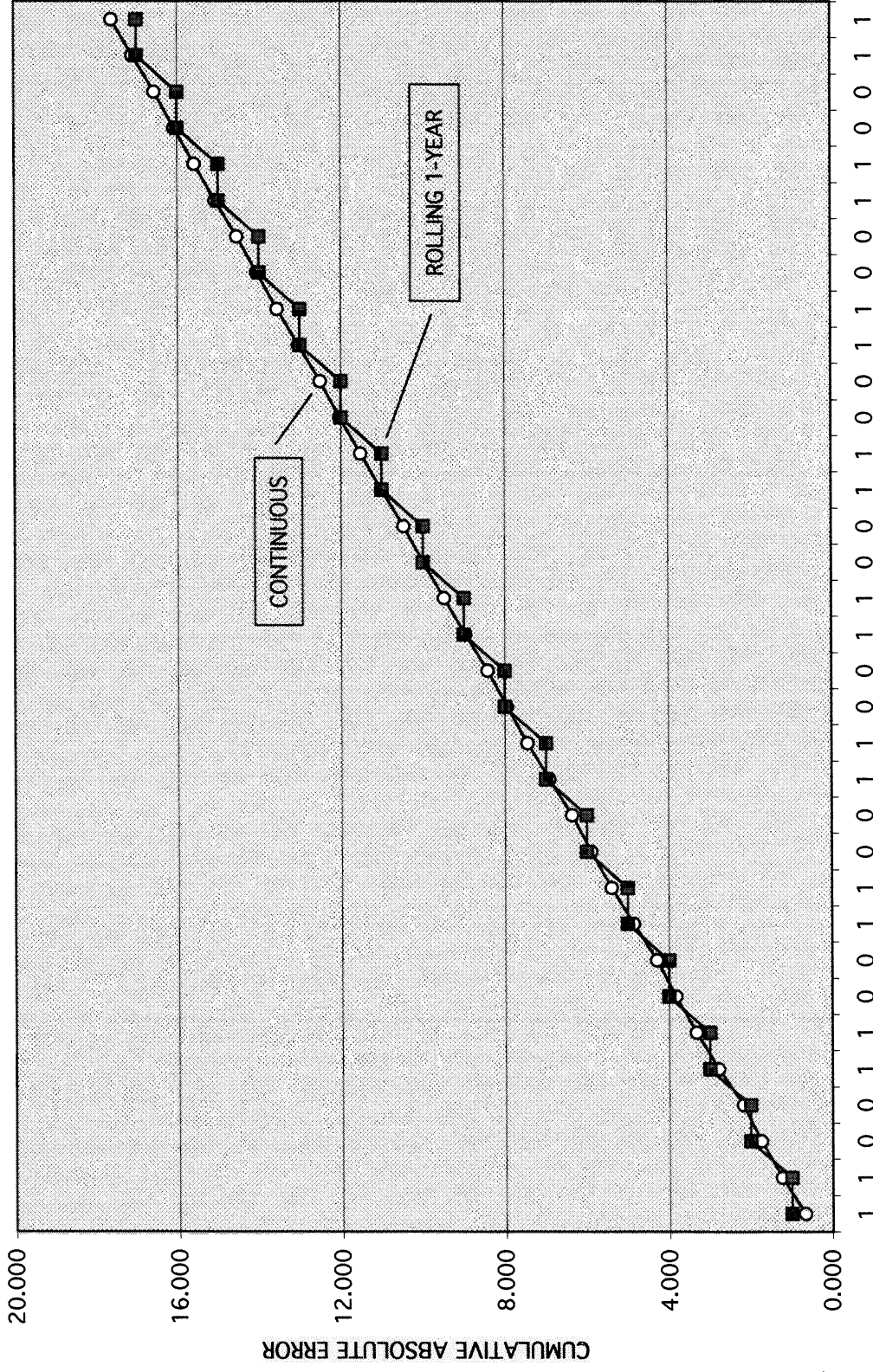
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____(TDD-20)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

CUMULATIVE ERRORS WITH 2 ONES ALTERNATING WITH 2 ZEROS REPEATED
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING AVERAGE (MEMORY=1)



TRUE VALUE OF GOOD (1) OR POOR (0)

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-21)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

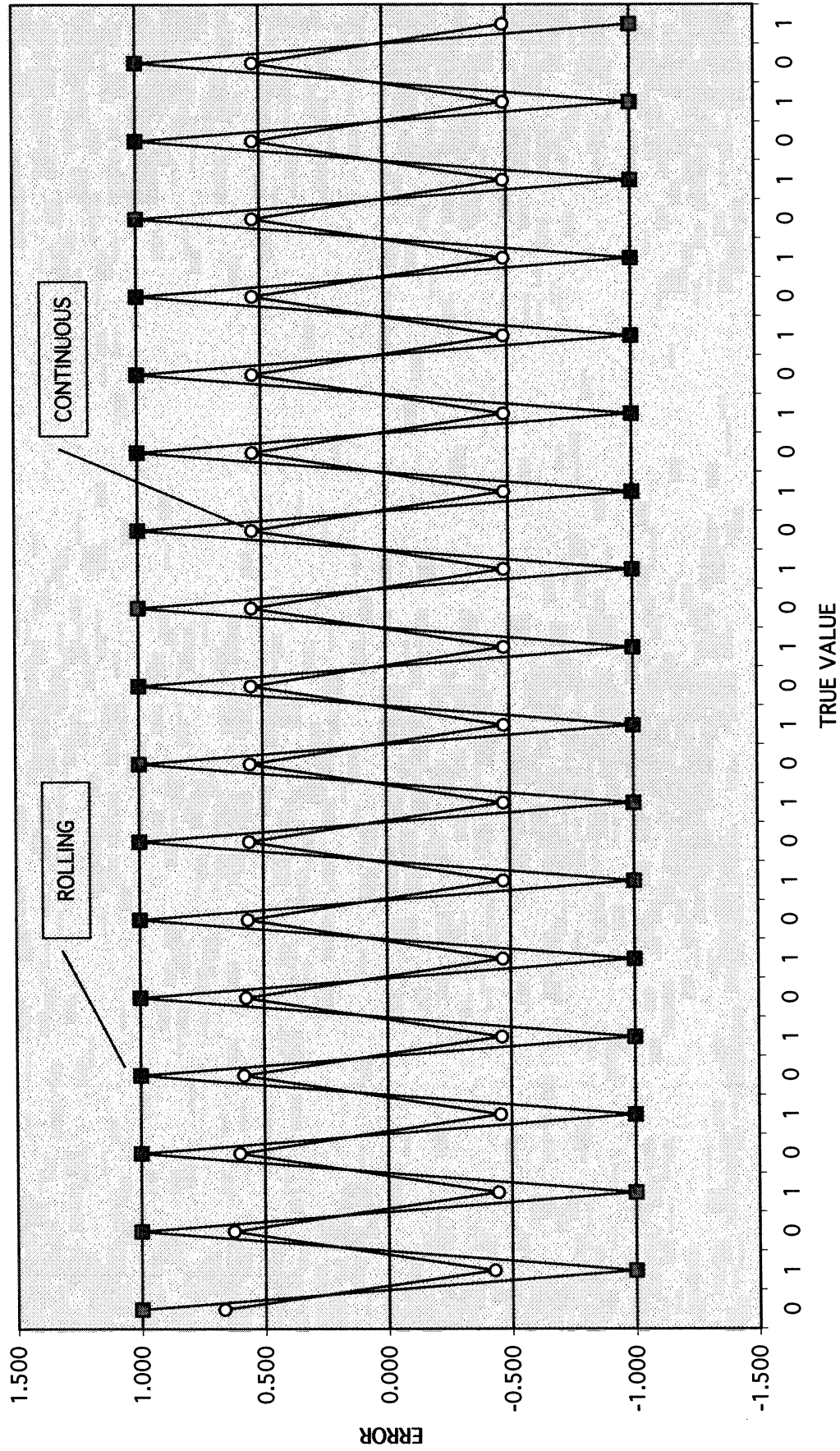
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-22)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

ERRORS WITH ONES AND ZEROS ALTERNATING
EXPECTED SERIES OUTCOME REMAINS AT ONE-HALF
CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING (MEMORY =1)



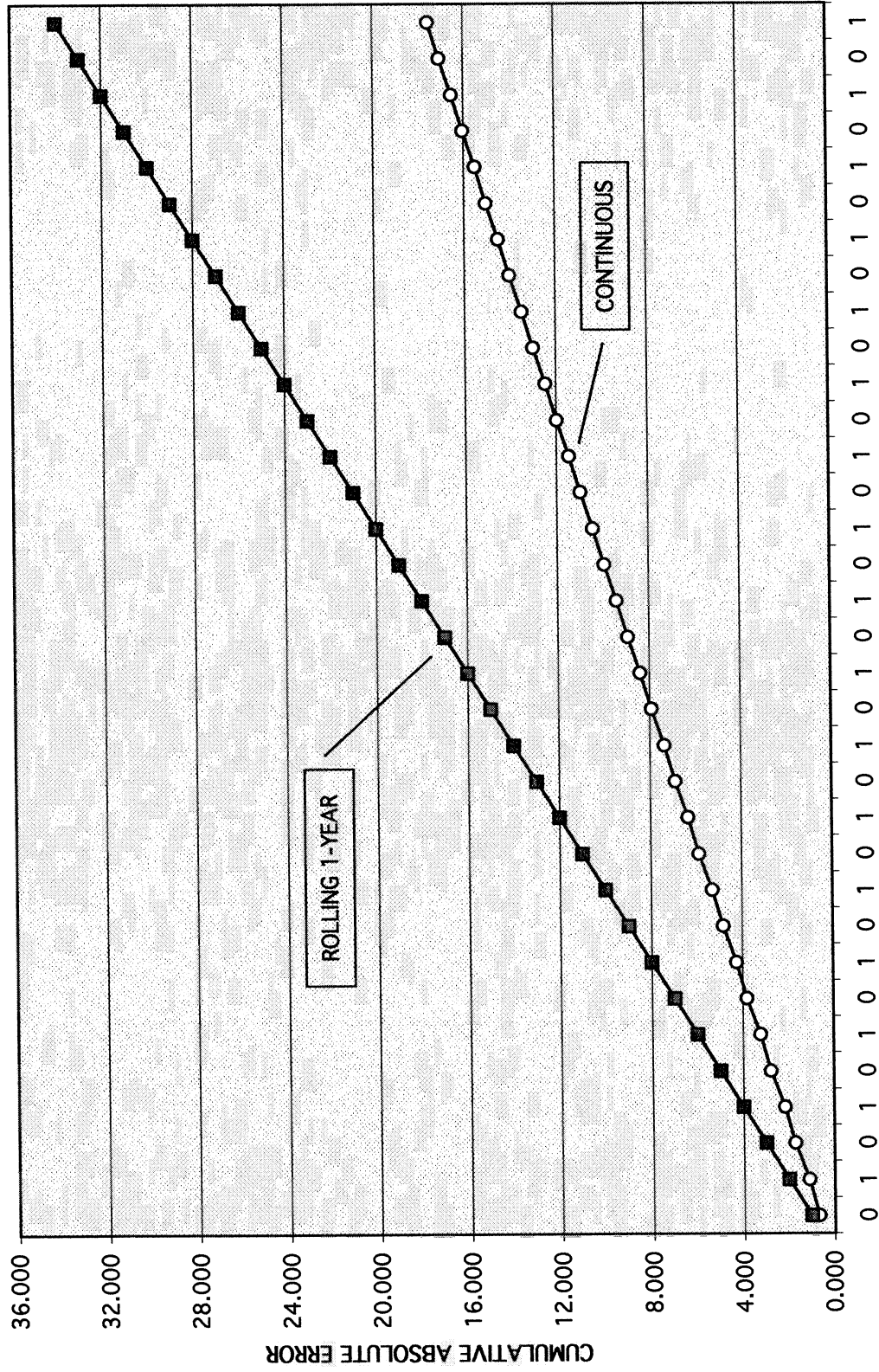
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-23)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

CUMULATIVE ERRORS WITH ONES AND ZEROS ALTERNATING
 CONTINUOUS RECORDS (MEMORY=40) VS I-YR ROLLING AVERAGE (MEMORY=1)



TRUE VALUE OF GOOD (1) OR POOR (0)

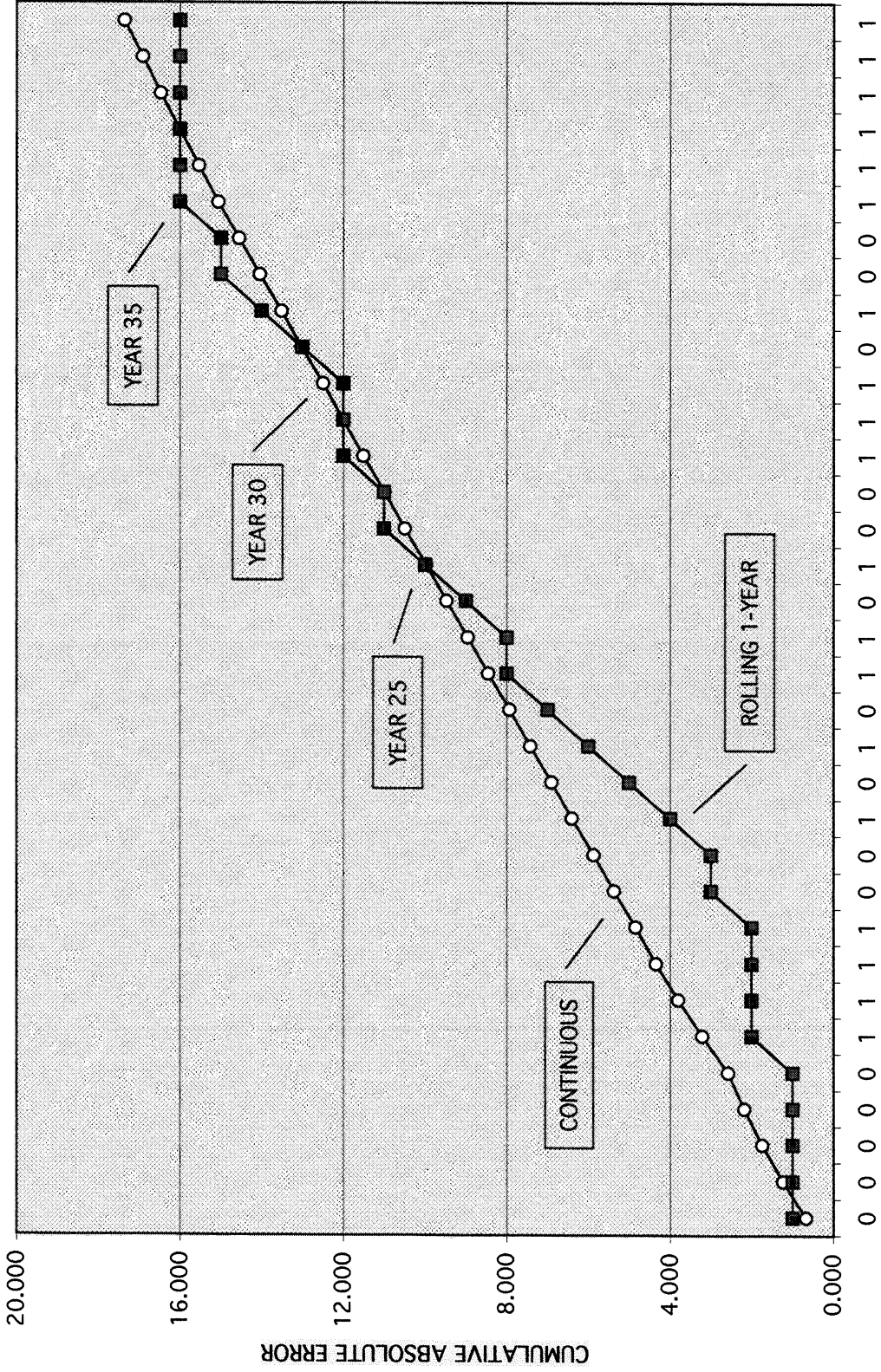
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01_____

EXHIBIT NO. _____(TDD-24)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

CUMULATIVE ABSOLUTE ERROR WITH ONES AND ZEROS PER WINTERFELD T-76 :
 CONTINUOUS RECORDS (MEMORY=40) VS 1-YR ROLLING AVERAGE (MEMORY=1)



TRUE VALUE OF GOOD (1) OR POOR (0)

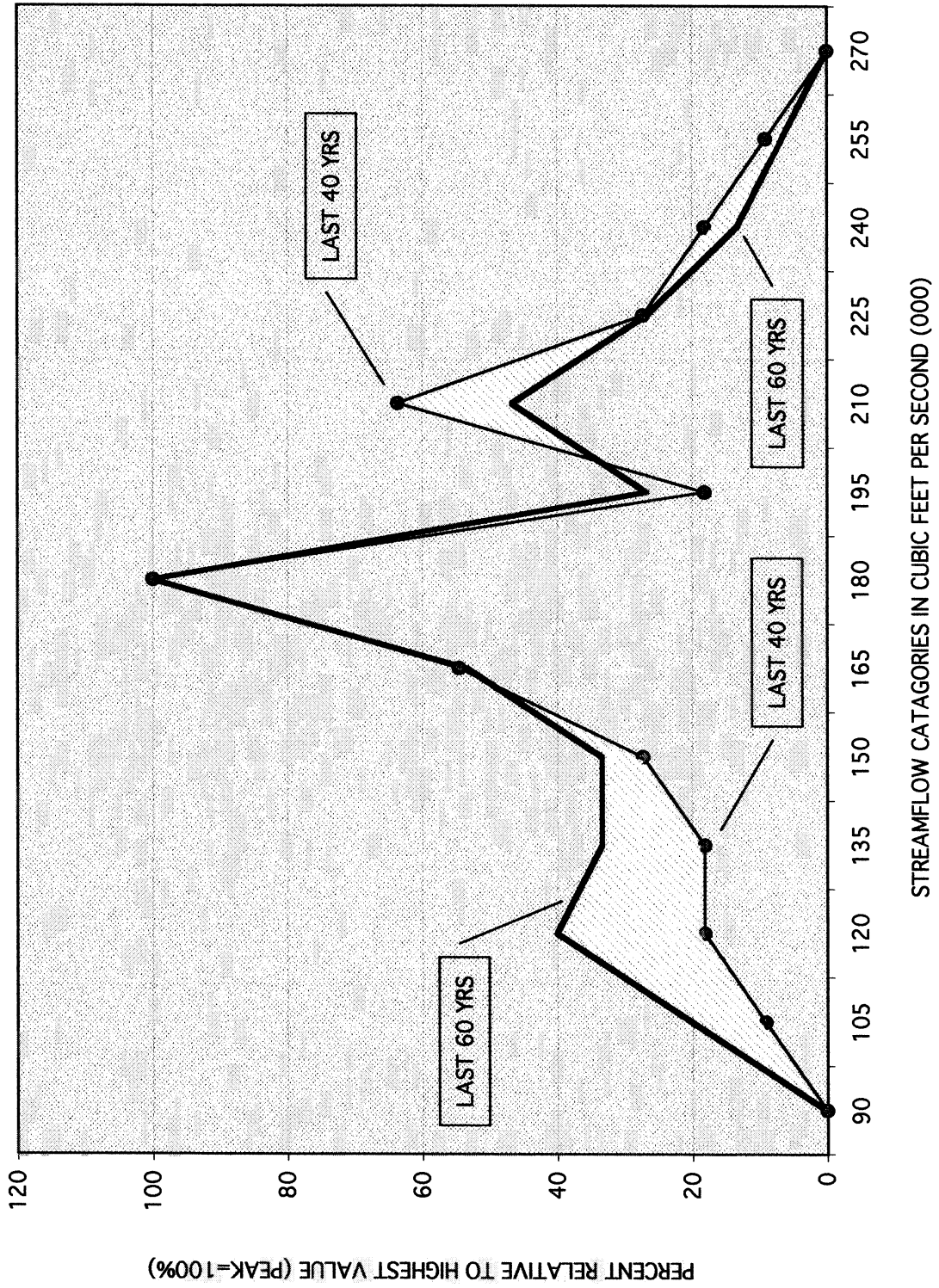
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____(TDD-25)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

DISTRIBUTION OF STREAMFLOWS FOR
THE LAST 60 YEARS VS THE LAST 40 YEARS



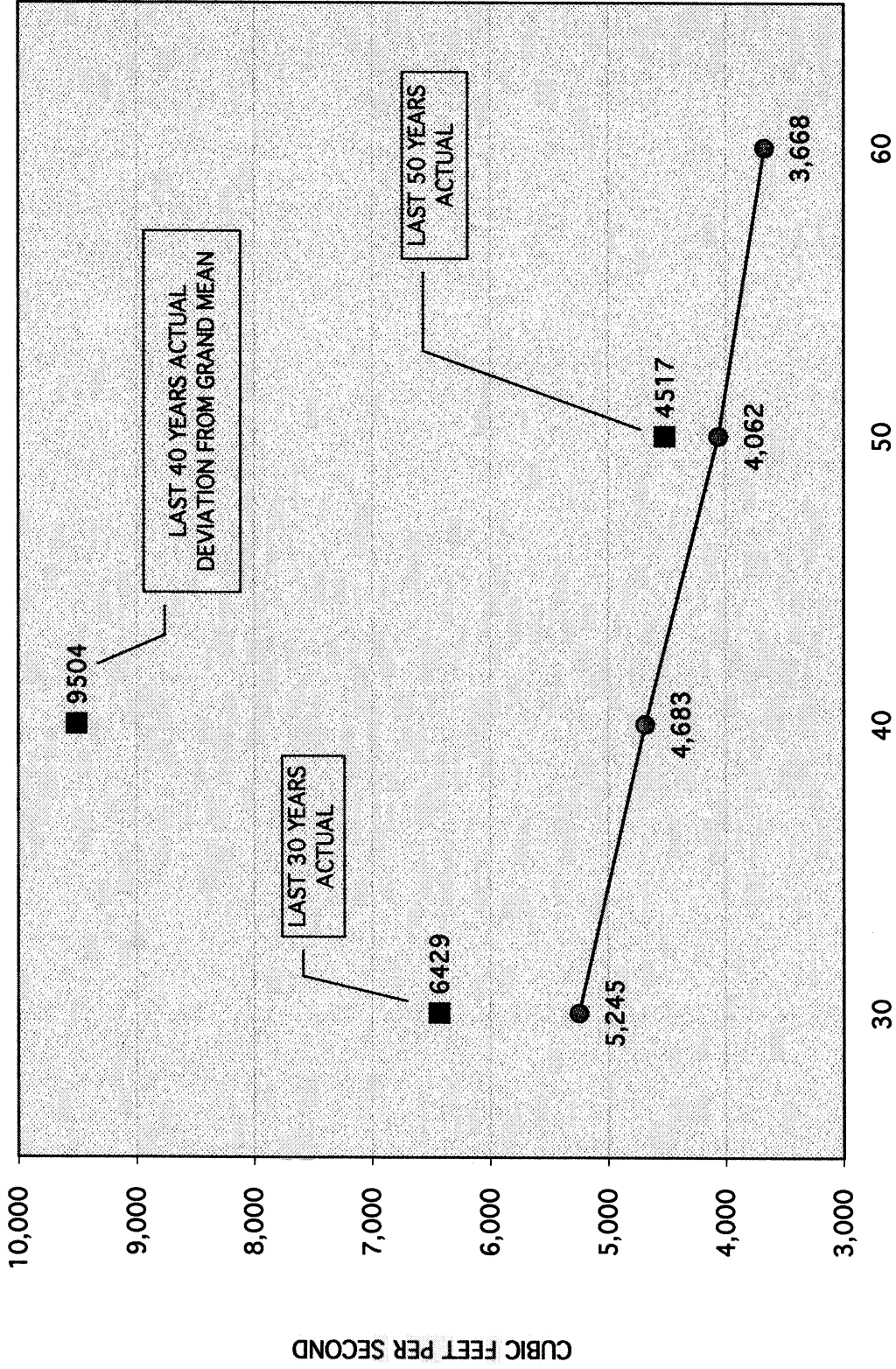
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____ (TDD-26)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

AVERAGE DEVIATION FOR THE MEAN FROM THE GRAND MEAN FOR
 VARIOUS SAMPLE SIZES BASED ON 1,000 MEANS FOR EACH SAMPLE PLUS
 DEVIATION FOR THE LAST 30, 40 AND 50 CONTINUOUS WATER YEARS



1,000 SAMPLES OF 30, 40, 50 AND 60 PLUS ACTUALS FOR CONTINUOUS 30, 40 AND 50

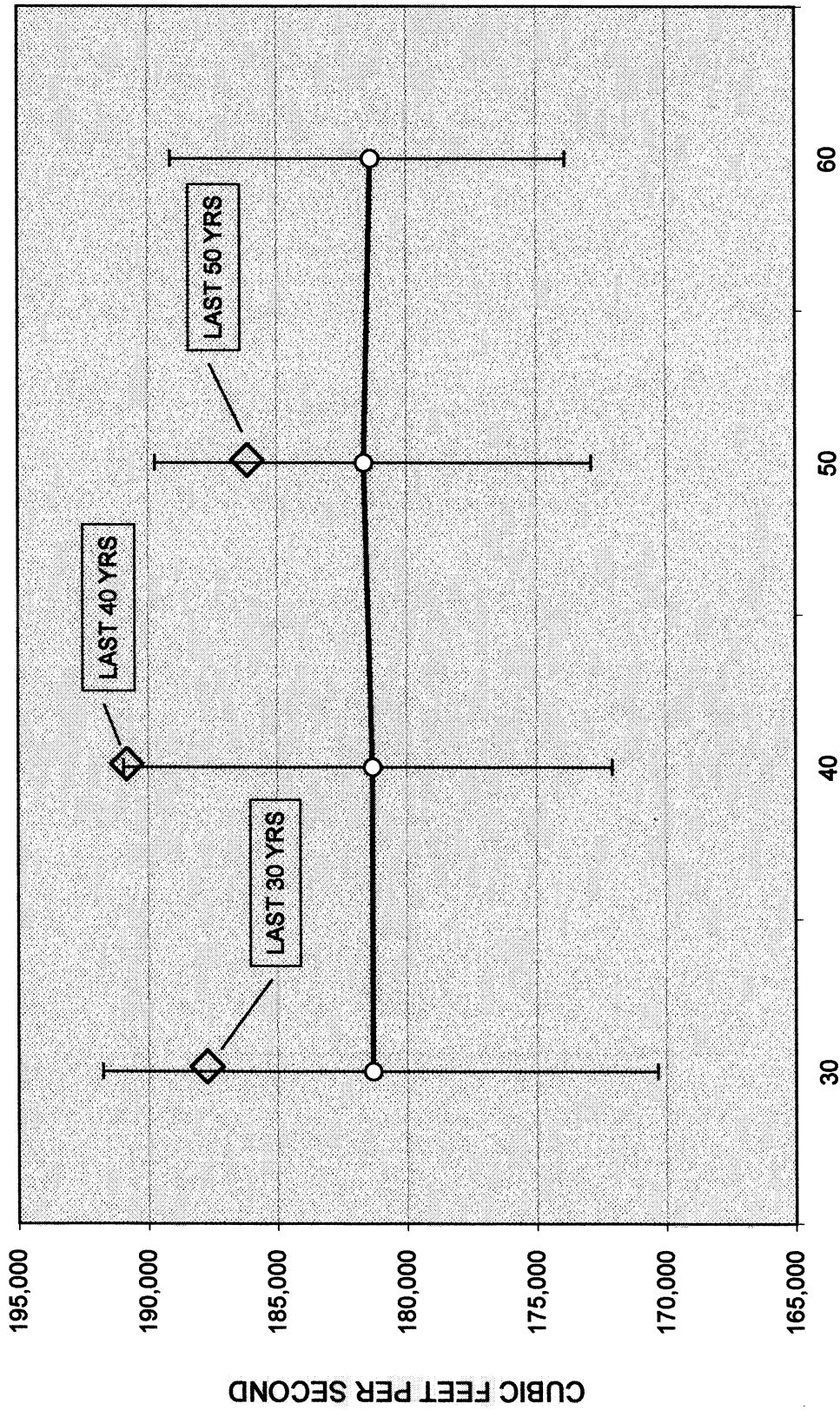
BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DOCKET NO. UE-01 _____

EXHIBIT NO. _____(TDD-27)

WITNESS: DR. THOMAS D. DUKICH, AVISTA CORP.

RESAMPLING 90% CONFIDENCE LIMITS FOR THE MEAN AROUND THE GRAND MEAN FOR VARIOUS SAMPLE SIZES BASED ON 1,000 MEANS FOR EACH SAMPLE SIZE. ALSO SHOWS THE ACTUAL MEAN OF THE LAST CONTINUOUS 30, 40 AND 50 YEARS.



1,000 SAMPLES OF A GIVEN SIZE X (X=30, 40, 50, and 60)