Exhibit No.:	
Issues:	Response to OPC Rebuttal statements related to MAWC usage analysis, Response to Staff Rebuttal statements related to fixture and appliance efficiency standards.
Witness:	Gregory P. Roach
Exhibit Type:	Surrebuttal
Sponsoring Party:	Missouri-American Water Company
Case No.:	WR-2017-0285 SR-2017-0286
Date:	February 9, 2018

MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. WR-2017-0285
CASE NO. SR-2017-0286

SURREBUTTAL TESTIMONY

OF

GREGORY P. ROACH

ON BEHALF OF

MISSOURI-AMERICAN WATER COMPANY

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

IN THE MATTER OF MISSOURI-AMERICAN WATER COMPANY FOR AUTHORITY TO FILE TARIFFS REFLECTING INCREASED RATES FOR WATER AND SEWER SERVICE	)))))	**CASE NO. WR-2017-0285** **CASE NO. SR-2017-0286**

AFFIDAVIT OF GREGORY P. ROACH

Gregory P. Roach, being first duly sworn, deposes and says that he is the witness who sponsors the accompanying testimony entitled "Rebuttal Testimony Revenue Requirement of Gregory P. Roach"; that said testimony and schedules were prepared by him and/or under his direction and supervision; that if inquiries were made as to the facts in said testimony and schedules, he would respond as therein set forth; and that the aforesaid testimony and schedules are true and correct to the best of his knowledge.

Gregory P. Roach
Gregory P. Roach

State of Indiana
County of Johnson
SUBSCRIBED and sworn to
Before me this 8th **day of** February **2018.**

Lori L. McAtee
Notary Public

My commission expires: 11/5/2025

LORI L MCATEE
Notary Public – Seal
Hendricks County – State of Indiana
Commission Number 707236
My Commission Expires Nov 5, 2025

SURREBUTTAL TESTIMONY
GREGORY P. ROACH
MISSOURI-AMERICAN WATER COMPANY
CASE NO. WR-2017-0285
CASE NO. SR-2017-0286

TABLE OF CONTENTS

SURREBUTTAL TESTIMONY

REVENUE REQUIREMENT

GREGORY P. ROACH

I. INTRODUCTION

Q. Please state your name and business address.

A. My name is Gregory P. Roach and my business address is 153 North Emerson Avenue, Greenwood, Indiana 46143.

Q. Are you the same Gregory P. Roach who previously submitted direct and rebuttal testimony in this proceeding?

A. Yes.

Q. What is the purpose of your surrebuttal testimony in this proceeding?

A. The purpose of my surrebuttal testimony is to respond to the rebuttal testimonies of Office of the Public Counsel (OPC) witnesses Geoff Marke and Lena Mantle and to the rebuttal testimony of Missouri Public Service Commission Staff (Staff) witness Jarrod Robertson.

II. OVERVIEW

Q. What is the scope and conclusions of your rebuttal testimony presented below?

A. My testimony will respond to OPC rebuttal allegations of: 1) witness Lena Mantle related to certain technical assessments of MAWC's residential usage modeling; and, 2) OPC witness Geoff Marke related to MAWC residential usage data, price elasticity analysis, water appliance and device saturation data, water fixture and federal/state appliance efficiency standards. My testimony will demonstrate that the OPC witnesses' observations related to State of Missouri or MAWC sponsored water efficiency programs are inconsequential to residential water usage trends as compared to federal water appliance and fixture standards. Further, my testimony will address and illustrate that each one of the technical critiques leveled at the MAWC residential usage modeling are without technical foundation, baseless and hence lack merit. Lastly, my testimony will address mathematical and climatic issues with Staff witness Robertson's five-averaging technique for Test Year residential sales volumes and revenues that make the Staff analysis unreliable and unsupportable for setting Test Year billing determinants.

III. RESPONSE TO OPC WITNESS LENA MANTLE

a. MAWC DECLINE TOILET FLUSHING ANALYSIS

Q. OPC Witness Mantle asserts that the MAWC estimated base residential usage decline of 3.715 gallons per day is "counter-intuitive" as it results in unrealistic usage frequencies in her toilet example to support such a decline in usage. (Reb. p.2) What has OPC witness Mantle omitted in her example?

A. OPC witness Mantle alleges that the estimated MAWC base water usage decline of 3.715 gallons per customer day is "counter-intuitive" based solely on a contrived example using unrealistic toilet usage frequencies. OPC witness Mantle's example totally ignores the results of the four-user analysis I detailed on pages 32-34 of my direct testimony in this proceeding and summarized in Schedule GPR-7, page 1 or 1 of my direct testimony. Unlike OPC witness Mantle's narrow focus on toilets only, that analysis illustrates the impact of installation of not only more efficient toilets, but shower heads, water fixtures and appliances, such as dish and clothes washers. My analysis shows a combination of 2.5% of the toilets, showerheads, fixtures, clothes washers and dishwashers annually replaced on the MAWC system account for the decline of 3.715 gallon per customer day reduction in the projected residential base usage per customer.

Q. What other factors did OPC witness Mantle ignore in her analysis that affect the historic trend and continuation of the 3.715-gallon base usage per customer day reduction?

A. OPC witness Mantle chose to ignore the impact of residential housing stock vintages on both the historic trend and continuation of that trend. Table GPR-5 of my direct testimony shows that 84% of MO residential housing stock was built prior to implementation of the majority of federal water efficiency standards for fixtures and appliances. As a result, a vast reservoir of potential fixture and appliance replacements that began in the early 2000s looms over the course of at least the next 20 years, leading to further reductions in residential base usage per customer into the near future

Q. In light of the limited nature of OPC witness Mantle's analysis, does that analysis support her allegation that the MAWC analysis estimating a 3.715-gallon base usage per customer day reduction is "counter-intuitive"?

A. No. OPC witness Mantle's contrived example, focused solely on toilet usage, fails to consider residential usage reductions due to replacement of less efficient showerheads, fixtures and numerous water-using appliances with their more efficient counterparts. Further, OPC witness Mantle's failure to take into consideration the impact of the vintage of residential housing stock on water device and appliance replacement further undermines the credibility of her allegations. As such, OPC witness Mantle's analysis provides no insight to the relative merits of the MAWC residential base usage per customer trend.

b. IMPACT OF APRIL 2017 DATA POINT ON MAWC ANALYSIS

Q. OPC witness Mantle alludes in both her direct and rebuttal testimony to the potential impact of the April 2017 data value on the MAWC analysis of residential base usage analysis. (Dir., p. 3; Reb., p. 4) Have you analyzed the impact of that data point and its impact on the result of the MAWC residential base usage analysis?

A. Yes, I have. On pages 17-18 of my rebuttal testimony, I summarize my analysis on the impact of potential data correction for the April 2017 data point to our residential base usage modeling. As reported in my rebuttal testimony, the estimated impact on our residential base usage analysis for the April 2017 data point departure from the average results in 0.005 change to the R2 and 72 gallon change, or 0.11%, to the gallons/customer/year forecasted decline.

Q. Based on your analysis of the impact of the April 2017 data point on the MAWC residential base usage analysis, is OPC witness Mantle's concern related to the April 2017 data point having significant impact on your residential base usage trend analysis supportable?

A. No. The April 2017 data point did not materially influence the results of the MAWC residential base usage analysis presented in my direct testimony. As a result, OPC witness Mantle's concern related to the April 2017 data point as somehow significantly affecting the results of the MAWC residential trend analysis is analytically baseless. As such, OPC witness Mantle's concern and claim of some type of negative bias in the MAWC analysis is without merit and should be ignored by the Commission.

c. STATISTICAL IMPACT OF ANNUAL BASE USAGE AVERAGING TECHNIQUE

Q. OPC witness Mantle, on page 6 of her rebuttal testimony, criticizes the MAWC base usage statistical modeling for both the number of observations (due to annualization of monthly values) and the number of variables utilized in the modeling. Why is the MAWC residential base usage analysis performed on annualized data?

A. As I discuss on page 14 of my rebuttal testimony, and illustrated with Graph GPR-5R on page 15 of that testimony, MAWC elected to annualize the monthly residential base usage in order to mitigate the effects due to billing/meter reading variance in the usage data on any discreet monthly residential base usage value. An example of such potential variance is the April 2017 residential base usage value that troubles OPC witness Mantle. The very annualizing technique of the monthly base usage observations criticized by OPC witness Mantle mitigates the very problem she "identifies".

Q. OPC witness Mantle criticizes the annualization technique as limiting the observations and hence corresponding degrees of freedom in the MAWC residential base usage modeling. Is there an issue with limited degrees of freedom affecting the results of the MAWC residential base usage modeling?

A. No, there are no issues with number of observations or degrees of freedom related to the MAWC residential base usage modeling or the analytical results of that modeling. In the case of the MAWC residential base usage models, OPC witness Mantle claims the following: "While good models can be developed with eight degrees of freedom, the low degrees of freedom combined with the data problems shown above, raises grave concerns regarding Mr. Roach's analysis". (Reb., p. 7) As with the majority of OPC witness Mantle's observations contained in her rebuttal testimony, she describes an issue that a) doesn't exist; and, b) offers no corroborating statistical or analytical evidence to support her claims.

Q. What are degrees of freedom in statistical modeling? How are degrees of freedom calculated and used when measuring the statistical significance of regression models?

A. A general definition of degrees of freedom as used in statistics is as follows:

> "Estimates of statistical parameters can be based upon different amounts of information or data. The number of independent pieces of information that go into the estimate of a parameter are called the degrees of freedom. In general, the degrees of freedom of an estimate of a parameter are equal to the number of independent [observations] that go into the estimates minus the number of parameters used as intermediate steps in the estimation of the parameter itself (e.g. the sample variance has N-1 degrees of freedom, since it is computed from N random [observations] minus the only 1 parameter estimated as intermediate step, which is the sample mean)." [1]

[1] Lane, David M. "Degrees of Freedom". HyperStat Online. Statistics Solutions. Retrieved 2008-08-21.

Degrees of freedom are used as statistical inputs into diagnostic calculations that are indicative of a particularly model's ability to have estimated the slope and independent variable coefficients within certain levels of confidence. For example, at a 99% confidence level, with statistically significant coefficients, the analyst is able to ascertain that the model has estimated coefficients accurately reflecting a statistical relationship between the dependent and independent variables and there exists a 1% chance that the model did not accurately reflect a statistical relationship between the dependent and independent variables. The 1% uncertainty is called the "Null Hypothesis," which presumes that there isn't a relationship between the dependent and independent variables. Hence, in statistical terms, statistically significant coefficients allow the analyst to reject the Null Hypothesis at certain levels of certainty. In the example above, the analyst has a 99% percent probability of correctly rejecting the Null Hypothesis and accepts that the model has correctly estimated the value of the independent variable coefficients.

Q. What diagnostic statistic is used to test regression model significance and how is that statistic affected by the degrees of freedom available to the regression model?

A. Typically, the statistical analyst will use the F-test (expressed using an F-statistic) to judge the ability of a fitted regression model to best explain the variance in the population data. The F-test is a statistical test in which the test statistic is compared to an F-distribution under the Null Hypothesis that varies with degrees of freedom and the confidence interval chosen.

Q. Using the MAWC residential system average base usage model as an example, please describe how to conduct such a test using an F-statistic and an F-table?

A. I have attached a standard F-distribution table to my surrebuttal testimony as Schedule GPR-1SR. This schedule reports numerous combinations of degrees of freedom for number of variables (numerator, sometimes referred to as degrees of freedom of the model) with the number of observations used in a particular model (denominator, sometimes referred to as degrees of freedom of the error) at the 90%, 95%, 97.5%, 99% and 99.9% confidence intervals. To test a particular model's statistical significance via the F-distribution, the numerator (degrees of freedom of the model) is equal to the number of predictors -1 and the denominator (degrees of freedom of the error) is the number of observations less the number of predictors. The sum of these two numbers gives the total degrees of freedom of the model, or the number or observations −1.

In the case of the MAWC system wide residential base usage model, the regression has three predictive variables (intercept, time and binary) resulting in a denominator value of two. So too, the model has 10 annual observations (2008-2017) resulting in a numerator of 7 (10 observations less 3 predictors). Schedule GPR-2SR, page 1 of 11, shows that the regression modeling software calculates an F value of 38.864 for the system level model. I have combined the values from the F-Table in Schedule GPR-1SR, page 1 of 1, with the F value from the regression modeling to populate Table GPR-1SR below. Table GPR-1SR illustrates that the system level regression model is a significant predictor of residential system-level base usage up to and beyond the 99.9% confidence interval. Further, I have included the F-statistics for the D-1, D-2 and D-3 rate area models. In every case, system level, D-1, D-2 and D-3, the model results reject the Null Hypothesis with 99.9% confidence and the models are very significant predictors of base usage dependent on time.

Table GPR-1SR Missouri American Water Company Residential Base Usage Modeling Critical F Values and Statistical Significance of Results	
Confidence	**F-Value**
0.1 (90%)	3.26
0.05 (95%)	4.74
0.025 (97.5%)	6.54
0.01 (99%)	9.35
0.001 (99.9%)	21.69
Model Type	
System	38.864
D-1	39.872
D-2	30.862
D-3	45.206

Q. What do the statistical results reported in Table GPR-1SR indicate about OPC witness Mantle's observations related to number of observations and degrees of freedom in your annual residential base usage models?

A. The F-statistic test clearly indicates that had OPC witness Mantle performed a standard comparison of the F-Statistics from any of the four annual residential base usage models provided to the OPC to the critical confidence interval values reported above, she would have concluded that there isn't an issue with either: a) the number of observations analyzed; or, b) the degrees of freedom associated with the residential base usage models. In summary, as opposed to performing definitive analytical statistical comparisons to ascertain the validity of her concerns, OPC witness Mantle choose to make what are demonstrably false claims related to the number of observations and degrees of freedom in the MAWC residential base usage models. As a result, OPC witness Mantle's concerns and observations related to degrees of freedom and number of predictor observations are without merit.

d. COMPARISION OF MONTHLY vs. ANNUAL BASE USAGE MODEL RESULTS

Q. OPC witness Mantle was critical of the MAWC residential base usage analysis due to its usage of annual frequency data. Have you performed a similar residential base usage analysis employing all 30 months of base usage data from 2008-2017?

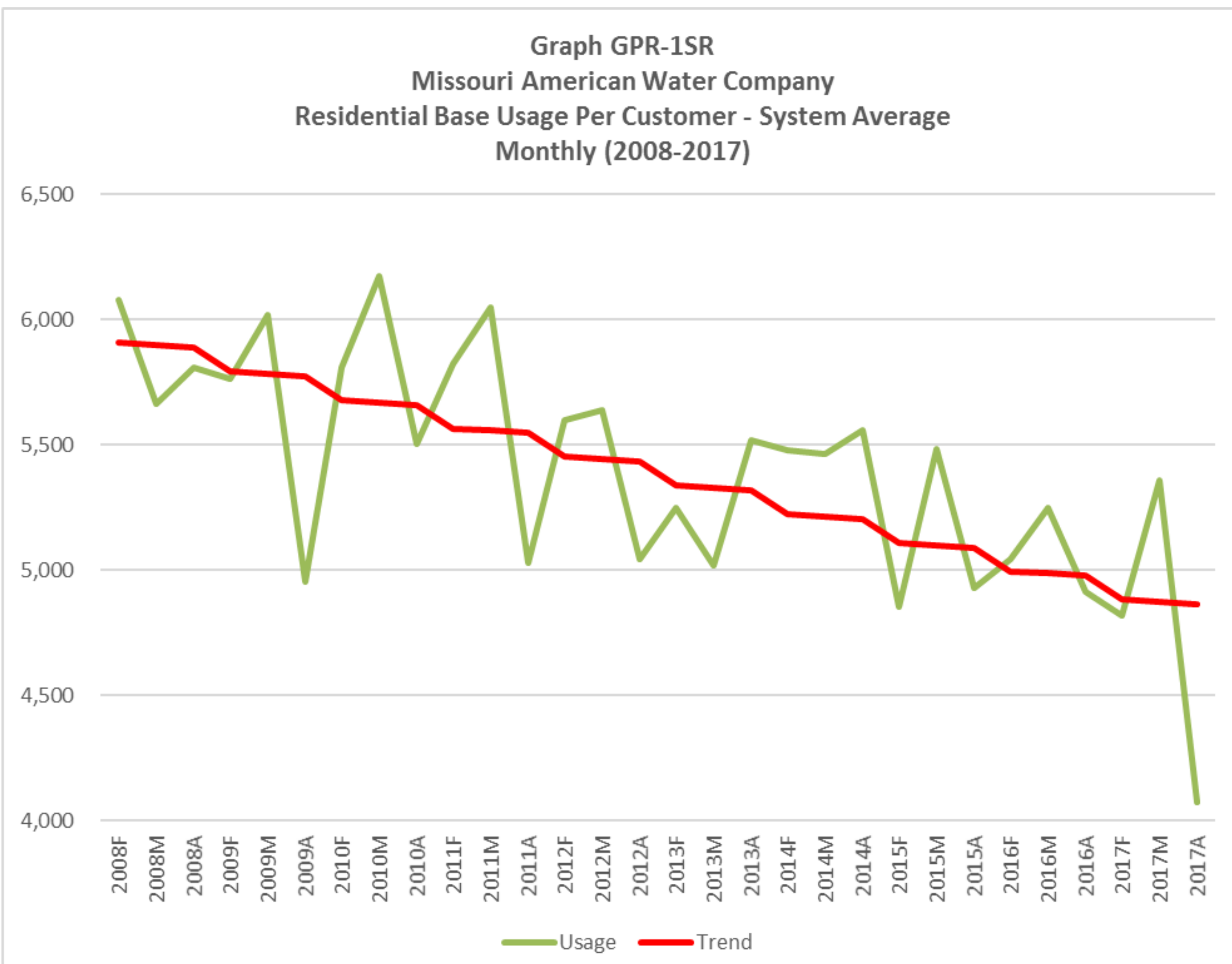
A. Yes, we have. Presented in Table GPR-2SR, is a summary statistical comparison of the annual vs. monthly frequency residential base usage modeling we have performed. In general, Table GPR-2SR shows that the results of the residential base usage monthly frequency analysis confirm the results of the annual frequency analysis. Further, given the usage of monthly frequency data in this analysis, which is susceptible to the effects of meter reading and billing events shifting usage from one month to another, the R-square is lower than that attained using annual frequency data due to the greater month-to-month variances of the residential base usage data. Overall, the results of this analysis confirms the slope of the underlying annual residential base usage decline by district, while illustrating that aggregating the monthly observations into annual

Table GPR-2SR
Missouri American Water Company
Residential Base Usage Trends
(2008-2017)

	Annual Frequency				Monthly Frequency				
District	R2	F-Stat	%	g/cust/yr	R2	F-Stat *	%	g/cust/yr	Customers
MAWC	0.912	38.864	-1.89%	-1,356	0.495	13.234	-1.90%	-1,367	426k
East District (D-1)	0.905	33.180	-1.82%	-1,380	0.424	9.930	-1.85%	-1,401	358k
Northwest District (D-2)	0.896	30.862	-1.74%	-912	0.265	6.684	-1.80%	-946	34 k
Southwest District (D-3)	0.928	45.206	-2.68%	-1,344	0.511	19.346	-2.72%	-1,362	34 k

* Note: F Critical Values at 99% confidence are 8.65 for Annual, 5.45 for MAWC/D-1 (30 Obs) and 5.21 for D-2/D-3 (40 Obs).

observations eliminates the impact of the month-to-month meter reading/billing perturbations resulting in higher R-Squares and lower overall forecast model error. Reviewing the analysis visually, Graph GPR-1SR below, shows the monthly MAWC system level residential base usage data with the statistically derived 10-year trend line generated by the monthly data illustrated in red. This graph clearly illustrates a similar, steady residential base usage decline from 2008-2017 confirmed by the regression model results. When reviewing Graph GPR-1SR, it is difficult to understand how OPC witness Mantle could ignore what is an obvious declining trend to the monthly data over time.



Q. What do the results of the monthly frequency residential base usage analysis illustrate related to OPC witness Mantle's proposed five year average of the 2012-2017 residential base usage values?

A. Generally, the results of the monthly frequency residential base usage analysis illustrate the lack of analytical rigor employed by the OPC to substantiate its claims. First, the results indicate that OPC witness Mantle either failed to recognize or chose to ignore what is a statistically significant and obvious declining time series trend to the monthly frequency data. Second, Graph GPR-1SR, clearly illustrates that the slope of the trend prior to and following 2012 have relatively the same magnitude, which directly contradicts OPC witness Mantle's claim (and basis for her proposed five-year residential base usage averaging) that somehow there appears to be two different trends to that data pre and post 2012. Third, as with other analyses I have offered in my rebuttal testimony, the monthly frequency analysis clearly indicates that the April 2017 data point has no significant statistical impact on either the analysis or the results of the analysis. Thus, OPC witness Mantle's claims related to the number of observations used in the MAWC annual analysis, the results of monthly vs. annual models, the trend of the monthly residential base usage data from 2008-2017, and her claims related to the impact of the April 2017 data point on modeling results are without analytical support or merit.

e. SYSTEM AVERAGE MODEL RESULTS vs DISTRICT LEVEL RESULTS

Q. On page 3 of her rebuttal testimony, OPC witness Mantle noted that none of the district level analysis reported in Table GPR-1, page 8 of your direct testimony

result in an annual reduction in residential usage that is equal to or greater than the system level average. Can you explain why that occurred?

A. Yes. The values reported for East District (D-1) are incorrect resulting in the seeming contradiction comparing the district results to the MAWC system total.

Q. Have you performed an analysis that provides the correct values for East District (D-1)?

A. Yes. I provide a comparison of the values originally reported in my direct testimony in Table GPR-3SR and those that result following correction of an errant time value for the year 2017, which altered the East District (D-1) values included in the original modeling. Following correction of the errant 2017 time value, the regression modeling results for the East District (D-1) decreased that districts' annual usage by approximately 48 gallons per year.

Table GPR-3SR
Missouri American Water Company
Residential Base Usage Trends
(2008-2017)

	As Originally Filed				2017 Time Value Corrected D-1					
District	R2	F-Stat	%	g/cust/yr	R2	F-Stat *	%	g/cust/yr	Diff	Customers
MAWC	0.912	38.864	-1.89%	-1,356	0.912	38.864	-1.89%	-1,356	0	426k
East District (D-1)	0.919	39.872	-1.75%	-1,332	0.905	33.180	-1.82%	-1,380	48	358k
Northwest District (D-2)	0.896	30.862	-1.74%	-912	0.896	30.862	-1.74%	-912	0	34 k
Southwest District (D-3)	0.928	45.206	-2.68%	-1,344	0.928	45.206	-2.68%	-1,344	0	34 k

Q. Do the district level results satisfy OPC witness Mantle's expressed concern that none of the district level residential usage decline rates where not equal to or greater than the system total modeling?

A. Yes, it should. As expected, the Eastern District (D-1) has the greatest decline overall and largest percentage of the system total (usage and number of customers), counter balancing relatively lower declines in D-2 and D-3.

Q. Is MAWC proposing to update its Test Year residential usage and revenue for the now 48 gallons per customer greater usage decline?

A. In order to maintain a clean evidentiary record, we are not updating our originally filed usage numbers.

f. 2014 BASE USAGE AND BINARY VARIABLE

Q. What climatic event (Reb, p.2) occurred during the residential base usage period of 2014?

A. During the residential base usage period of 2014, a prolonged period of arctic temperature conditions persisted over much of North America resulting in 16.7% greater heating degree-days and 22.4% lower mean minimum temperatures than the 40-year average. The media labelled this event as the "Polar Vortex..." This climatic event resulted in residential base usage perturbations due to the unusual breadth and depth of the arctic temperature incursion into North America. These climatic perturbations were expressed as increased usage for the residential base usage period in 2014, as residential customers choose to drip water in order to prevent potential plumbing damage.

Q. What is residential base usage and is it defined as being responsive to climatic changes?

A. First, it is important to recall the definition of residential base usage. For purposes of our residential customer usage analysis, base usage is non-discretionary and non-weather sensitive indoor water usage. For example, base usage includes (but is not limited too) the habitual day-to-day water usage for showers and baths, clothes washing, dish washing, cleaning and general food preparation. Second, none of those "non-discretionary" usages anticipates climatic changes having a significant impact on base usage levels. Rather, residential base usage changes result from the replacement of older less efficient water using appliances and water fixtures with their newer more efficient counterparts.

Q. How have you accounted for this extraordinary climatic event and its impact on the MAWC residential customer base usage modeling?

A. Yes. The goal for residential base usage modeling is to capture the trend or the non-discretionary, non-weather sensitive usage, and, accordingly, the analyst must attempt to account for any one-time extraordinary events that occurred during the period modeled. This is accomplished by employing the statistical technique of a binary variable. A binary variable is quite simple. To account for the one-time extraordinary event, the time series accounting for the event has a constant value for every observation in the series except for the observation impacted by the one-time extraordinary event. In the case of the MAWC residential base usage modeling, the time series has a value of zero for every observation except 2014 when the binary variable is 'activated" with a value of one. In this manner, the MAWC analysis mitigates the impact of the 2014 outlier value allowing the model to reflect the mean slope of the 2008 through 2017 values while excluding the bias of the 2014 one-time extraordinary event.

Q. Have you measured the effect on your trend results due to the binary variable's inclusion in the system level and district level residential base usage models? If so, what is that impact?

A. Yes, I have. Presented in Table GPR-4SR below are results of each model with the binary variable included and excluded from the analysis. In summary, at the district level, excluding the binary variable results in a modest reduction in the residential base usage annual decline by approximately 36 to 60 gallons per customer year depending on the rate district analyzed. I do not believe it is appropriate to exclude the binary variable. The binary variable accounts for the impact of an event, i.e.; the Polar Vortex, that is extraordinary and resulted in more usage from residential customers mitigating the effect of extraordinarily cold conditions by leaving faucets to drip, than would be experienced normally. Nevertheless, as the above Table GPR-4SR demonstrates conclusively, the use of the binary variable had a *de minimis* effect on the continuing trend of a decline in customer usage. In other words, the persistent statistically significant downward trend in use per customer is shown with or without the binary variable.

Table GPR-4SR
Missouri American Water Company
Residential Base Usage Trends
(2008-2017)

	With Binary Variable				Without Binary Variable					
District	R2	F-Stat	%	g/cust/yr	R2	F-Stat *	%	g/cust/yr	Diff	Customers
MAWC	0.912	38.864	-1.89%	-1,356	0.842	42.629	-1.77%	-1,284	-72	426k
East District (D-1)	0.905	33.180	-1.82%	-1,380	0.829	38.861	-1.73%	-1,320	-60	358k
Northwest District (D-2)	0.896	30.862	-1.74%	-912	0.793	30.789	-1.63%	-864	-48	34 k
Southwest District (D-3)	0.928	45.206	-2.68%	-1,344	0.912	82.502	-2.59%	-1,308	-36	34 k

g. NONBASE ANNUAL MODELING

Q. OPC witness Mantle is critical of the MAWC annual frequency residential non-base usage modeling. (Reb., p. 8) She claims that the MAWC annual frequency, non-base usage modeling is unable to capture what she sees as daily or weekly responses to climatic effects. What is the goal of the MAWC residential non-base modeling and why is an annual frequency to the data adequate for the MAWC analysis?

A. In order to better understand the MAWC approach applied to residential non-base modeling described in my direct testimony, it is important to understand how non-base modeling is determined. The estimation of residential non-base usage is the difference between total annual residential usage and total annual base usage. The result is total annual non-base usage. For purposes of setting residential billing determinants in this proceeding, MAWC is seeking to estimate the relationship between the annual residential non-base usage and those climatic factors that may influence residential non-base usage. Since we are seeking to model and forecast levels of annual non-base usage, we have chosen to employ an annual climatic factor, cooling degree-days, to analyze annual residential non-base usage. In this way, we have matched an annual level of residential non-base usage to annual climatic factor, cooling degree-days.

Q. OPC witness Mantle claims that non-base usage is determined on a daily and weekly basis in response to changing climatic conditions, which MAWC has failed to capture in its annual analysis of residential non-base usage. (Reb., p. 8) Why does that frequency of climatic causation not affect your analysis?

A. Clearly non-base usage occurs in response to varying climatic factors including, but not limited to; precipitation, maximum temperature, average temperature and cooling degree-days among others. We have not ignored those relationships in our modeling. Rather, we have simply chosen statistics that summarize the impact of the relative levels of annual climatic events on annual residential non-base usage. As such, we are not attempting to measure or forecast weekly or monthly events as you might do in system planning when seeking to estimate maximum volumes produced for a particular system during extreme climatic conditions. Instead, we are attempting to forecast annual non-residential usage based on an annual casual factor much as an automobile market analyst might model and forecast annual car sales based on annual levels of gross domestic product. Hence, OPC witness Mantle's observations and criticisms of the frequency of the MAWC non-base modeling completely miss the purpose of such modeling and her criticism lacks analytical support.

Q. Are MAWC's annual frequency Residential non-base usage models statistically significant?

A. Yes. As reported on page 12, Table GPR-2, of my direct testimony, the system level D-1 and D-2 models, all produced statistically significant results to 99% confidence interval. For D-3, we chose to employ an averaging technique, as the non-base load for that district was not responsive to any of the climatic variables we used in our regression analysis.

<u>h. THE NATURE OF TIME SERIES DATA AND IMPACT OF AVERAGES</u>

Q. What kind of data (Mantle Reb., p.5) is the MAWC residential usage data that you have analyzed?

A. The MAWC usage data is organized as measurements from one time-period to another. As such, the data is defined by the time period in which the data was observed or measured. Statistics and Economics refer to this type of data as time series data.

A definition of time series data is as follows:

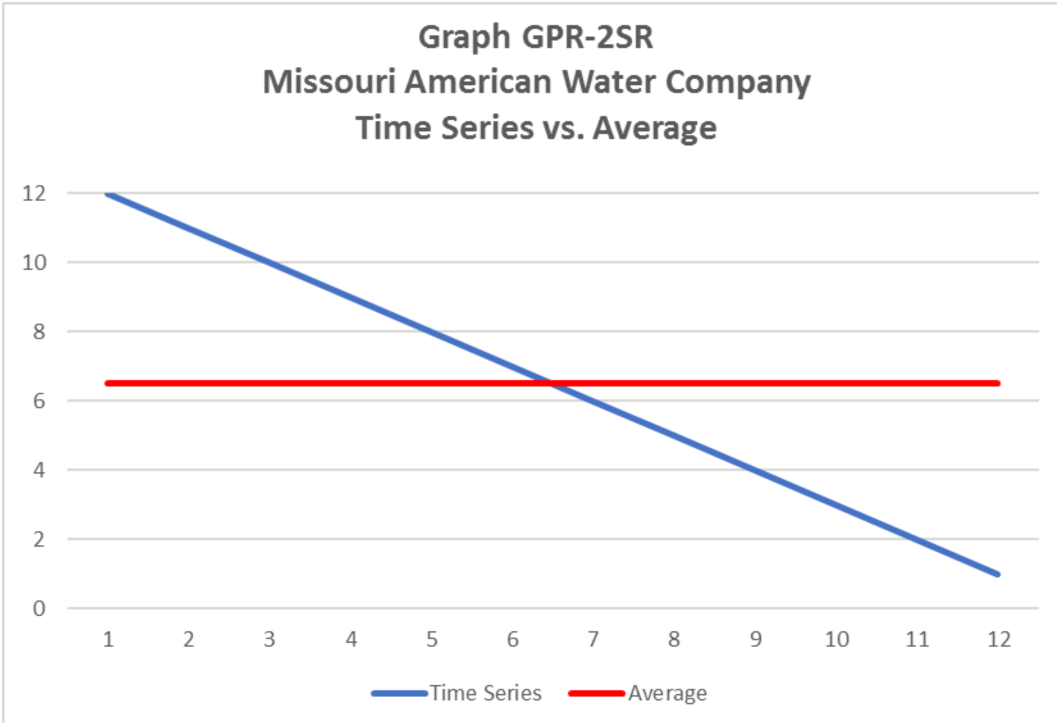
"A time series is a series of data points indexed (or listed or graphed) in time order. Most commonly, a time series is a sequence taken at successive equally spaced points in time. Thus it is a sequence of discrete-time data."[2]

Q. Can you give an example of the results of averaging time series data that is trending?

A. Yes, I can. Presented in Graph GPR-2SR is a set of time series data that has 12 successive observations with the largest value occurring in first time period and the lowest value occurring in final time period. In addition, presented in the graph is a series of data that reflects the average value of the 12 time series observations. The graph illustrates three phenomena when using an average to model or forecast the time series. First, the average will be lower than the first six observations. Second, the average will be higher than the final six observations. Third, the average completely

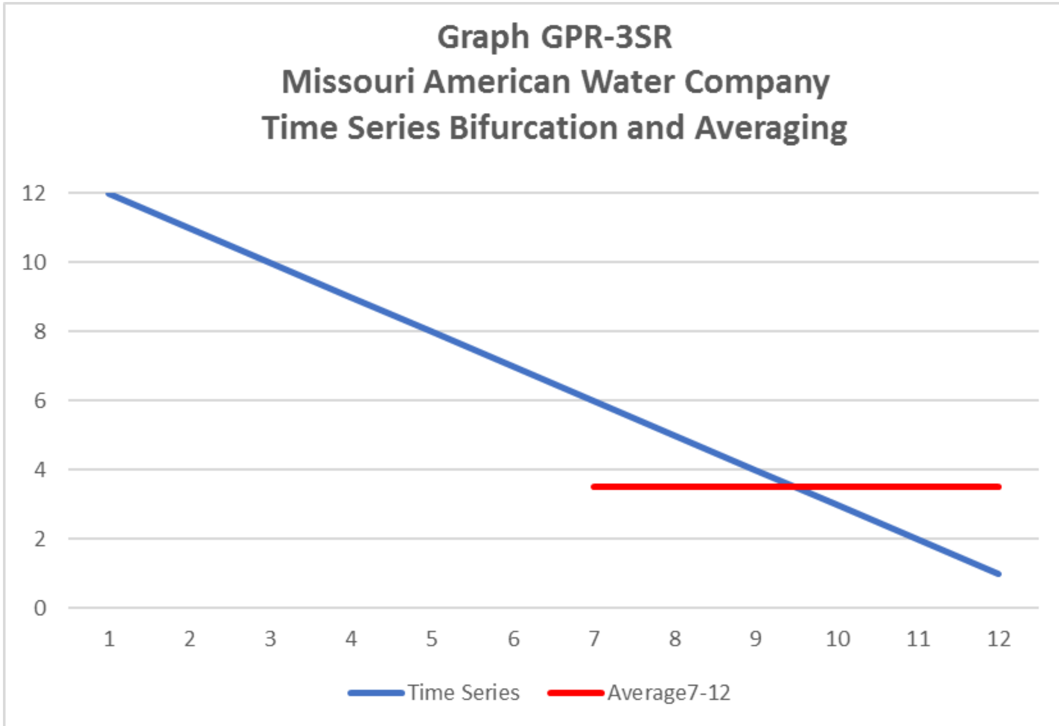
[2] Wikipedia, https://en.wikipedia.org/wiki/Time_series

misleads the analyst as it fails to convey the overall trend of the data, which is a one unit successive decline every period over which the time series was measured.



Q. How is OPC witness Mantle's time series bifurcation and double averaging technique different from the time series averaging technique you illustrate in Graph GPR-2SR?

A. OPC witness Mantle has chosen to bifurcate the residential base usage data into two groups, 2006-2011 and 2012-2017. For purposes of recommending billing determinants in this proceeding, OPC witness Mantle chose to average the 2012-2017 residential base usage data. Graph GPR-3SR illustrates the result of that averaging technique below. As with the total series averaging technique above, OPC witness Mantle's bifurcation and then averaging results in the same pattern of underestimating the early observations and over estimating the later observations albeit with less variance than the technique illustrated in Graph GPR-2SR.



Q. What do these examples above illustrate concerning the impact of both the OPC and Staff averaging techniques related to forecasting a time series?

A. These examples illustrate that the Staff and OPC averaging techniques both fail to capture the downward trend of the time series data. Further, as the technique applies to a time series with a negative slope, such as MAWC residential base usage, both the Staff and OPC averaging techniques will tend to overstate usage the further away in time you get from the mid-point of the average. Hence, in this particular application, the Staff and OPC averaging techniques will overstate the value of the historic Test Year, and that overstatement will become ever greater with each successive year beyond the historic Test Year.

Q. Will you please summarize your thoughts related to the claims made by OPC witness Mantle in her rebuttal testimony related to the MAWC residential base and non-base usage modeling approach and results?

A. Yes, I will. When addressing OPC witness Mantle, I have:

1) Demonstrated that OPC witness Mantle's toilet flushing example is too narrowly focused and ignores the impact on usage of replacing all other water-using devices;

2) Demonstrated that OPC witness Mantle's concern is unfounded, as the normalization of the April 2017 data point results in an insignificant change to the residential declining use trend;

3) Demonstrated that the annualization of the monthly residential base usage observations result in statistically significant models that meet the 99.9% confidence interval;

4) Demonstrated that monthly frequency residential base usage models produce results which are nearly identical to the annual frequency models confirming the validity of annual frequency models;

5) Reported a minor update to the East District (D-1) model results that addresses OPC witness Mantle's concern related to the relationship of the district level models results to the system level model results illustrating the results are logical;

6) Performed a comparative analysis which identifies a small impact on the residential base usage forecast by including a binary variable to explain the historically cold climatic events of the 2014 base usage period;

7) Explained the reason for MAWC employing non-base annual frequency models and illustrated they are statistically very significant models; and,

8) Illustrated the impact on forecast error of using statistical averaging techniques when analyzing time series data.

IV. RESPONSE TO OPC WITNESS GEOFF MARKE

a. MUELLER METER READING IMPACT ON RESIDENTIAL USAGE

Q. OPC witness Marke on page 16 of his rebuttal testimony questions the validity of the MAWC residential usage data due to the impact of replacement of Mueller meters during the period of August 2015 through February 2016. Have you performed an analysis that gives insight into the possible impact those meter failures and replacements may have caused?

A. Yes I have. In responding to MO PSC Staff findings in Case No. WO-2017-0012 attached here as Schedule GPR-2, MAWC provided an analysis that estimated the potential impact of Mueller meter malfunctions on MAWC billing and usage data. Using the results of flow testing performed on approximately 1,200 of the removed Muller meters as a sample; MAWC was able to estimate that the potential Mueller meter weighted total reading error was -0.34%. This total average meter reading error amounted to an approximate 70-gallon/customer/year reduction in total residential usage, a less than $100k change in residential revenue during that Test Year.

Q. Mr. Roach is that potential meeting reading error a significant departure from your original estimates of residential usage?

A. No, as demonstrated to the Staff in WO-2017-0012 the potential meter reading error is of minimal magnitude and has not significantly affected the results of our residential base or non-base usage analysis for the historic Test Year. This analysis clearly shows that there is no analytical support for OPC witness Mark's assertions that the meter reading errors somehow render the MAWC residential usage analysis unreliable. As such, OPC Witness Mark's assertions are without merit and should be ignored by this Commission.

b. BASE USAGE PERIOD EMPLOYED IN ANALYSIS

Q. OPC witness Marke makes several assertions (Reb. p.17) related to the base periods used in the MAWC residential base usage analysis. Why are there minor differences between base periods for MAWC and across other AWC affiliate companies?

A. OPC witness Marke, in criticizing the MAWC analysis, makes this assertion on page 18 of his rebuttal testimony:

> "The real issue that should give the Commission pause is the variation in the selection of months between districts. These deviations undermine the credibility of his results. Far from being conclusive, further scrutiny of MAWC's analysis suggests that there is nearly unlimited room to manipulate data, especially if one is predisposed to a specific outcome."

In making this statement, OPC witness Marke has chosen to ignore one of the primary principals of statistical analysis. That is, let the data speak and define the model.

Q. What does that mean in the case of modeling MAWC residential base usage?

A. This means that varying billing periods, varying meter-reading routes and perhaps some differences in usage patterns or fixture/appliance saturation cause the data to define the base period for the data being analyzed. That is, there are minor differences in billing, meter reading routes, usage patterns and appliance/fixture saturation rates that may lead to different residential base usage periods when analyzing MAWC on a system wide basis or by each individual district. When analyzing residential base usage by district, the results of our regression modeling indicated that for Northwest (D-2) and Southwest (D-3) districts, the base usage data from those districts produced a better statistical fit using the months of January through April to define the base period. When analyzing residential base usage on a system wide basis and for the East (D-1) district, the data indicated that a Feb-April base period was the best fit. First, this is not a massive difference in the definition of the residential base period. The inclusion of one additional month to define the base period in districts that have only 10% the amount of customers (and observations) that are included in either the East (D-1) district or the system wide modeling is totally predictable. Varying base periods are likely to occur in districts with fewer customers and observations as one would expect the impact of bill timing, meter reading and appliance saturation to have a greater impact (variance) by observing any single monthly value. Thus, by including one additional month of data for purposes of analyzing the residential base usage trend for the smaller districts, additional information is gained that allows for a better statistical fit to the data that is not necessarily expressed (or needed) in the larger East (D-1) or system wide modeling.

Q. By asserting that each of the various district models (and AMW affiliate) should employ the same residential base usage period, what is OPC witness Marke asserting in analytical or statistical terms?

A. Arguing that each of the various MAWC districts and AMW affiliates should employ the same residential base period, implies that each district and each affiliate would have the same billing periods, the same meter reading schedules, similar appliance saturation levels as well as usage patterns. Such an assumption is demonstrable false based on analysis of the residential base usage data itself. Further, such an assumption implies that residential base usage in West Virginia is the same as Missouri while ignoring vast differences in climate, income levels, appliance and fixture saturations, topography and the age of residential housing stock levels. To assume that each district and affiliates residential base periods must be the same is a baseless position presuming that a demonstrably incorrect preconceived notion is somehow more accurate than what the data itself clearly indicates. As such, OPC witness Marke's claim related to residential base usage periods necessarily being the same is without analytical support, illogical based on statistical principals and without merit. I recommend the Commission ignore OPC witness Mark's illogical and analytically unsupported claims related to residential base period definition.

c. PRICE ELASTICITY ANALYSIS

Q. In his rebuttal testimony, OPC witness Marke makes certain claims related to MAWC evidence provided related to price elasticity, conservation laws, appliance efficiency standards and appliance/fixture saturation rates. What claims did the witness make related to these items in his rebuttal testimony?

A. OPC witness Marke asserts the following on page 20 of his rebuttal testimony:

> "To summarize, there is no price elasticity study, no end-use saturation study, no customer water conservation study, no federal conservation

laws enacted, no state conservation laws enacted, and only a handful of local municipalities who have some degree of water conservation ordinances in place "

Q. OPC witness Marke summarizes the MAWC response to discovery request OPC DR-2053 and asserts that MAWC did not perform a "price elasticity" study. Is he correct in his assertion that MAWC did not provide a "price elasticity" study?

A. In alleging that MAWC did not provide a price elasticity study in response to OPC DR-2053, OPC witness is being disingenuous. As part of the MAWC response to OPC DR-2053 attached here as Schedule GPR-4SR, MAWC provided the OPC all of its detailed modeling, including basic data and regression models, performed to explore the inclusion of certain price variables in our MAWC residential base usage modeling. As we explained in our response to the OPC discovery request (and demonstrated with the statistical modeling included with our response to that OPC discovery request), although a price variable as an explanatory variable was explored in our residential base usage modeling, the price term's explanatory capability was less significant than the time variable. Further, when a price term was included with time, the resulting models suffered from autocorrelation of the error terms and were thus statistically unreliable models. Based on those statistical properties, MAWC chose to base its residential base usage models using a time variable to reflect both the change of usage to the relative changes in appliance/fixture saturation as well as price. To claim that MAWC did not provide such information, data or modeling related to price as OPC witness Marke does on page 18, is misleading. Rather, MAWC investigated the matter of price elasticity and deliberately made what was the statistically supportable decision and chose to not employ a price variable in its base and non-base residential usage models. Further, for OPC witness Marke to assert on page 30 of his rebuttal testimony that MAWC did not consider the effects of price elasticity in its residential modeling is also demonstrably false. As a result, all of OPC witness Marke's allegations related to MAWC not providing a price elasticity study and not considering the effects of price as part of its residential usage analysis, are disputed by both the analytical and factual evidence provided by MAWC.

d. FEDERAL WATER EFFICIENCY DEVICE & APPLIANCE STANDARDS

Q. In his rebuttal testimony, OPC witness Marke claims that MAWC evidence provides "no federal conservation laws enacted" as evidence for conservation or reduced residential customer usage rendering the MAWC analysis incomplete or inaccurate. What evidence of federally mandated water conservation and flow rates did MAWC provide in its direct testimony?

A. OPC witness Marke's claims are curious in light of the fact that MAWC provided rather copious evidence beginning on page 19, and ending on page 24 of my direct testimony. This information clearly explains the role of federal legislation and regulations (administered by the United States Environmental Protection Administration) that define and prescribe certain water conserving flow rates for both appliances and fixtures. In my direct testimony, I illustrate the impact of these federally mandated lower flow rates for appliances and fixtures beginning with the Energy Policy and Conservation Acts of 1992, revised lower with the Acts update in 2005 and then revised lower again with the Energy Independence and Security Act of 2007 - demonstrating increasingly more stringent conservation standards. The impact of these revised flow rates, and current consideration of potential future reductions of the flow rates, continue to impact residential base usage consumption with each old water-using appliance and fixture replaced with newer appliance/fixture in the MAWC system. Specifically, our analysis indicates that there is the potential for somewhere between 25 to 30 years of additional reductions in residential usage due to the installation of these appliances and devices with lower flow rates then the devices they replace.

Q. Mr. Roach, what is fallacious about all of the conservation and efficiency claims made by OPC witness Marke as it applies to the MAWC residential usage analysis?

A. In his rebuttal testimony, OPC witness Marke chose to focus nearly exclusively on the lack of water conservation laws, regulations and programs promoted or enacted by the State of Missouri, certain municipalities within the MAWC system or by MAWC. Throughout nine pages of his rebuttal testimony, witness Marke provides example after example of very limited or no state, municipal legislated or company sponsored "conservation" programs, which he argues undermines the credibility of our residential usage analysis. In making such an assertion, OPC witness Marke is asking the Commission, in the face of incontrovertible evidence to the contrary, to believe that that the majority of water appliance and fixtures sold in Missouri were designed, and produced specifically for the Missouri market. Nothing could be further from reality. In order to accomplish economies of scale and compete at national price points, manufactures of water using appliances and fixtures design and manufacture devices to be sold and distributed on a national basis in accordance to federal standards that are enforced by the US, and each state EPA, based on the federal legislation detailed above.

As a result, the lack of State, municipal or MAWC level conservation actions has no impact on the design, manufacture or distribution of water using appliance or fixtures. Since the lack of state, municipal or MAWC conservation actions do not impact water appliance design or manufacture, the lack of those conservation actions has no impact on the existing trend of residential water usage nor will it impact the future trend of residential water usage. As a result, OPC witness Marke's assertions that nonexistent state, municipal or MAWC conservation legislation, codes or actions somehow negate the results of the MAWC residential base usage analysis which is based on federal flow regulations applicable in the entire United States, which includes Missouri, are not supported by any analytical or factual evidence and are without merit. In fact, he stunningly ignores federal law which is the major factor driving the trend of declining usage per customer.

e. RESIDENTIAL END USE DATA AND ANALYSIS

Q. In his rebuttal testimony, amongst OPC witness Marke also criticizes (Reb. p.5) MAWC residential end use analysis because it lacks a water appliance or fixture saturation study. Why has neither MAWC, nor any of its affiliate companies, provided or had performed a water appliance or fixture saturation study?

A. The short answer is that the cost of performing and collecting such water appliance and fixture saturation data is prohibitive and a cost that is not prudent for the MAWC ratepayers to bear. OPC witness Marke made this same assentation in the 2015 general rate case. My response to his claim remains the same. Manufactures and manufacturing trade groups do not wish to share what is proprietary corporate production data that each manufacture works diligently to keep confidential from their competitors.

Alternatively, MAWC is unwilling to perform what would be an imprudent and costly customer appliance and fixture saturation survey of its residential customer base as such survey would require routine updates to collect the data necessary to analyze a trend related to appliance saturation changes over time. Such an ongoing study would be a permanent, massive undertaking requiring ongoing administration of the surveys as well as the maintenance and analytical interrogation of the data.

Q. Would the acquisition of such water appliance and fixture saturation data guarantee more accurate results as compared to the time series regression analysis MAWC has provided in this proceeding?

A. No. There are no guarantees that after collecting such data on an on-going basis that end-use modeling, based on the saturation data, would lead to residential base usage analyses and forecasts of greater precision than the regression based analysis filed in this case due to numerous simplifications that must be made in end-use modeling. Just as with certain simplifications made in our regression analysis (that time stands for the effects of appliance/fixture saturation and price), an end-use model based on saturation survey data must make assumptions based on certain simplifications as well. Such end-use simplifications and assumptions include, but are not limited to, number of each type of appliance stock per household, number of each type of water fixture stock per household, corresponding flow rates of each appliance and fixture connected to the system, duration of consumption on each device or appliance and number of users per household to name but a few of the assumptions necessary to make an end-use model work. Thus, the analyst is forced to make even more assumptions and simplifications than those global simplifications made in the MAWC regression analysis after collecting and collating voluminous survey data over successive years. Due to those simplifications and assumptions that must be made to make the end-use modeling work, there is no guarantee nor even any implication that such an approach would result in more precise or accurate estimates of residential base usage trends.

Q. Mr. Roach, would you recommend this Commission order MAWC to undertake the cost and effort required to acquire water appliance and fixture saturation data on an on-going basis?

A. No, I would not. The cost of such an on-going project would not be a prudent investment for either the MAWC ratepayers or stockholders to make. The limited probability that the accuracy of residential base usage trend analysis would somehow be enhanced by undergoing a massive investment to collect saturation data on an ongoing basis as compared to the current methods employed by MAWC makes such an investment imprudent. In any event, the example of the Joplin tornado, addressed in my direct testimony, is more than sufficient evidence of the fact that there is abundant potential for significantly more appliance replacement and the dramatic effects on consumption when they are all replaced at once. Here, again, OPC witness Marke is trying to muster any discordant claim to refute what is generally acknowledged by all those who examine it – there is a persistent trend of declining use per customer in the water industry that is not going away any time soon.

<u>V. RESPONSE TO STAFF WITNESS JARROD ROBERTSON</u>

a. STAFF ACKNOWLEDGEMENT OF RESIDENTIAL USAGE REDUCTIONS

Q. Mr. Roach, does Staff witness Robertson agree with MAWC that residential usage per customer has declined over time?

A. Yes. In Staff Witness Jarrod Robertson's rebuttal testimony, beginning on page 6, he states:

> "Even with these changes in usage patterns, and a multitude of other variables, it does appear residential customer usage on a per day basis is less today than it was in the past."

Q. Does Staff witness Robertson give a specific cause for such reductions in residential customer usage?

A. No, he does not. On page 5 of his rebuttal testimony, Mr. Robertson makes the following observation related to the trend of residential usage per customer:

> "Staff is aware that consumer usage patterns have changed over the years due to many different factors. Consumers are displaying more discretionary use patterns as a result of efficiency education, more water-efficient appliances, low-flow toilets, and other efficient fixtures. On the opposite end of the spectrum there are subdivisions that require individual residential water use via lawn watering/sprinkler operation during the summer months."

Based on these two statements, it is clear that Staff acknowledges that residential usage per customer has declined over the recent past, but is unable to identify the main causality due to numerous simultaneously interacting factors.

b. STAFF 5-YEAR AVERAGE – TEST YEAR RESIDENTIAL USAGE

Q. Since Staff was unable to identify or employ a method through which to simulate and account for the numerous, simultaneous factors that identify as catalyst for residential usage per customer declines, what method has Staff chosen to employ to set Test Year residential Test Year sales volumes and revenues in this proceeding?

A. As with the direct testimony of Staff Witness Natelle Dietrich, Mr. Robertson's rebuttal testimony acknowledges that Staff has employed a simple 5-year average of residential usage per customer encompassing the period 2012-2016.

Q. What is the result and issue with employing the five-year averaging technique proposed by Staff to set Test Year residential sales and revenues in this proceeding?

A. Based on a detailed analysis delineated in my rebuttal testimony, employment of the Staff's five-year average technique has the following deficiencies:

1) The five-year averaging technique overstates 2016 residential actual usage by approximately 2.3 trillion gallons of water or 7%;

2) The five-year averaging technique employs usage data from a period that was approximately 12% warmer than the corresponding 40-year period ending in 2016;

3) The five-year averaging technique employs usage data from a period that was approximately 9.1% warmer than the corresponding 40-year period ending in 2016; and,

4) The five-year averaging technique employs usage data from the Summer of 2012, which was a historically warm and dry summer as compared to all other Summer seasons in the 40-year period ending in 2016.

The result of employing such a warmer and dryer than average period to set Test Year residential sales and revenues is to significantly overstate Test Year 2016 residential usage and revenues. Setting 2016 Test Year usage and revenues by the Staff technique would put MAWC in an ongoing position where it could only meet its authorized revenues if the Commission were to suspend acknowledgment of what Staff has identified as clear reductions in residential usage per customer and, simultaneously, experience historically warm and dry summer climatic conditions. Either of those assumptions on its own is illogical. Both assumptions taken together ignore significant evidence that clearly indicate that the Staff five-year averaging technique lacks the analytical or common sense rigor required to reliably set Test Year residential sales volumes or revenues. Due to these deficiencies, I recommend the Commission reject the Staff proposed five-year averaging technique for setting residential Test Year sales and revenues in this proceeding.

c. STAFF 5-YEAR AVERAGE TECHNIQUE – IMPACT ON TIME SERIES

Q. What is the impact of employing the Staff proposed five-year averaging technique when using time series data whose value is declining over time?

A. As delineated on page 19 of this testimony, usage of OPC witness Mantle's five-year base usage averaging technique (illustrated by Graph GPR-2SR and GPR-3SR) implies that by the nature of the mathematics, the five-year average will understate the first 2.5 years as compared to the trend value, and will overstate the last 2.5 years as compared to the trend value. In other words, in the face of a declining residential usage per customer trend that Mr. Robertson and Staff have acknowledged, Staff is knowingly overstating the residential Test Year 2016 sales volumes and revenues by employing the mathematics of the simple five-year average.

Q. What is the impact of employing the Staff proposed five-year averaging technique for residential usage beyond Test Year 2016?

A. Using Graph GPR-3SR as the example, every year beyond the mid-point of the average, in this case, June 2014, the five-year average results in an ever-greater error as compared to the value of the actual trend of residential usage. As a result, each year removed from the mid-point of the five-year average becomes ever more impossible for MAWC to meet its authorized revenue or residential sales volumes when such a technique is employed to set Test Year residential sales volumes and revenue.

Q. Is there historic evidence in this proceeding that illustrates the averaging technique's impact when applied to a declining time series?

A. Yes, there is. On page 29 of my direct testimony, Table GPR-7 illustrates that, over the period of 2008 through 2016, MAWC was under its collective authorized revenue by approximately $69.4 million. The inability of MAWC to collect its authorized revenue over the period of 2008-2016 is directly linked to overstated water sales levels set in the MAWC cases over that same time period. In each case, some type of averaging technique was used to set Test Year residential sales volumes and revenues. The historic results clearly illustrate the mathematical issues associated with applying an average in the face of declining time series.

Q. Mr. Roach can you illustrate the extreme sensitivity of the Staff 5 year averaging approach to the time period averaged, the climatic factors during the time period averaged and the averaging technique's incapability to reflect a declining slope time series?

A. Yes I can. Presented below in Table GPR-5SR is a comparison of residential volumetric revenue and usage as filed by Staff for five-year average ending June 30, 2017 and as we have updated that approach to 6 months later to a five-year average for period ending December 31, 2017. Table GPR-5SR illustrates that by moving the Staff five-year averaging technique to a mere 6 months in the future results in a 2.5% reduction in total residential usage and revenues. This is prima fascia evidence which clearly illustrates that the Staff and OPC proposed approaches are very dependent on the five-year period averaged, the climatic conditions during that five-year period and the approaches total disregard for what is a declining trend in time series data.

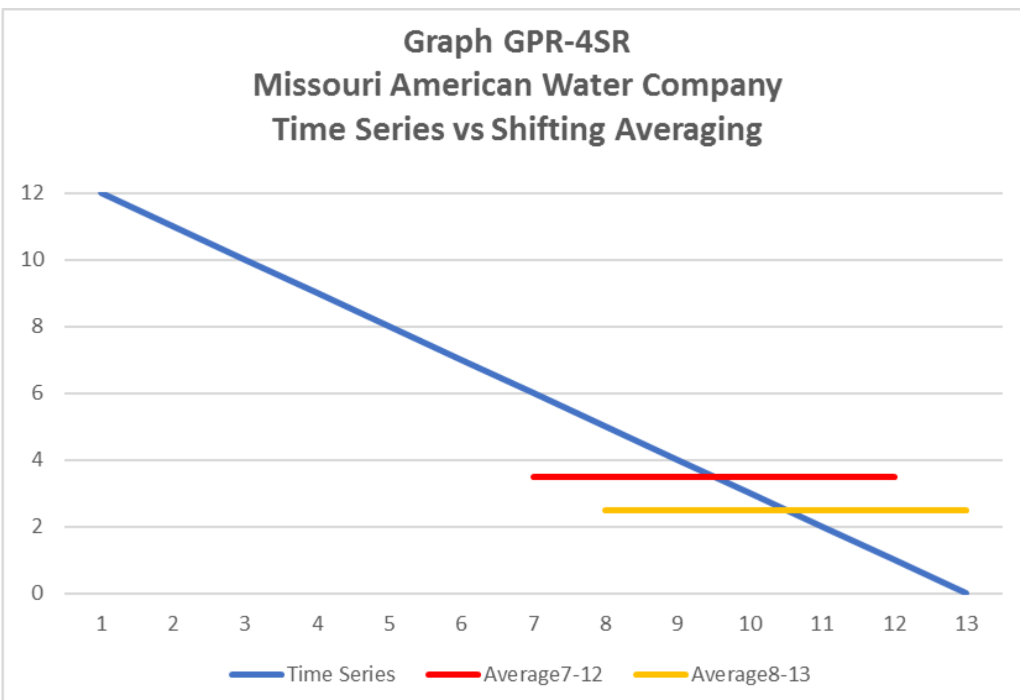
Table GPR-5SR
Missouri American Water Company
Residential Usage and Revenue
Staff Filed vs. Six Month Update

	Staff Workpaper Annualized, 5Y Avg Usage 6/30/17		MAWC Adjusted Workpaper 12M Average, 5Y Avg Usage 12/31/17		Staff Filed vs Update			
					Usage		Revenue	
Volumetric	Usage	Revenue	Usage	Revenue	Gallons (000)	Percent	$	Percent
District 1	29,463,957	$ 121,979,050	28,726,700	$ 118,926,954	(737,257)	-2.50%	$ (3,052,096)	-2.50%
District 2	1,948,221	9,230,280	1,909,232	9,045,559	(38,989)	-2.00%	(184,721)	-2.00%
District 3	1,806,991	6,762,484	1,758,026	6,579,237	(48,965)	-2.71%	(183,247)	-2.71%
Total	33,219,169	$ 137,971,814	32,393,958	$ 134,551,750	(825,211)	-2.48%	$ (3,420,064)	-2.48%

* Annualized is derived using Customer Count at 6/30/2017 annualized
** 12 M Average is derived using Customer Count Jan-Dec Annualized

Q. Mr. Roach can you graphically illustrate what a 6-month update implies related to the relationship of a declining time series vs updating the five-year average for six months additional data?

A. Yes I can. Presented in Graph GPR-4SR below, I illustrate the impact of moving a five period average by one period. As I have delineated above on pages 21-22 related to using a five-period average to represent a declining time series, the five-year average will by definition of the mathematical technique overstate usage the further away in time you get from the mid-point of the average as compared to declining time series. Hence, in this particular application, the Staff and OPC averaging techniques will overstate the value of the historic residential Test Year usage and revenues, and that overstatement will become ever greater with each successive year beyond the historic Test Year. By updating those five-year averages 6 months further into the future, you are simply advancing the five-year averages overstatement compared to the time series by one period.



Q. What is your recommendation related to Staff and OPC's five-year averaging techniques?

A. Due to the analytical and historically illustrated issues created by using a five-year average technique with declining time series data, amplified by the Staff's usage of a significant warmer and dryer period to average as compared to the 40 year climatic averages, I recommend that the Commission reject both the Staff and OPC five-year averaging techniques. Neither technique reflects the nature of a declining residential customer usage trend that Staff has acknowledged. Further, the Staff technique results in Test Year residential sales volumes and revenues that are unattainable due to the mathematical properties of the technique itself and which is amplified by the nature of the climatic conditions occurring during the five-year period that was averaged as clearly delineated through my example of a six-month advancement of the five-year averaging period above.

VI. RECOMMENDATIONS

Q. What are your recommendations for the Commission related to setting Pro Forma Test Year sales and billing determinants in this proceeding?

A. I recommend that the Commission reject both the Staff and OPC proposed averaging techniques for setting Pro Forma Test Year sales and billing determinants in this proceeding. The Commission should reject both the Staff and OPC five-year averaging techniques as they ignore the fact that Staff acknowledged the trend of declining residential usage per customer and result in an overstatement of Test Year residential sales volumes and revenues. Further, the Commission should reject the Staff's simple averaging technique due to its biased results that are further unduly influenced by the unusually warm and dry climatic factors during the period averaged. The Commission should also reject the OPC proposed residential base usage averaging technique as it relies on monthly data heavily influenced by discreet monthly meter reading/billing peculiarities that do not allow for visibility to the underlying annual trend of declines in residential base usage resulting from ever-greater saturation of more efficient water using fixtures and devices.

Q. Does this conclude your surrebuttal testimony?

A. Yes, it does.

Model: Model 19 *January 12, 2018 10:35 AM regressit Model 19*
Dependent Variable: Usage
Independent Variables:
Binary, Day
Equation:
Predicted Usage = 17,403 + 279.004*Binary - 0.292*Day

Regression Statistics: Model 19 for Usage (2 variables, n=10)

	R-Squared	Adj.R-Sqr.	Std.Err.Reg.	Std. Dev.	# Cases	# Missing	t(2.50%,7)	Conf. level
	0.917	0.894	108.773	333.743	10	0	2.365	95.0%

Coefficient Estimates: Model 19 for Usage (2 variables, n=10)

Variable	Coefficient	Std.Err.	t-Stat.	P-value	Lower95%	Upper95%	Std. Dev.	Std. Coeff.
Constant	17,403	1,369	12.715	0.000	14,166	20,639		
Binary	279.004	116.434	2.396	0.048	3.682	554.325	0.316	0.264
Day	-0.292	0.033	-8.772	0.000	-0.371	-0.213	1,106	-0.968

Analysis of Variance: Model 19 for Usage (2 variables, n=10)

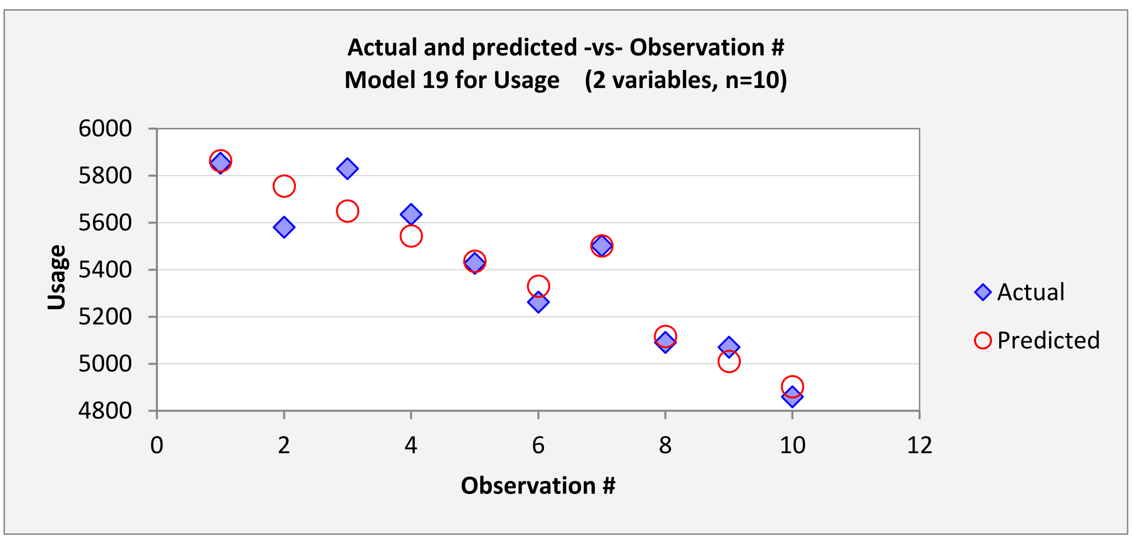
Source	df	Sum Sqrs.	Mean Sqr.	F	P-value
Regression	2	919,640	459,820	38.864	0.000
Residual	7	82,821	11,832		
Total	9	1,002,461			

Residual Distribution Statistics: Model 19 for Usage (2 variables, n=10)

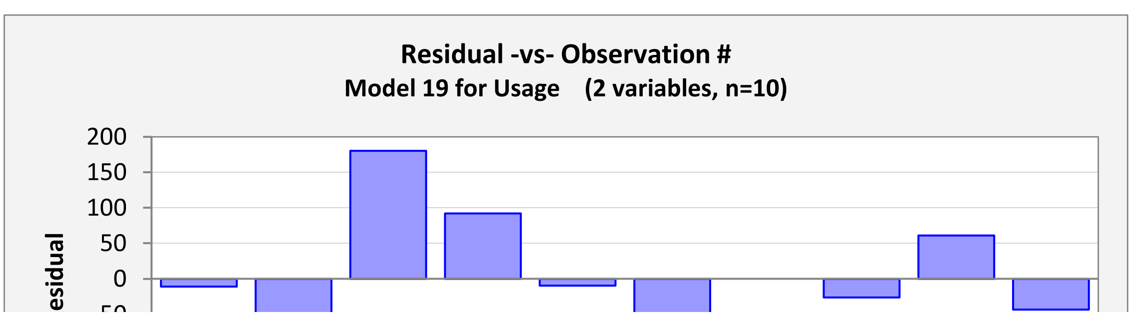
#Res.>0	#Res.<=0	A-D* Stat.	P-value	MinStdRes	MaxStdRes
4	6	0.339	0.503	-1.616	1.657

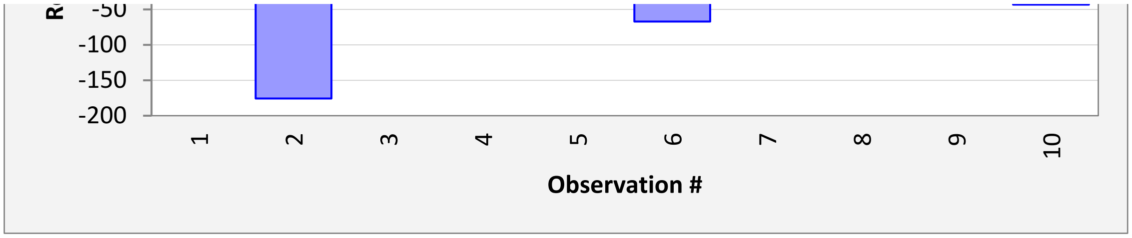
See the residual histogram for more details of the error distribution.

Actual and predicted -vs- Observation #

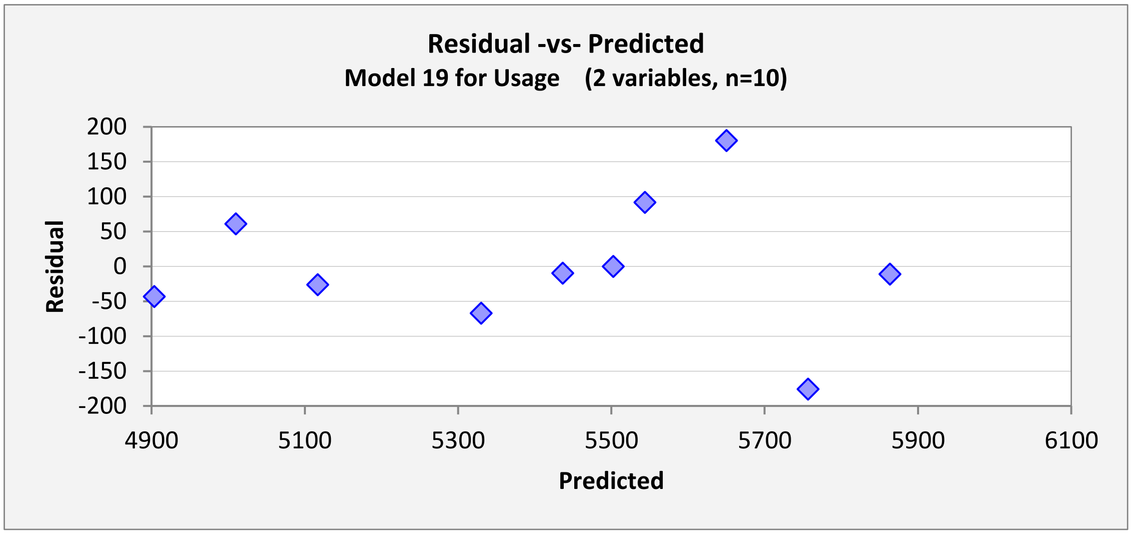


Residual -vs- Observation #

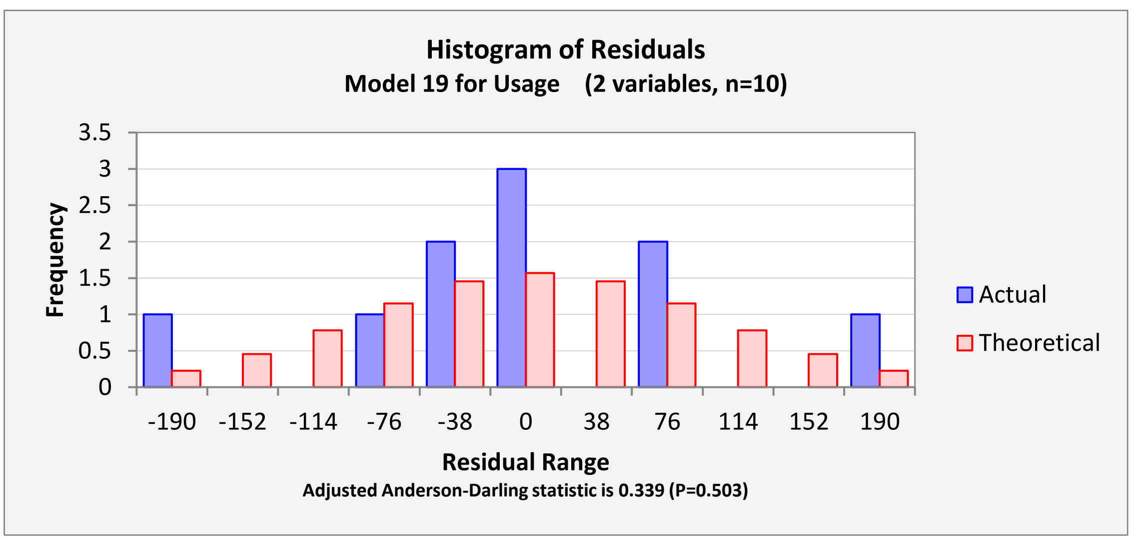




Residual -vs- Predicted



Histogram of Residuals



Model: 10yr Base Regression
Dependent Variable: Usage

May 9, 2017 9:13 AM regressit 10yr Base Regression

Regression Statistics: 10yr Base Regression for Usage (2 variables, n=10)

	R-Squared	Adj.R-Sqr.	Std.Err.Reg.	Std. Dev.	# Cases	# Missing	t(2.50%,7)	Conf. level
	0.919	0.896	117.463	364.668	10	0	2.365	95.0%

Coefficient Estimates: 10yr Base Regression for Usage (2 variables, n=10)

Variable	Coefficient	Std.Err.	t-Stat.	P-value	Lower95%	Upper95%	Std. Dev.	Std. Coeff.
Constant	18,120	1,407	12.877	0.000	14,793	21,447		
Binary	304.585	125.367	2.430	0.045	8.139	601.031	0.316	0.264
Day	-0.303	0.034	-8.868	0.000	-0.384	-0.222	1,159	-0.964

Analysis of Variance: 10yr Base Regression for Usage (2 variables, n=10)

Source	df	Sum Sqrs.	Mean Sqr.	F	P-value
Regression	2	1,100,260	550,130	39.872	0.000
Residual	7	96,583	13,798		
Total	9	1,196,842			

Residual Distribution Statistics: 10yr Base Regression for Usage (2 variables, n=10)

#Res.>0	#Res.<=0	A-D* Stat.	P-value	MinStdRes	MaxStdRes	Durbin-Watson Stat
4	6	0.335	0.508	-1.510	1.650	2.258

See the residual histogram and normal quantile plot for more details of the error distribution.

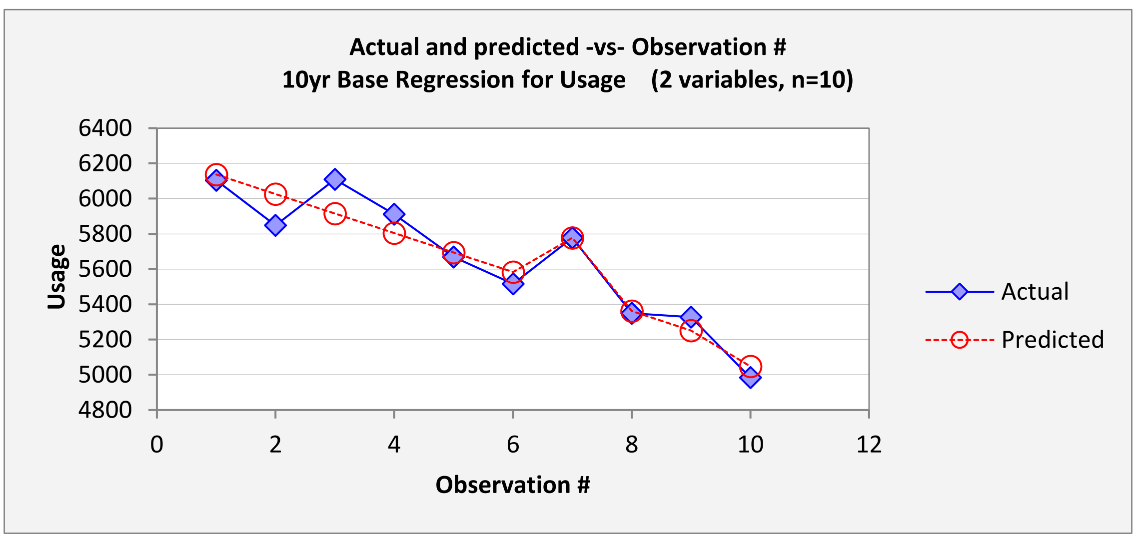
Residual Autocorrelations: 10yr Base Regression for Usage (2 variables, n=10)

Lag	1	2	3	4	5
Autocorrelation	-0.155	-0.366	-0.173	0.141	0.099

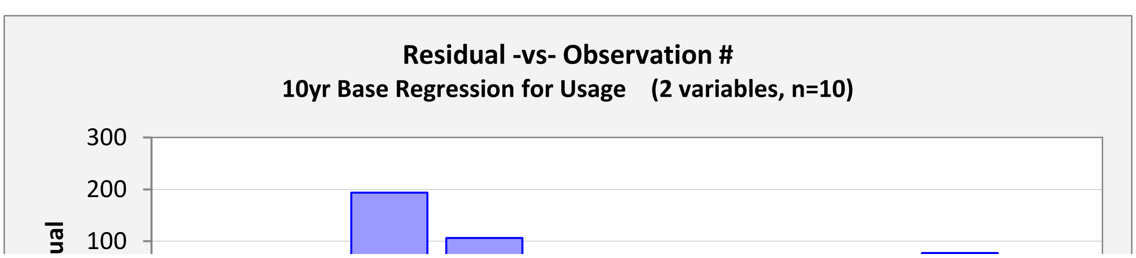
See the Residual-vs-Observation # plot for more details of the time pattern in the errors.

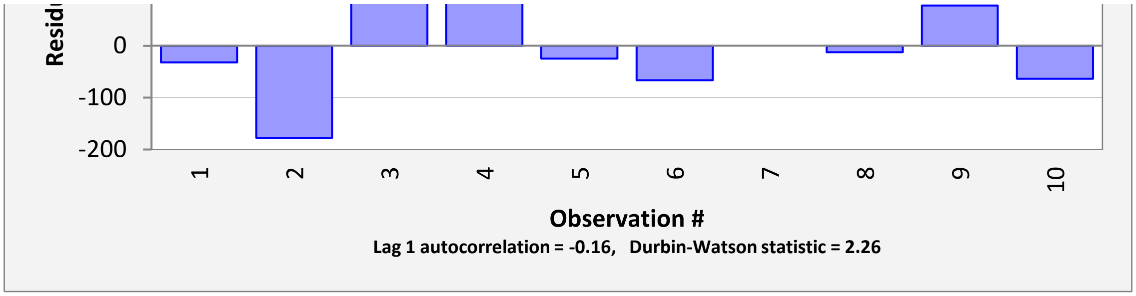
Std. err.	0.333	0.354	0.378	0.408	0.447

Actual and predicted -vs- Observation #

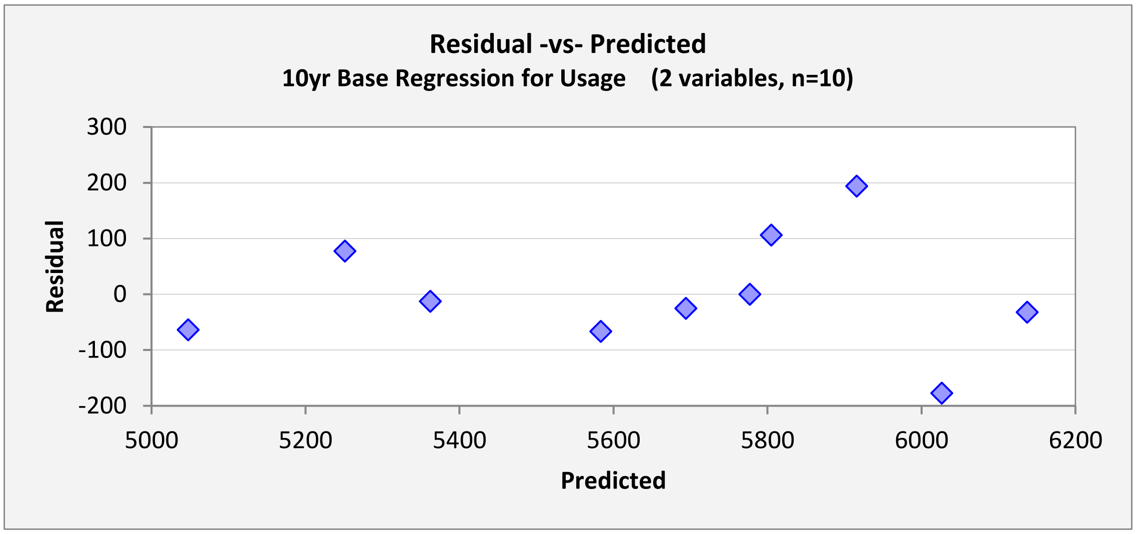


Residual -vs- Observation #

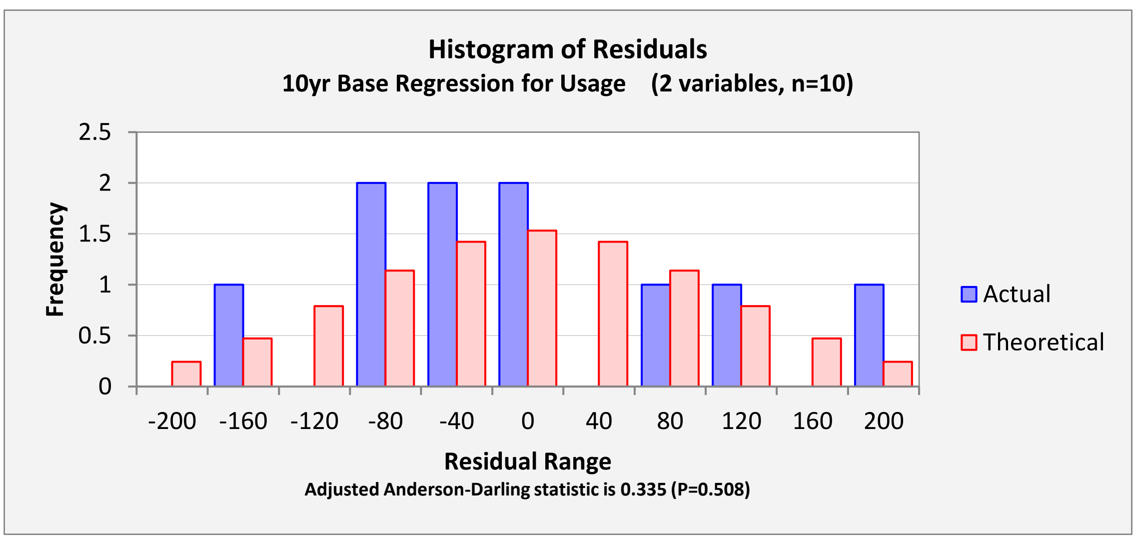




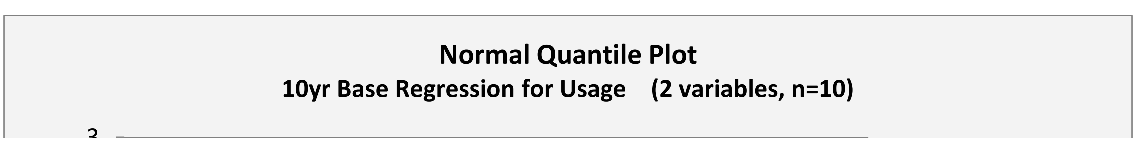
Residual -vs- Predicted

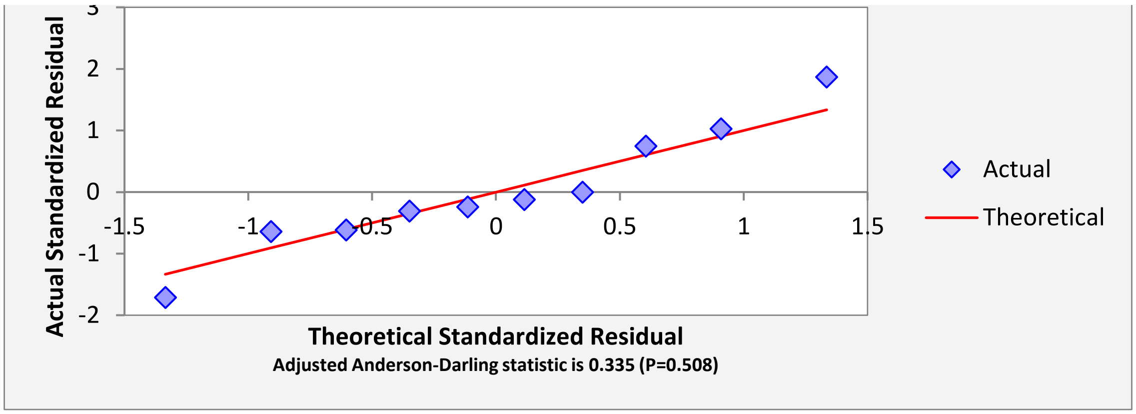


Histogram of Residuals



Normal Quantile Plot





Correlation Matrix of Coefficient Estimates : 10yr Base Regression for Usage (2 variables, n=10)

Residual -vs- Independent Variable Plots. . .

Model: 10yr Base Regression *May 9, 2017 9:28 AM regressit 10yr Base Regression*
Dependent Variable: Usage

Regression Statistics: 10yr Base Regression for Usage (2 variables, n=10)

R-Squared	Adj.R-Sqr.	Std.Err.Reg.	Std. Dev.	# Cases	# Missing	t(2.50%,7)	Conf. level
0.898	0.869	88.205	243.738	10	0	2.365	95.0%

Coefficient Estimates: 10yr Base Regression for Usage (2 variables, n=10)

Variable	Coefficient	Std.Err.	t-Stat.	P-value	Lower95%	Upper95%	Std. Dev.	Std. Coeff.
Constant	12,828	1,110	11.558	0.000	10,204	15,452		
Binary	253.206	94.417	2.682	0.031	29.946	476.467	0.316	0.329
Day	-0.209	0.027	-7.739	0.000	-0.273	-0.145	1,106	-0.948

Analysis of Variance: 10yr Base Regression for Usage (2 variables, n=10)

Source	df	Sum Sqrs.	Mean Sqr.	F	P-value
Regression	2	480,213	240,107	30.862	0.000
Residual	7	54,461	7,780		
Total	9	534,674			

Residual Distribution Statistics: 10yr Base Regression for Usage (2 variables, n=10)

#Res.>0	#Res.<=0	A-D* Stat.	P-value	MinStdRes	MaxStdRes	Durbin-Watson Stat
5	5	0.187	0.904	-1.348	1.422	2.470

See the residual histogram and normal quantile plot for more details of the error distribution.

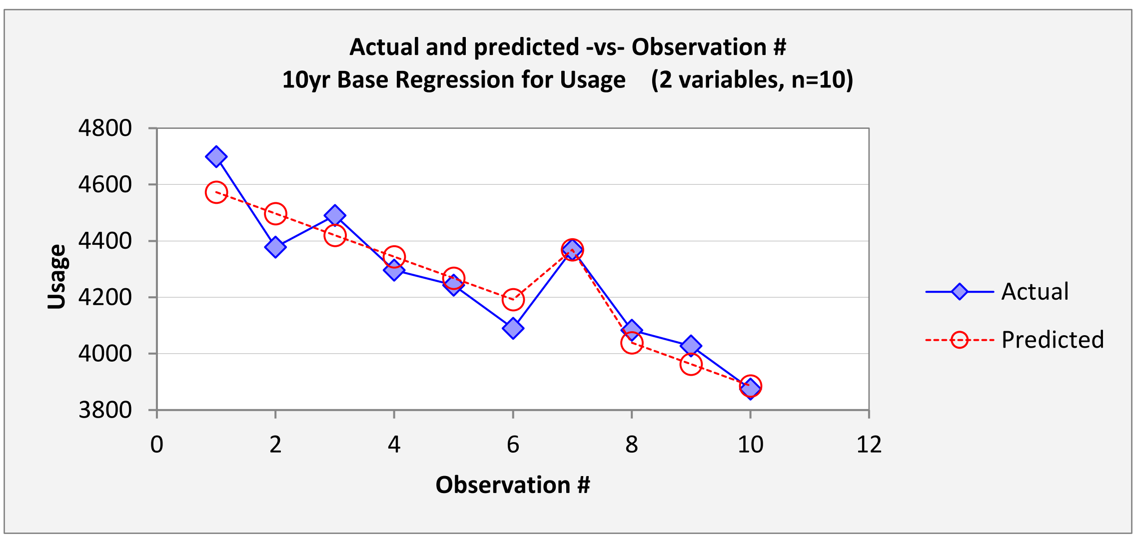
Residual Autocorrelations: 10yr Base Regression for Usage (2 variables, n=10)

Lag	1	2	3	4	5
Autocorrelation	-0.381	0.232	-0.331	0.120	-0.231

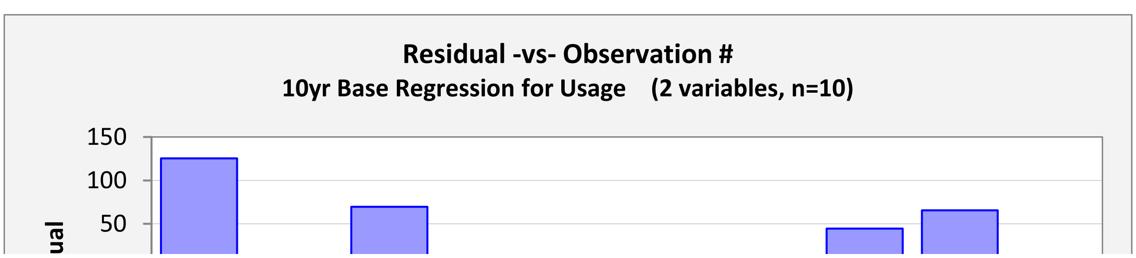
See the Residual-vs-Observation # plot for more details of the time pattern in the errors.

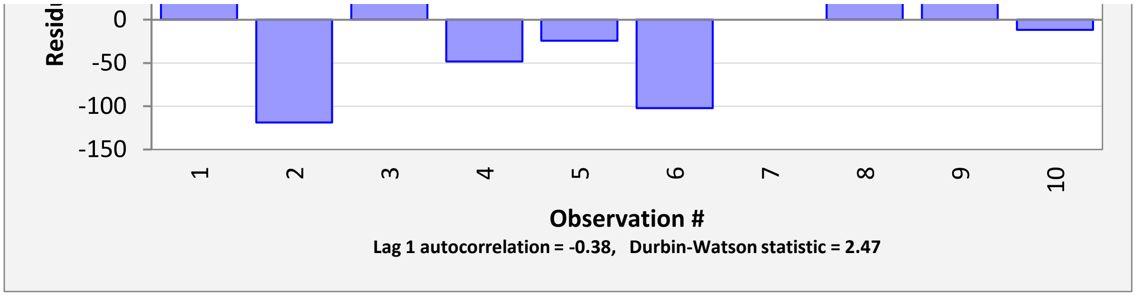
Std. err.	0.333	0.354	0.378	0.408	0.447

Actual and predicted -vs- Observation #

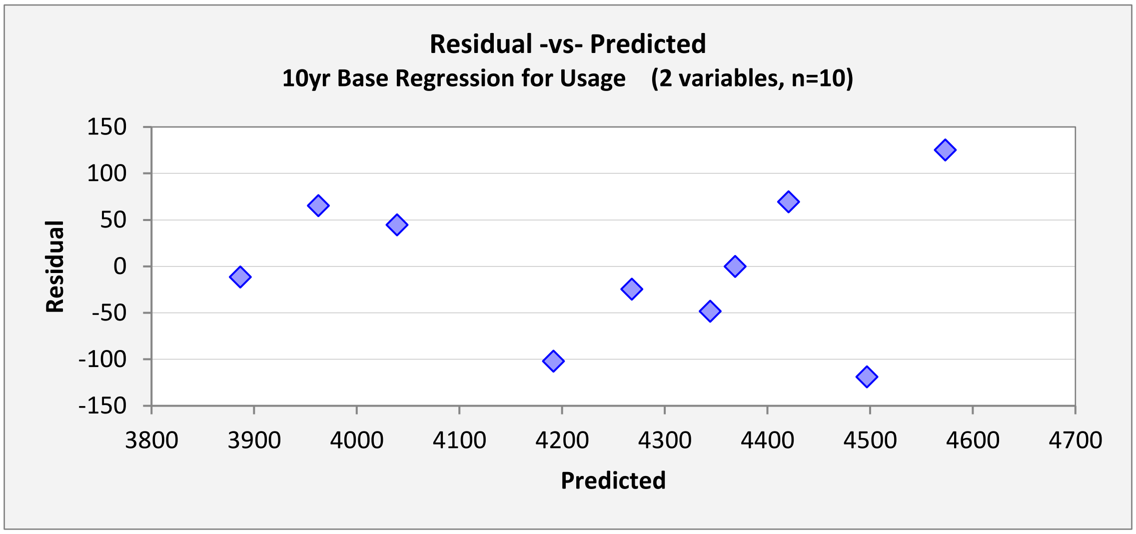


Residual -vs- Observation #

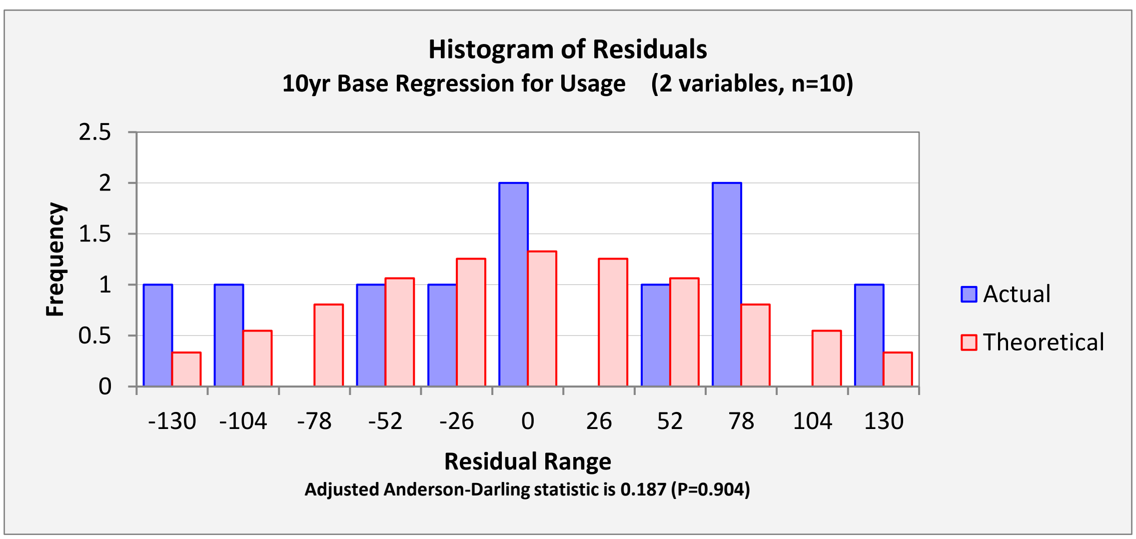




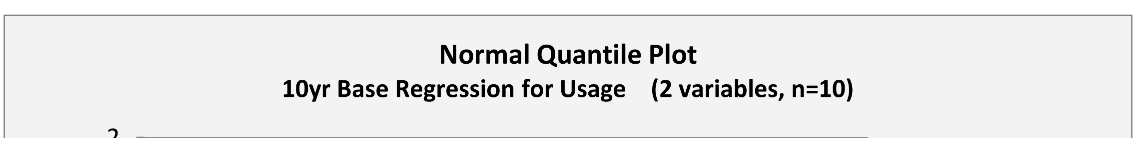
Residual -vs- Predicted

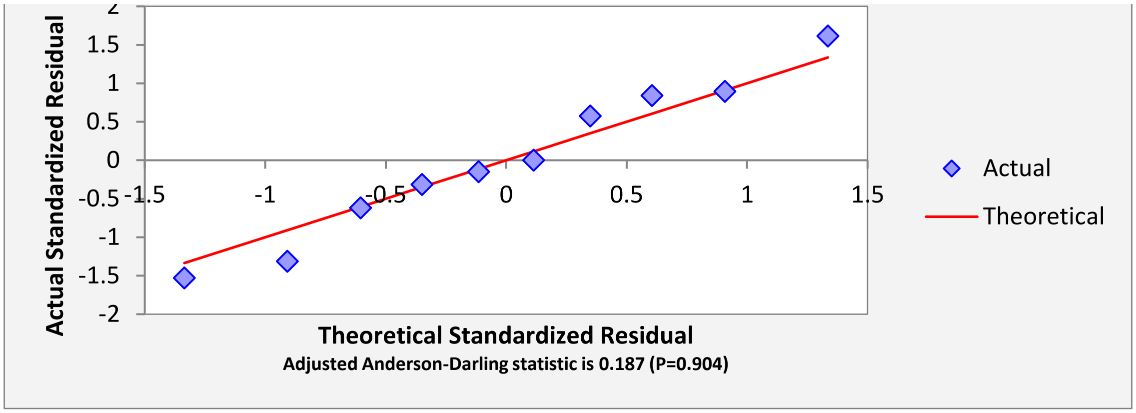


Histogram of Residuals



Normal Quantile Plot





Correlation Matrix of Coefficient Estimates : 10yr Base Regression for Usage (2 variables, n=10)

Residual -vs- Independent Variable Plots. . .

Model: 10yr Base Regression *May 9, 2017 9:35 AM regressit 10yr Base Regression*
Dependent Variable: Usage

Regression Statistics: 10yr Base Regression for Usage (2 variables, n=10)

	R-Squared	Adj.R-Sqr.	Std.Err.Reg.	Std. Dev.	# Cases	# Missing	t(2.50%,7)	Conf. level
	0.928	0.908	105.210	346.134	10	0	2.365	95.0%

Coefficient Estimates: 10yr Base Regression for Usage (2 variables, n=10)

Variable	Coefficient	Std.Err.	t-Stat.	P-value	Lower95%	Upper95%	Std. Dev.	Std. Coeff.
Constant	16,500	1,323	12.473	0.000	13,372	19,628		
Binary	142.939	112.622	1.269	0.245	-123.370	409.247	0.316	0.131
Day	-0.306	0.032	-9.500	0.000	-0.382	-0.230	1,106	-0.978

Analysis of Variance: 10yr Base Regression for Usage (2 variables, n=10)

Source	df	Sum Sqrs.	Mean Sqr.	F	P-value
Regression	2	1,000,794	500,397	45.206	0.000
Residual	7	77,485	11,069		
Total	9	1,078,279			

Residual Distribution Statistics: 10yr Base Regression for Usage (2 variables, n=10)

#Res.>0	#Res.<=0	A-D* Stat.	P-value	MinStdRes	MaxStdRes	Durbin-Watson Stat
5	5	0.123	0.987	-1.455	1.539	2.326

See the residual histogram and normal quantile plot for more details of the error distribution.

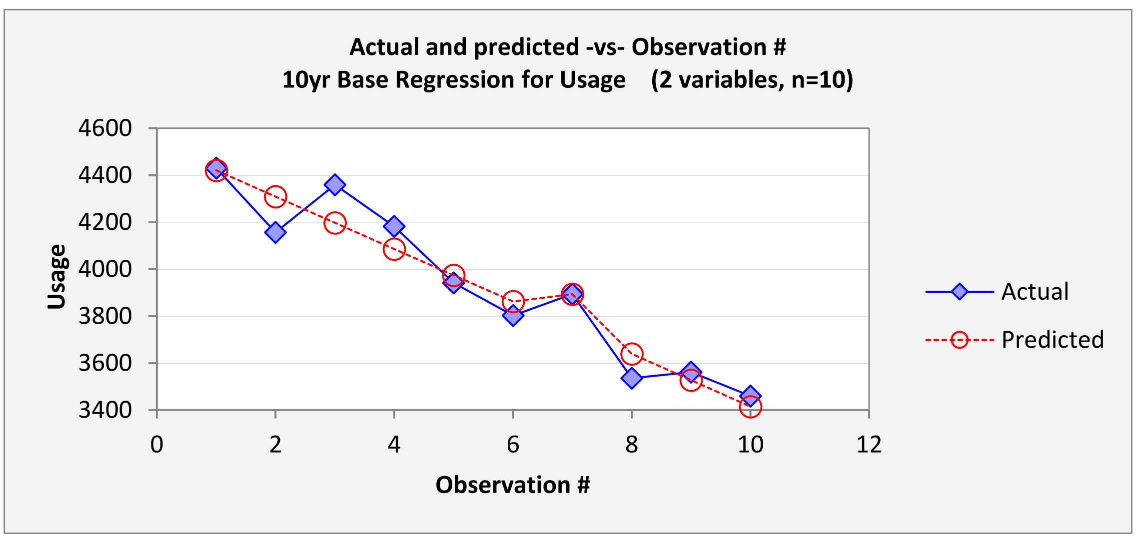
Residual Autocorrelations: 10yr Base Regression for Usage (2 variables, n=10)

Lag	1	2	3	4	5
Autocorrelation	-0.177	-0.295	-0.033	-0.063	-0.197

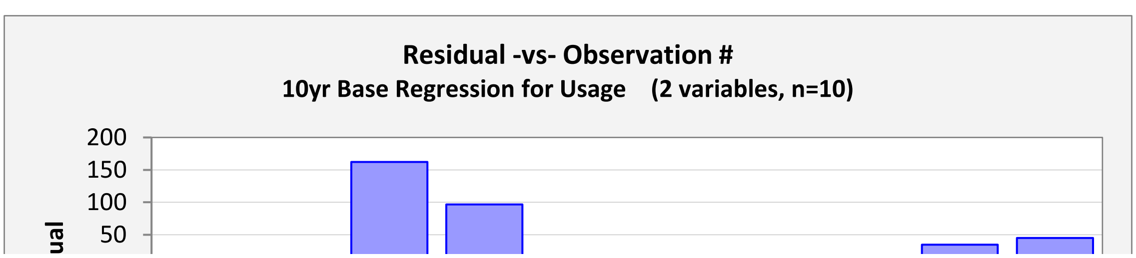
See the Residual-vs-Observation # plot for more details of the time pattern in the errors.

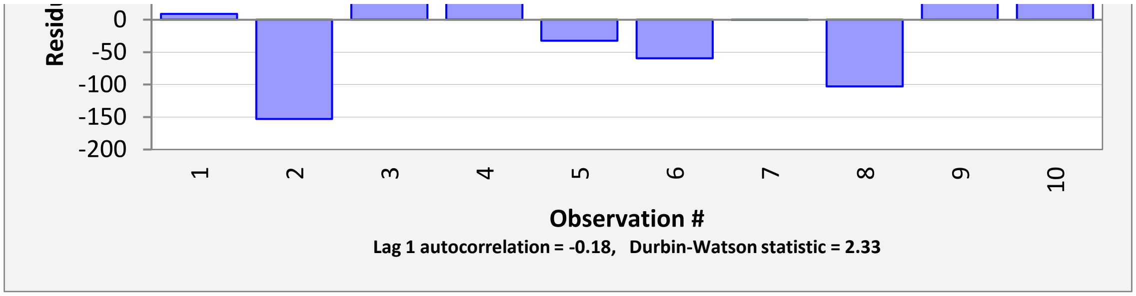
Std. err.	0.333	0.354	0.378	0.408	0.447

Actual and predicted -vs- Observation #

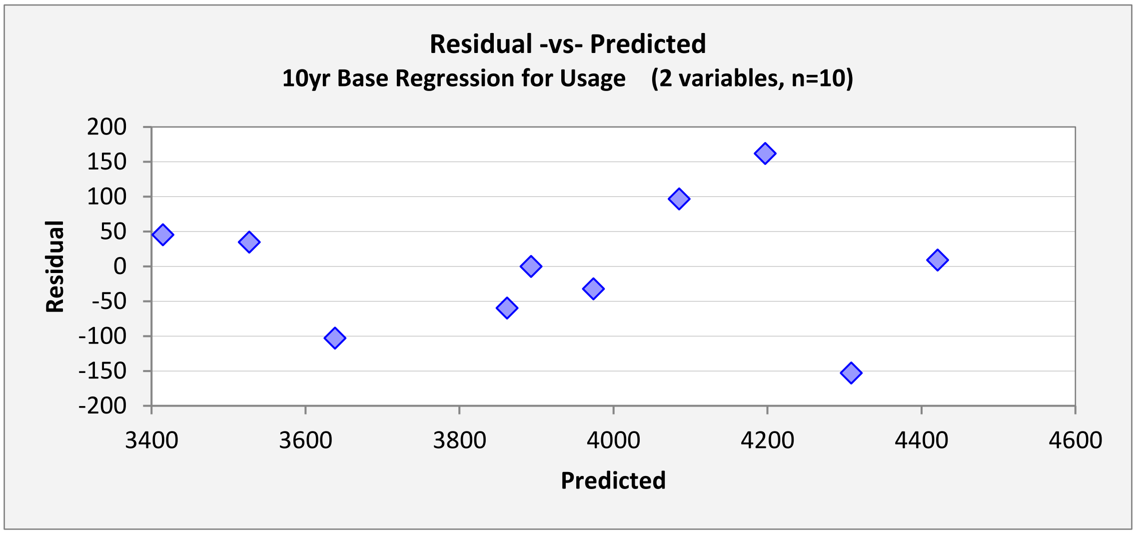


Residual -vs- Observation #

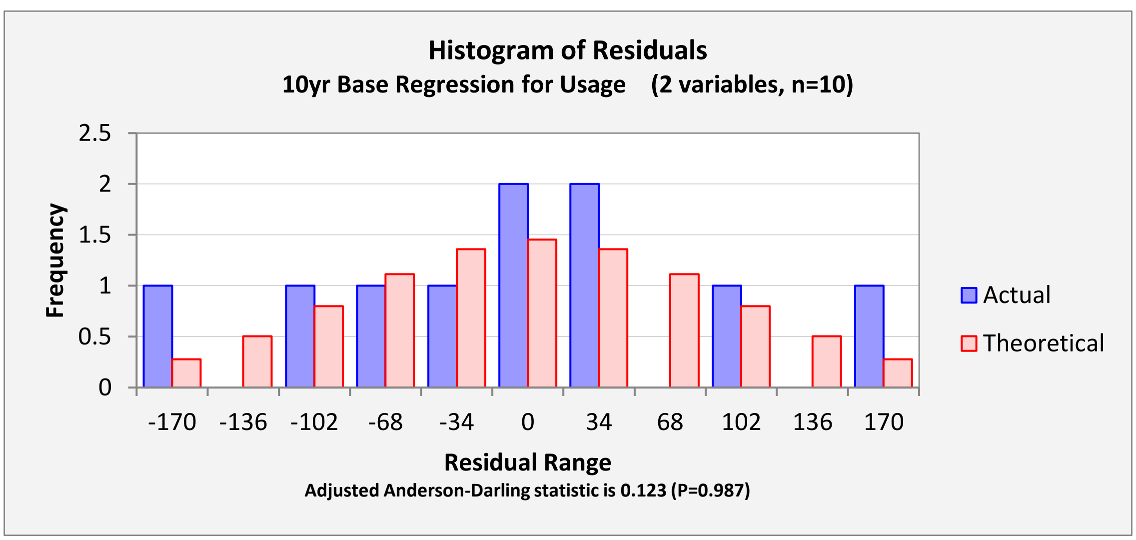




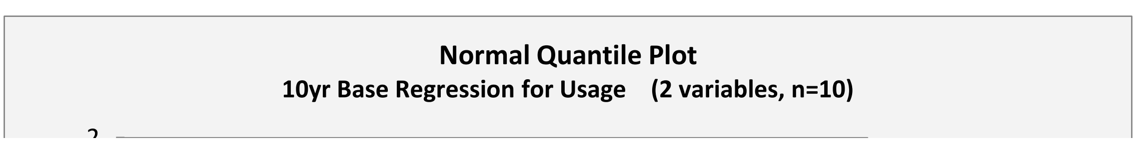
Residual -vs- Predicted

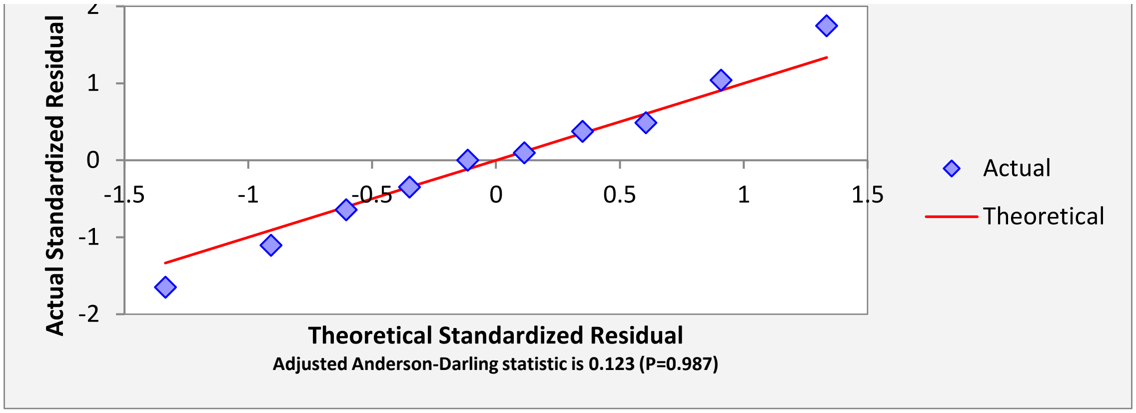


Histogram of Residuals



Normal Quantile Plot





Correlation Matrix of Coefficient Estimates : 10yr Base Regression for Usage (2 variables, n=10)

Residual -vs- Independent Variable Plots. . .

Table entry for p is the critical value F^* with probability p lying to its right.

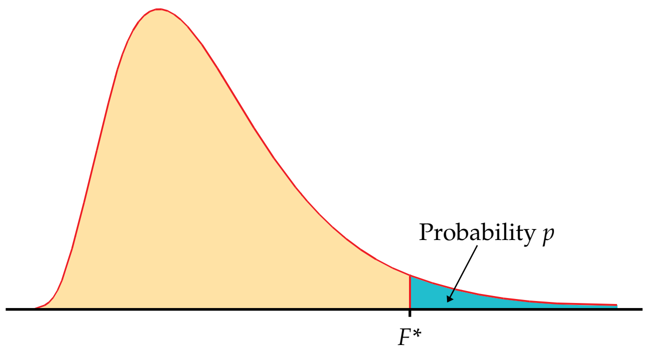


TABLE E

F critical values

Degrees of freedom in the denominator	p	1	2	3	4	5	6	7	8	9
		Degrees of freedom in the numerator								
1	.100	39.86	49.50	53.59	55.83	57.24	58.20	58.91	59.44	59.86
	.050	161.45	199.50	215.71	224.58	230.16	233.99	236.77	238.88	240.54
	.025	647.79	799.50	864.16	899.58	921.85	937.11	948.22	956.66	963.28
	.010	4052.2	4999.5	5403.4	5624.6	5763.6	5859.0	5928.4	5981.1	6022.5
	.001	405284	500000	540379	562500	576405	585937	592873	598144	602284
2	.100	8.53	9.00	9.16	9.24	9.29	9.33	9.35	9.37	9.38
	.050	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38
	.025	38.51	39.00	39.17	39.25	39.30	39.33	39.36	39.37	39.39
	.010	98.50	99.00	99.17	99.25	99.30	99.33	99.36	99.37	99.39
	.001	998.50	999.00	999.17	999.25	999.30	999.33	999.36	999.37	999.39
3	.100	5.54	5.46	5.39	5.34	5.31	5.28	5.27	5.25	5.24
	.050	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81
	.025	17.44	16.04	15.44	15.10	14.88	14.73	14.62	14.54	14.47
	.010	34.12	30.82	29.46	28.71	28.24	27.91	27.67	27.49	27.35
	.001	167.03	148.50	141.11	137.10	134.58	132.85	131.58	130.62	129.86
4	.100	4.54	4.32	4.19	4.11	4.05	4.01	3.98	3.95	3.94
	.050	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00
	.025	12.22	10.65	9.98	9.60	9.36	9.20	9.07	8.98	8.90
	.010	21.20	18.00	16.69	15.98	15.52	15.21	14.98	14.80	14.66
	.001	74.14	61.25	56.18	53.44	51.71	50.53	49.66	49.00	48.47
5	.100	4.06	3.78	3.62	3.52	3.45	3.40	3.37	3.34	3.32
	.050	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77
	.025	10.01	8.43	7.76	7.39	7.15	6.98	6.85	6.76	6.68
	.010	16.26	13.27	12.06	11.39	10.97	10.67	10.46	10.29	10.16
	.001	47.18	37.12	33.20	31.09	29.75	28.83	28.16	27.65	27.24
6	.100	3.78	3.46	3.29	3.18	3.11	3.05	3.01	2.98	2.96
	.050	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10
	.025	8.81	7.26	6.60	6.23	5.99	5.82	5.70	5.60	5.52
	.010	13.75	10.92	9.78	9.15	8.75	8.47	8.26	8.10	7.98
	.001	35.51	27.00	23.70	21.92	20.80	20.03	19.46	19.03	18.69
7	.100	3.59	3.26	3.07	2.96	2.88	2.83	2.78	2.75	2.72
	.050	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68
	.025	8.07	6.54	5.89	5.52	5.29	5.12	4.99	4.90	4.82
	.010	12.25	9.55	8.45	7.85	7.46	7.19	6.99	6.84	6.72
	.001	29.25	21.69	18.77	17.20	16.21	15.52	15.02	14.63	14.33

Table entry for p is the critical value F^* with probability p lying to its right.

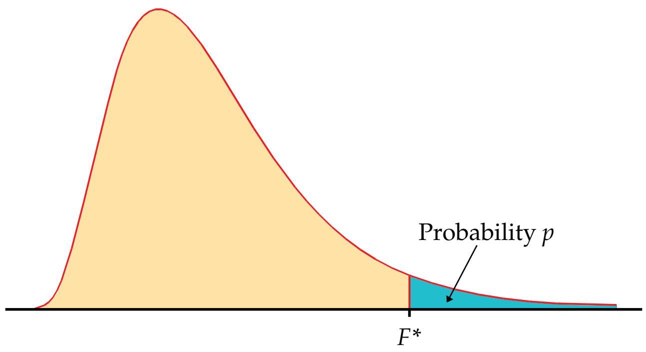


TABLE E

F critical values (continued)

Degrees of freedom in the numerator

10	12	15	20	25	30	40	50	60	120	1000
60.19	60.71	61.22	61.74	62.05	62.26	62.53	62.69	62.79	63.06	63.30
241.88	243.91	245.95	248.01	249.26	250.10	251.14	251.77	252.20	253.25	254.19
968.63	976.71	984.87	993.10	998.08	1001.4	1005.6	1008.1	1009.8	1014.0	1017.7
6055.8	6106.3	6157.3	6208.7	6239.8	6260.6	6286.8	6302.5	6313.0	6339.4	6362.7
605621	610668	615764	620908	624017	626099	628712	630285	631337	633972	636301
9.39	9.41	9.42	9.44	9.45	9.46	9.47	9.47	9.47	9.48	9.49
19.40	19.41	19.43	19.45	19.46	19.46	19.47	19.48	19.48	19.49	19.49
39.40	39.41	39.43	39.45	39.46	39.46	39.47	39.48	39.48	39.49	39.50
99.40	99.42	99.43	99.45	99.46	99.47	99.47	99.48	99.48	99.49	99.50
999.40	999.42	999.43	999.45	999.46	999.47	999.47	999.48	999.48	999.49	999.50
5.23	5.22	5.20	5.18	5.17	5.17	5.16	5.15	5.15	5.14	5.13
8.79	8.74	8.70	8.66	8.63	8.62	8.59	8.58	8.57	8.55	8.53
14.42	14.34	14.25	14.17	14.12	14.08	14.04	14.01	13.99	13.95	13.91
27.23	27.05	26.87	26.69	26.58	26.50	26.41	26.35	26.32	26.22	26.14
129.25	128.32	127.37	126.42	125.84	125.45	124.96	124.66	124.47	123.97	123.53
3.92	3.90	3.87	3.84	3.83	3.82	3.80	3.80	3.79	3.78	3.76
5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.70	5.69	5.66	5.63
8.84	8.75	8.66	8.56	8.50	8.46	8.41	8.38	8.36	8.31	8.26
14.55	14.37	14.20	14.02	13.91	13.84	13.75	13.69	13.65	13.56	13.47
48.05	47.41	46.76	46.10	45.70	45.43	45.09	44.88	44.75	44.40	44.09
3.30	3.27	3.24	3.21	3.19	3.17	3.16	3.15	3.14	3.12	3.11
4.74	4.68	4.62	4.56	4.52	4.50	4.46	4.44	4.43	4.40	4.37
6.62	6.52	6.43	6.33	6.27	6.23	6.18	6.14	6.12	6.07	6.02
10.05	9.89	9.72	9.55	9.45	9.38	9.29	9.24	9.20	9.11	9.03
26.92	26.42	25.91	25.39	25.08	24.87	24.60	24.44	24.33	24.06	23.82
2.94	2.90	2.87	2.84	2.81	2.80	2.78	2.77	2.76	2.74	2.72
4.06	4.00	3.94	3.87	3.83	3.81	3.77	3.75	3.74	3.70	3.67
5.46	5.37	5.27	5.17	5.11	5.07	5.01	4.98	4.96	4.90	4.86
7.87	7.72	7.56	7.40	7.30	7.23	7.14	7.09	7.06	6.97	6.89
18.41	17.99	17.56	17.12	16.85	16.67	16.44	16.31	16.21	15.98	15.77
2.70	2.67	2.63	2.59	2.57	2.56	2.54	2.52	2.51	2.49	2.47
3.64	3.57	3.51	3.44	3.40	3.38	3.34	3.32	3.30	3.27	3.23
4.76	4.67	4.57	4.47	4.40	4.36	4.31	4.28	4.25	4.20	4.15
6.62	6.47	6.31	6.16	6.06	5.99	5.91	5.86	5.82	5.74	5.66
14.08	13.71	13.32	12.93	12.69	12.53	12.33	12.20	12.12	11.91	11.72

(*Continued*)

TABLE E

F critical values (continued)

Degrees of freedom in the denominator	*p*	1	2	3	4	5	6	7	8	9
		Degrees of freedom in the numerator								
8	.100	3.46	3.11	2.92	2.81	2.73	2.67	2.62	2.59	2.56
	.050	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39
	.025	7.57	6.06	5.42	5.05	4.82	4.65	4.53	4.43	4.36
	.010	11.26	8.65	7.59	7.01	6.63	6.37	6.18	6.03	5.91
	.001	25.41	18.49	15.83	14.39	13.48	12.86	12.40	12.05	11.77
9	.100	3.36	3.01	2.81	2.69	2.61	2.55	2.51	2.47	2.44
	.050	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18
	.025	7.21	5.71	5.08	4.72	4.48	4.32	4.20	4.10	4.03
	.010	10.56	8.02	6.99	6.42	6.06	5.80	5.61	5.47	5.35
	.001	22.86	16.39	13.90	12.56	11.71	11.13	10.70	10.37	10.11
10	.100	3.29	2.92	2.73	2.61	2.52	2.46	2.41	2.38	2.35
	.050	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02
	.025	6.94	5.46	4.83	4.47	4.24	4.07	3.95	3.85	3.78
	.010	10.04	7.56	6.55	5.99	5.64	5.39	5.20	5.06	4.94
	.001	21.04	14.91	12.55	11.28	10.48	9.93	9.52	9.20	8.96
11	.100	3.23	2.86	2.66	2.54	2.45	2.39	2.34	2.30	2.27
	.050	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90
	.025	6.72	5.26	4.63	4.28	4.04	3.88	3.76	3.66	3.59
	.010	9.65	7.21	6.22	5.67	5.32	5.07	4.89	4.74	4.63
	.001	19.69	13.81	11.56	10.35	9.58	9.05	8.66	8.35	8.12
12	.100	3.18	2.81	2.61	2.48	2.39	2.33	2.28	2.24	2.21
	.050	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80
	.025	6.55	5.10	4.47	4.12	3.89	3.73	3.61	3.51	3.44
	.010	9.33	6.93	5.95	5.41	5.06	4.82	4.64	4.50	4.39
	.001	18.64	12.97	10.80	9.63	8.89	8.38	8.00	7.71	7.48
13	.100	3.14	2.76	2.56	2.43	2.35	2.28	2.23	2.20	2.16
	.050	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71
	.025	6.41	4.97	4.35	4.00	3.77	3.60	3.48	3.39	3.31
	.010	9.07	6.70	5.74	5.21	4.86	4.62	4.44	4.30	4.19
	.001	17.82	12.31	10.21	9.07	8.35	7.86	7.49	7.21	6.98
14	.100	3.10	2.73	2.52	2.39	2.31	2.24	2.19	2.15	2.12
	.050	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65
	.025	6.30	4.86	4.24	3.89	3.66	3.50	3.38	3.29	3.21
	.010	8.86	6.51	5.56	5.04	4.69	4.46	4.28	4.14	4.03
	.001	17.14	11.78	9.73	8.62	7.92	7.44	7.08	6.80	6.58
15	.100	3.07	2.70	2.49	2.36	2.27	2.21	2.16	2.12	2.09
	.050	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59
	.025	6.20	4.77	4.15	3.80	3.58	3.41	3.29	3.20	3.12
	.010	8.68	6.36	5.42	4.89	4.56	4.32	4.14	4.00	3.89
	.001	16.59	11.34	9.34	8.25	7.57	7.09	6.74	6.47	6.26
16	.100	3.05	2.67	2.46	2.33	2.24	2.18	2.13	2.09	2.06
	.050	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54
	.025	6.12	4.69	4.08	3.73	3.50	3.34	3.22	3.12	3.05
	.010	8.53	6.23	5.29	4.77	4.44	4.20	4.03	3.89	3.78
	.001	16.12	10.97	9.01	7.94	7.27	6.80	6.46	6.19	5.98
17	.100	3.03	2.64	2.44	2.31	2.22	2.15	2.10	2.06	2.03
	.050	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49
	.025	6.04	4.62	4.01	3.66	3.44	3.28	3.16	3.06	2.98
	.010	8.40	6.11	5.19	4.67	4.34	4.10	3.93	3.79	3.68
	.001	15.72	10.66	8.73	7.68	7.02	6.56	6.22	5.96	5.75

TABLE E

F critical values (continued)

Degrees of freedom in the numerator										
10	12	15	20	25	30	40	50	60	120	1000
2.54	2.50	2.46	2.42	2.40	2.38	2.36	2.35	2.34	2.32	2.30
3.35	3.28	3.22	3.15	3.11	3.08	3.04	3.02	3.01	2.97	2.93
4.30	4.20	4.10	4.00	3.94	3.89	3.84	3.81	3.78	3.73	3.68
5.81	5.67	5.52	5.36	5.26	5.20	5.12	5.07	5.03	4.95	4.87
11.54	11.19	10.84	10.48	10.26	10.11	9.92	9.80	9.73	9.53	9.36
2.42	2.38	2.34	2.30	2.27	2.25	2.23	2.22	2.21	2.18	2.16
3.14	3.07	3.01	2.94	2.89	2.86	2.83	2.80	2.79	2.75	2.71
3.96	3.87	3.77	3.67	3.60	3.56	3.51	3.47	3.45	3.39	3.34
5.26	5.11	4.96	4.81	4.71	4.65	4.57	4.52	4.48	4.40	4.32
9.89	9.57	9.24	8.90	8.69	8.55	8.37	8.26	8.19	8.00	7.84
2.32	2.28	2.24	2.20	2.17	2.16	2.13	2.12	2.11	2.08	2.06
2.98	2.91	2.85	2.77	2.73	2.70	2.66	2.64	2.62	2.58	2.54
3.72	3.62	3.52	3.42	3.35	3.31	3.26	3.22	3.20	3.14	3.09
4.85	4.71	4.56	4.41	4.31	4.25	4.17	4.12	4.08	4.00	3.92
8.75	8.45	8.13	7.80	7.60	7.47	7.30	7.19	7.12	6.94	6.78
2.25	2.21	2.17	2.12	2.10	2.08	2.05	2.04	2.03	2.00	1.98
2.85	2.79	2.72	2.65	2.60	2.57	2.53	2.51	2.49	2.45	2.41
3.53	3.43	3.33	3.23	3.16	3.12	3.06	3.03	3.00	2.94	2.89
4.54	4.40	4.25	4.10	4.01	3.94	3.86	3.81	3.78	3.69	3.61
7.92	7.63	7.32	7.01	6.81	6.68	6.52	6.42	6.35	6.18	6.02
2.19	2.15	2.10	2.06	2.03	2.01	1.99	1.97	1.96	1.93	1.91
2.75	2.69	2.62	2.54	2.50	2.47	2.43	2.40	2.38	2.34	2.30
3.37	3.28	3.18	3.07	3.01	2.96	2.91	2.87	2.85	2.79	2.73
4.30	4.16	4.01	3.86	3.76	3.70	3.62	3.57	3.54	3.45	3.37
7.29	7.00	6.71	6.40	6.22	6.09	5.93	5.83	5.76	5.59	5.44
2.14	2.10	2.05	2.01	1.98	1.96	1.93	1.92	1.90	1.88	1.85
2.67	2.60	2.53	2.46	2.41	2.38	2.34	2.31	2.30	2.25	2.21
3.25	3.15	3.05	2.95	2.88	2.84	2.78	2.74	2.72	2.66	2.60
4.10	3.96	3.82	3.66	3.57	3.51	3.43	3.38	3.34	3.25	3.18
6.80	6.52	6.23	5.93	5.75	5.63	5.47	5.37	5.30	5.14	4.99
2.10	2.05	2.01	1.96	1.93	1.91	1.89	1.87	1.86	1.83	1.80
2.60	2.53	2.46	2.39	2.34	2.31	2.27	2.24	2.22	2.18	2.14
3.15	3.05	2.95	2.84	2.78	2.73	2.67	2.64	2.61	2.55	2.50
3.94	3.80	3.66	3.51	3.41	3.35	3.27	3.22	3.18	3.09	3.02
6.40	6.13	5.85	5.56	5.38	5.25	5.10	5.00	4.94	4.77	4.62
2.06	2.02	1.97	1.92	1.89	1.87	1.85	1.83	1.82	1.79	1.76
2.54	2.48	2.40	2.33	2.28	2.25	2.20	2.18	2.16	2.11	2.07
3.06	2.96	2.86	2.76	2.69	2.64	2.59	2.55	2.52	2.46	2.40
3.80	3.67	3.52	3.37	3.28	3.21	3.13	3.08	3.05	2.96	2.88
6.08	5.81	5.54	5.25	5.07	4.95	4.80	4.70	4.64	4.47	4.33
2.03	1.99	1.94	1.89	1.86	1.84	1.81	1.79	1.78	1.75	1.72
2.49	2.42	2.35	2.28	2.23	2.19	2.15	2.12	2.11	2.06	2.02
2.99	2.89	2.79	2.68	2.61	2.57	2.51	2.47	2.45	2.38	2.32
3.69	3.55	3.41	3.26	3.16	3.10	3.02	2.97	2.93	2.84	2.76
5.81	5.55	5.27	4.99	4.82	4.70	4.54	4.45	4.39	4.23	4.08
2.00	1.96	1.91	1.86	1.83	1.81	1.78	1.76	1.75	1.72	1.69
2.45	2.38	2.31	2.23	2.18	2.15	2.10	2.08	2.06	2.01	1.97
2.92	2.82	2.72	2.62	2.55	2.50	2.44	2.41	2.38	2.32	2.26
3.59	3.46	3.31	3.16	3.07	3.00	2.92	2.87	2.83	2.75	2.66
5.58	5.32	5.05	4.78	4.60	4.48	4.33	4.24	4.18	4.02	3.87

(Continued)

TABLE E

F critical values (continued)

Degrees of freedom in the denominator	*p*	Degrees of freedom in the numerator 1	2	3	4	5	6	7	8	9
18	.100	3.01	2.62	2.42	2.29	2.20	2.13	2.08	2.04	2.00
	.050	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46
	.025	5.98	4.56	3.95	3.61	3.38	3.22	3.10	3.01	2.93
	.010	8.29	6.01	5.09	4.58	4.25	4.01	3.84	3.71	3.60
	.001	15.38	10.39	8.49	7.46	6.81	6.35	6.02	5.76	5.56
19	.100	2.99	2.61	2.40	2.27	2.18	2.11	2.06	2.02	1.98
	.050	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42
	.025	5.92	4.51	3.90	3.56	3.33	3.17	3.05	2.96	2.88
	.010	8.18	5.93	5.01	4.50	4.17	3.94	3.77	3.63	3.52
	.001	15.08	10.16	8.28	7.27	6.62	6.18	5.85	5.59	5.39
20	.100	2.97	2.59	2.38	2.25	2.16	2.09	2.04	2.00	1.96
	.050	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39
	.025	5.87	4.46	3.86	3.51	3.29	3.13	3.01	2.91	2.84
	.010	8.10	5.85	4.94	4.43	4.10	3.87	3.70	3.56	3.46
	.001	14.82	9.95	8.10	7.10	6.46	6.02	5.69	5.44	5.24
21	.100	2.96	2.57	2.36	2.23	2.14	2.08	2.02	1.98	1.95
	.050	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37
	.025	5.83	4.42	3.82	3.48	3.25	3.09	2.97	2.87	2.80
	.010	8.02	5.78	4.87	4.37	4.04	3.81	3.64	3.51	3.40
	.001	14.59	9.77	7.94	6.95	6.32	5.88	5.56	5.31	5.11
22	.100	2.95	2.56	2.35	2.22	2.13	2.06	2.01	1.97	1.93
	.050	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34
	.025	5.79	4.38	3.78	3.44	3.22	3.05	2.93	2.84	2.76
	.010	7.95	5.72	4.82	4.31	3.99	3.76	3.59	3.45	3.35
	.001	14.38	9.61	7.80	6.81	6.19	5.76	5.44	5.19	4.99
23	.100	2.94	2.55	2.34	2.21	2.11	2.05	1.99	1.95	1.92
	.050	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32
	.025	5.75	4.35	3.75	3.41	3.18	3.02	2.90	2.81	2.73
	.010	7.88	5.66	4.76	4.26	3.94	3.71	3.54	3.41	3.30
	.001	14.20	9.47	7.67	6.70	6.08	5.65	5.33	5.09	4.89
24	.100	2.93	2.54	2.33	2.19	2.10	2.04	1.98	1.94	1.91
	.050	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30
	.025	5.72	4.32	3.72	3.38	3.15	2.99	2.87	2.78	2.70
	.010	7.82	5.61	4.72	4.22	3.90	3.67	3.50	3.36	3.26
	.001	14.03	9.34	7.55	6.59	5.98	5.55	5.23	4.99	4.80
25	.100	2.92	2.53	2.32	2.18	2.09	2.02	1.97	1.93	1.89
	.050	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28
	.025	5.69	4.29	3.69	3.35	3.13	2.97	2.85	2.75	2.68
	.010	7.77	5.57	4.68	4.18	3.85	3.63	3.46	3.32	3.22
	.001	13.88	9.22	7.45	6.49	5.89	5.46	5.15	4.91	4.71
26	.100	2.91	2.52	2.31	2.17	2.08	2.01	1.96	1.92	1.88
	.050	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27
	.025	5.66	4.27	3.67	3.33	3.10	2.94	2.82	2.73	2.65
	.010	7.72	5.53	4.64	4.14	3.82	3.59	3.42	3.29	3.18
	.001	13.74	9.12	7.36	6.41	5.80	5.38	5.07	4.83	4.64
27	.100	2.90	2.51	2.30	2.17	2.07	2.00	1.95	1.91	1.87
	.050	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25
	.025	5.63	4.24	3.65	3.31	3.08	2.92	2.80	2.71	2.63
	.010	7.68	5.49	4.60	4.11	3.78	3.56	3.39	3.26	3.15
	.001	13.61	9.02	7.27	6.33	5.73	5.31	5.00	4.76	4.57

TABLE E

F critical values (continued)

Degrees of freedom in the numerator

10	12	15	20	25	30	40	50	60	120	1000
1.98	1.93	1.89	1.84	1.80	1.78	1.75	1.74	1.72	1.69	1.66
2.41	2.34	2.27	2.19	2.14	2.11	2.06	2.04	2.02	1.97	1.92
2.87	2.77	2.67	2.56	2.49	2.44	2.38	2.35	2.32	2.26	2.20
3.51	3.37	3.23	3.08	2.98	2.92	2.84	2.78	2.75	2.66	2.58
5.39	5.13	4.87	4.59	4.42	4.30	4.15	4.06	4.00	3.84	3.69
1.96	1.91	1.86	1.81	1.78	1.76	1.73	1.71	1.70	1.67	1.64
2.38	2.31	2.23	2.16	2.11	2.07	2.03	2.00	1.98	1.93	1.88
2.82	2.72	2.62	2.51	2.44	2.39	2.33	2.30	2.27	2.20	2.14
3.43	3.30	3.15	3.00	2.91	2.84	2.76	2.71	2.67	2.58	2.50
5.22	4.97	4.70	4.43	4.26	4.14	3.99	3.90	3.84	3.68	3.53
1.94	1.89	1.84	1.79	1.76	1.74	1.71	1.69	1.68	1.64	1.61
2.35	2.28	2.20	2.12	2.07	2.04	1.99	1.97	1.95	1.90	1.85
2.77	2.68	2.57	2.46	2.40	2.35	2.29	2.25	2.22	2.16	2.09
3.37	3.23	3.09	2.94	2.84	2.78	2.69	2.64	2.61	2.52	2.43
5.08	4.82	4.56	4.29	4.12	4.00	3.86	3.77	3.70	3.54	3.40
1.92	1.87	1.83	1.78	1.74	1.72	1.69	1.67	1.66	1.62	1.59
2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.94	1.92	1.87	1.82
2.73	2.64	2.53	2.42	2.36	2.31	2.25	2.21	2.18	2.11	2.05
3.31	3.17	3.03	2.88	2.79	2.72	2.64	2.58	2.55	2.46	2.37
4.95	4.70	4.44	4.17	4.00	3.88	3.74	3.64	3.58	3.42	3.28
1.90	1.86	1.81	1.76	1.73	1.70	1.67	1.65	1.64	1.60	1.57
2.30	2.23	2.15	2.07	2.02	1.98	1.94	1.91	1.89	1.84	1.79
2.70	2.60	2.50	2.39	2.32	2.27	2.21	2.17	2.14	2.08	2.01
3.26	3.12	2.98	2.83	2.73	2.67	2.58	2.53	2.50	2.40	2.32
4.83	4.58	4.33	4.06	3.89	3.78	3.63	3.54	3.48	3.32	3.17
1.89	1.84	1.80	1.74	1.71	1.69	1.66	1.64	1.62	1.59	1.55
2.27	2.20	2.13	2.05	2.00	1.96	1.91	1.88	1.86	1.81	1.76
2.67	2.57	2.47	2.36	2.29	2.24	2.18	2.14	2.11	2.04	1.98
3.21	3.07	2.93	2.78	2.69	2.62	2.54	2.48	2.45	2.35	2.27
4.73	4.48	4.23	3.96	3.79	3.68	3.53	3.44	3.38	3.22	3.08
1.88	1.83	1.78	1.73	1.70	1.67	1.64	1.62	1.61	1.57	1.54
2.25	2.18	2.11	2.03	1.97	1.94	1.89	1.86	1.84	1.79	1.74
2.64	2.54	2.44	2.33	2.26	2.21	2.15	2.11	2.08	2.01	1.94
3.17	3.03	2.89	2.74	2.64	2.58	2.49	2.44	2.40	2.31	2.22
4.64	4.39	4.14	3.87	3.71	3.59	3.45	3.36	3.29	3.14	2.99
1.87	1.82	1.77	1.72	1.68	1.66	1.63	1.61	1.59	1.56	1.52
2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.84	1.82	1.77	1.72
2.61	2.51	2.41	2.30	2.23	2.18	2.12	2.08	2.05	1.98	1.91
3.13	2.99	2.85	2.70	2.60	2.54	2.45	2.40	2.36	2.27	2.18
4.56	4.31	4.06	3.79	3.63	3.52	3.37	3.28	3.22	3.06	2.91
1.86	1.81	1.76	1.71	1.67	1.65	1.61	1.59	1.58	1.54	1.51
2.22	2.15	2.07	1.99	1.94	1.90	1.85	1.82	1.80	1.75	1.70
2.59	2.49	2.39	2.28	2.21	2.16	2.09	2.05	2.03	1.95	1.89
3.09	2.96	2.81	2.66	2.57	2.50	2.42	2.36	2.33	2.23	2.14
4.48	4.24	3.99	3.72	3.56	3.44	3.30	3.21	3.15	2.99	2.84
1.85	1.80	1.75	1.70	1.66	1.64	1.60	1.58	1.57	1.53	1.50
2.20	2.13	2.06	1.97	1.92	1.88	1.84	1.81	1.79	1.73	1.68
2.57	2.47	2.36	2.25	2.18	2.13	2.07	2.03	2.00	1.93	1.86
3.06	2.93	2.78	2.63	2.54	2.47	2.38	2.33	2.29	2.20	2.11
4.41	4.17	3.92	3.66	3.49	3.38	3.23	3.14	3.08	2.92	2.78

(*Continued*)

TABLE E

F critical values (continued)

Degrees of freedom in the denominator	p	1	2	3	4	5	6	7	8	9
28	.100	2.89	2.50	2.29	2.16	2.06	2.00	1.94	1.90	1.87
	.050	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24
	.025	5.61	4.22	3.63	3.29	3.06	2.90	2.78	2.69	2.61
	.010	7.64	5.45	4.57	4.07	3.75	3.53	3.36	3.23	3.12
	.001	13.50	8.93	7.19	6.25	5.66	5.24	4.93	4.69	4.50
29	.100	2.89	2.50	2.28	2.15	2.06	1.99	1.93	1.89	1.86
	.050	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22
	.025	5.59	4.20	3.61	3.27	3.04	2.88	2.76	2.67	2.59
	.010	7.60	5.42	4.54	4.04	3.73	3.50	3.33	3.20	3.09
	.001	13.39	8.85	7.12	6.19	5.59	5.18	4.87	4.64	4.45
30	.100	2.88	2.49	2.28	2.14	2.05	1.98	1.93	1.88	1.85
	.050	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21
	.025	5.57	4.18	3.59	3.25	3.03	2.87	2.75	2.65	2.57
	.010	7.56	5.39	4.51	4.02	3.70	3.47	3.30	3.17	3.07
	.001	13.29	8.77	7.05	6.12	5.53	5.12	4.82	4.58	4.39
40	.100	2.84	2.44	2.23	2.09	2.00	1.93	1.87	1.83	1.79
	.050	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12
	.025	5.42	4.05	3.46	3.13	2.90	2.74	2.62	2.53	2.45
	.010	7.31	5.18	4.31	3.83	3.51	3.29	3.12	2.99	2.89
	.001	12.61	8.25	6.59	5.70	5.13	4.73	4.44	4.21	4.02
50	.100	2.81	2.41	2.20	2.06	1.97	1.90	1.84	1.80	1.76
	.050	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07
	.025	5.34	3.97	3.39	3.05	2.83	2.67	2.55	2.46	2.38
	.010	7.17	5.06	4.20	3.72	3.41	3.19	3.02	2.89	2.78
	.001	12.22	7.96	6.34	5.46	4.90	4.51	4.22	4.00	3.82
60	.100	2.79	2.39	2.18	2.04	1.95	1.87	1.82	1.77	1.74
	.050	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04
	.025	5.29	3.93	3.34	3.01	2.79	2.63	2.51	2.41	2.33
	.010	7.08	4.98	4.13	3.65	3.34	3.12	2.95	2.82	2.72
	.001	11.97	7.77	6.17	5.31	4.76	4.37	4.09	3.86	3.69
100	.100	2.76	2.36	2.14	2.00	1.91	1.83	1.78	1.73	1.69
	.050	3.94	3.09	2.70	2.46	2.31	2.19	2.10	2.03	1.97
	.025	5.18	3.83	3.25	2.92	2.70	2.54	2.42	2.32	2.24
	.010	6.90	4.82	3.98	3.51	3.21	2.99	2.82	2.69	2.59
	.001	11.50	7.41	5.86	5.02	4.48	4.11	3.83	3.61	3.44
200	.100	2.73	2.33	2.11	1.97	1.88	1.80	1.75	1.70	1.66
	.050	3.89	3.04	2.65	2.42	2.26	2.14	2.06	1.98	1.93
	.025	5.10	3.76	3.18	2.85	2.63	2.47	2.35	2.26	2.18
	.010	6.76	4.71	3.88	3.41	3.11	2.89	2.73	2.60	2.50
	.001	11.15	7.15	5.63	4.81	4.29	3.92	3.65	3.43	3.26
1000	.100	2.71	2.31	2.09	1.95	1.85	1.78	1.72	1.68	1.64
	.050	3.85	3.00	2.61	2.38	2.22	2.11	2.02	1.95	1.89
	.025	5.04	3.70	3.13	2.80	2.58	2.42	2.30	2.20	2.13
	.010	6.66	4.63	3.80	3.34	3.04	2.82	2.66	2.53	2.43
	.001	10.89	6.96	5.46	4.65	4.14	3.78	3.51	3.30	3.13

Column headers 1–9: Degrees of freedom in the numerator

TABLE E

F critical values (continued)

Degrees of freedom in the numerator										
10	12	15	20	25	30	40	50	60	120	1000
1.84	1.79	1.74	1.69	1.65	1.63	1.59	1.57	1.56	1.52	1.48
2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.79	1.77	1.71	1.66
2.55	2.45	2.34	2.23	2.16	2.11	2.05	2.01	1.98	1.91	1.84
3.03	2.90	2.75	2.60	2.51	2.44	2.35	2.30	2.26	2.17	2.08
4.35	4.11	3.86	3.60	3.43	3.32	3.18	3.09	3.02	2.86	2.72
1.83	1.78	1.73	1.68	1.64	1.62	1.58	1.56	1.55	1.51	1.47
2.18	2.10	2.03	1.94	1.89	1.85	1.81	1.77	1.75	1.70	1.65
2.53	2.43	2.32	2.21	2.14	2.09	2.03	1.99	1.96	1.89	1.82
3.00	2.87	2.73	2.57	2.48	2.41	2.33	2.27	2.23	2.14	2.05
4.29	4.05	3.80	3.54	3.38	3.27	3.12	3.03	2.97	2.81	2.66
1.82	1.77	1.72	1.67	1.63	1.61	1.57	1.55	1.54	1.50	1.46
2.16	2.09	2.01	1.93	1.88	1.84	1.79	1.76	1.74	1.68	1.63
2.51	2.41	2.31	2.20	2.12	2.07	2.01	1.97	1.94	1.87	1.80
2.98	2.84	2.70	2.55	2.45	2.39	2.30	2.25	2.21	2.11	2.02
4.24	4.00	3.75	3.49	3.33	3.22	3.07	2.98	2.92	2.76	2.61
1.76	1.71	1.66	1.61	1.57	1.54	1.51	1.48	1.47	1.42	1.38
2.08	2.00	1.92	1.84	1.78	1.74	1.69	1.66	1.64	1.58	1.52
2.39	2.29	2.18	2.07	1.99	1.94	1.88	1.83	1.80	1.72	1.65
2.80	2.66	2.52	2.37	2.27	2.20	2.11	2.06	2.02	1.92	1.82
3.87	3.64	3.40	3.14	2.98	2.87	2.73	2.64	2.57	2.41	2.25
1.73	1.68	1.63	1.57	1.53	1.50	1.46	1.44	1.42	1.38	1.33
2.03	1.95	1.87	1.78	1.73	1.69	1.63	1.60	1.58	1.51	1.45
2.32	2.22	2.11	1.99	1.92	1.87	1.80	1.75	1.72	1.64	1.56
2.70	2.56	2.42	2.27	2.17	2.10	2.01	1.95	1.91	1.80	1.70
3.67	3.44	3.20	2.95	2.79	2.68	2.53	2.44	2.38	2.21	2.05
1.71	1.66	1.60	1.54	1.50	1.48	1.44	1.41	1.40	1.35	1.30
1.99	1.92	1.84	1.75	1.69	1.65	1.59	1.56	1.53	1.47	1.40
2.27	2.17	2.06	1.94	1.87	1.82	1.74	1.70	1.67	1.58	1.49
2.63	2.50	2.35	2.20	2.10	2.03	1.94	1.88	1.84	1.73	1.62
3.54	3.32	3.08	2.83	2.67	2.55	2.41	2.32	2.25	2.08	1.92
1.66	1.61	1.56	1.49	1.45	1.42	1.38	1.35	1.34	1.28	1.22
1.93	1.85	1.77	1.68	1.62	1.57	1.52	1.48	1.45	1.38	1.30
2.18	2.08	1.97	1.85	1.77	1.71	1.64	1.59	1.56	1.46	1.36
2.50	2.37	2.22	2.07	1.97	1.89	1.80	1.74	1.69	1.57	1.45
3.30	3.07	2.84	2.59	2.43	2.32	2.17	2.08	2.01	1.83	1.64
1.63	1.58	1.52	1.46	1.41	1.38	1.34	1.31	1.29	1.23	1.16
1.88	1.80	1.72	1.62	1.56	1.52	1.46	1.41	1.39	1.30	1.21
2.11	2.01	1.90	1.78	1.70	1.64	1.56	1.51	1.47	1.37	1.25
2.41	2.27	2.13	1.97	1.87	1.79	1.69	1.63	1.58	1.45	1.30
3.12	2.90	2.67	2.42	2.26	2.15	2.00	1.90	1.83	1.64	1.43
1.61	1.55	1.49	1.43	1.38	1.35	1.30	1.27	1.25	1.18	1.08
1.84	1.76	1.68	1.58	1.52	1.47	1.41	1.36	1.33	1.24	1.11
2.06	1.96	1.85	1.72	1.64	1.58	1.50	1.45	1.41	1.29	1.13
2.34	2.20	2.06	1.90	1.79	1.72	1.61	1.54	1.50	1.35	1.16
2.99	2.77	2.54	2.30	2.14	2.02	1.87	1.77	1.69	1.49	1.22

BEFORE THE PUBLIC SERVICE COMMISSION OF THE STATE OF MISSOURI

In the Matter of an Investigation of Missouri-American Water Company with Respect to Certain Issues Disclosed During the Recent Rate Case.	))))	File No. WO-2017-0012

MISSOURI-AMERICAN WATER COMPANY'S RESPONSE TO REPORT OF STAFF'S FINDINGS INTO FAULTY METERS AND NEGATIVE RESERVE BALANCES

Missouri-American Water Company (MAWC or Company) offers the following response to the Report of Staff's Findings Into Faulty Meters and Negative Reserve Balances filed March 31, 2017 (Final Report):

MAWC was given the opportunity and did comment on an earlier draft of Staff's Final Report and, in many instances, MAWC's suggestions and/or comments were incorporated by the Staff. As a result, MAWC believes that the Staff's Final Report is, in large measure, factually correct and the only response MAWC has relates to two summary statements on pages 16 and 17 of the Final Report.

First, Staff states at page 16 of its Final Report that:

> "MAWC was aware of certain metering problems at the time it filed its application to increase rates as part of its previous case, Case No. WR-2015-0301, and became aware of the dead/dying meter problems shortly after its filing, but remained silent about the problems in all of its testimony filings in all of its testimony filings from the rate case."

This statement implies that the problems that MAWC experienced with the Mueller meters prior to August, 2015, were significant enough to warrant special attention. That is not the case. The problems with the Mueller meters known prior to August, 2015, were neither significant nor material such that the Company believed it was necessary to address them in its prepared direct testimony filed on July 31, 2015. As MAWC explained in its response to Staff Data Request No. 8 in this case:

> "In May, 2013, American Water implemented a new business systems software program (SAP) for customer service, billing, and field service activities. This new system allowed us to track meter related data in much more detail than the previous system, but the tools to report and analyze this data were not immediately available. During the period from August 2012 through August 2015, the failure rate of the new Mueller meters being placed into service was only slightly higher than historical experience with Neptune meters."

However, American Water continued to work with Mueller to improve quality.

It was not until September of 2015, after MAWC filed its last rate case to include its direct testimony (WR-2015-0301), that it and other affiliates of American Water became aware of a higher failure rate for the Mueller meters. As MAWC further explained in its response to Staff Data Request No. 8:

> "Also in September, 2015, new data analysis tools became available which allowed American Water to analyze meter reliability in ways that were previously impractical. Analysis done at that time indicated a significantly higher failure rate for Mueller meters purchased in 2012 than for those purchased later and as compared to older Neptune meters. This result was expected and had been seen in Mueller return data but prior to that time could not be supported by American Water data."

Thus, the significantly higher failure rate for Mueller meters was not known to MAWC until after the filing of its rate case and testimony on July 31, 2015. And, as will be explained below, even taking into account the higher failure rate of the Mueller meters, the impact on customer usage data was not significant.

Second, at page 17 of Staff's Report, Staff states:

> "Finally, this issue has impacted customer usage by some undeterminable amount. Staff points out that during the timeframe

> of the defective metering issue, meter problems have reduced actual customer usage amounts by some unknown degree."

While Staff correctly notes in the Final Report that MAWC disagrees with Staff's conclusion in this regard, it is important to note that MAWC's disagreement is based upon an internal analysis of the impact of the defective Mueller meters on its customer usage data in March, 2016, when this issue was first raised in Staff's surrebuttal testimony. (This analysis was provided to Staff in response to its Data Request No. 1 in this case and further discussed and explained in a meeting with Staff at MAWC's offices on December 5, 2016.)

The Company analyzed approximately 1,200 Mueller meters that had previously been removed from service and tested in September, 2015. Based upon this analysis, MAWC was able to estimate the meter reading error rate of the sample set during low, medium and high flows. Applying an industry-standard percentage distribution residential usage at each flow rate (i.e., low, medium and high), MAWC estimated the Mueller meter composite meter reading error rate for all flows. Using that distribution, MAWC then estimated the potential weighted residential meter reading error rate for all residential sales volumes due to Mueller meter inaccuracies equal to the ratio of the total number of Mueller meters to all residential meters affected during the years of 2013 through 2015, multiplied by the Mueller meter reading error. MAWC then recalculated the change in declining use by increasing sales volumes for the weighted total potential meter reading error for the years 2013 through 2015. The impact of this re-estimation compared to MAWC's "filed" case on base, non-weather sensitive usage was an increase of 2.5 gallons per customer, per month; or 23.7 gallons per customer per year. Using a similar analysis to estimate the impact on non-base, weather sensitive usage, MAWC estimated an increase of 46.3 gallons per customer per year.

Overall, MAWC estimated an increase in residential usage of 70 gallons per customer, per year; which amounted to a change in the Company's "filed" residential declining use rate of 0.04% annually, or approximately $93,000 of water sales revenue during the test year. In other words, had the Mueller meters been reading correctly, MAWC estimated that it would have experienced an increase in its test year revenues of only $93,000, or one-half of 1% of its total test year residential revenues. Given this analysis, MAWC disagrees with Staff's conclusion that the faulty Mueller meters have impacted customer usage by some indeterminable amount. On the contrary, the impact can be determined, and it is insignificant.

Respectfully submitted,

____/s/ William R. England, III_______________
William R. England, III Mo. Bar 23975
BRYDON, SWEARENGEN & ENGLAND P.C.
312 East Capitol Avenue
P.O. Box 456
Jefferson City, MO 65102-0456
Telephone: (573) 635-7166
Facsimile: (573) 635-0427
trip@brydonlaw.com

Timothy W. Luft, MBE Mo. Bar 40506
Corporate Counsel
MISSOURI-AMERICAN WATER COMPANY
727 Craig Road
St. Louis, MO 63141
(314) 996-2279 telephone
(314) 997-2451 facsimile
timothy.luft@amwater.com
ATTORNEYS FOR MISSOURI-AMERICAN WATER COMPANY

CERTIFICATE OF SERVICE

The undersigned certifies that a true and correct copy of the foregoing document was sent by electronic mail on May 1, 2017, to the following:

General Counsel's Office
staffcounselservice@psc.mo.gov
jacob.westen@psc.mo.gov

Office of the Public Counsel
opcservice@ded.mo.gov
ryan.smith@ded.mo.gov

____/s/ William R. England, III_______________

OPC 2053

DATA INFORMATION REQUEST
Missouri-American Water Company
WR-2017-0285

Requested From: Tim Luft
Date Requested: 8/15/17

Information Requested:

Please disclose whether MWAC has conducted a price elasticity analysis on its historical and/or proposed rate increase in relation to customer usage. If yes, please provide said analysis.

Requested By: Geoff Marke - Office of Public Counsel – geoff.marke@ded.mo.gov

Information Provided:

In building its customer usage models, MAWC witness Roach has explored how a number of variables, including price, affected base and non-base usage. Generally, Mr. Roach has rejected the use of a price variable because he found the price term to be highly autocorrelated with the time variable over the historic period. This is illustrated by the additional data and modeling provided in OPC_2053_Attachment which takes the base and non-base modeling worksheet and adds a base price term (Feb-April) used in the base modeling and an annual average price used in non-base modeling.

For purposes of base usage modeling, the use of a price term in place of time as a variable produces general diagnostic statistics that are similar to those produced by the time variable but with a greater probability of the influence of autocorrelation. This renders time to be a superior value over price. Further, if the price variable is also used with a time variable, general diagnostic statistics result that are similar to those utilizing the time variable alone but with the probability of greater autocorrelation when both time and price are used as variables. Generally, the consequence of autocorrelation in any model is an increase of the t-statistics resulting in the estimator appearing more accurate than it actually is.

For purposes of non-base modeling, the inclusion of a price term results in general diagnostic statistics that are similar to those utilizing the two climatic variables and the t-statistic for average price illustrates that the explanatory properties of the price term are not statistically significant. In other words, price is not a predictive variable for non-base modeling.

In short, Mr. Roach has elected to use models based on time because they avoid the effects of autocorrelation on the modeling and estimation of the regression coefficients. Mr. Roach's models use time, which is a fixed known and measureable term for purposes of estimating future reductions in residential usage per customer.

As a real world check on the value of time as a variable over price as a variable, consider the effect of the tornado in Joplin. There was no change in price after the tornado struck and a significant share of housing was rebuilt. Nevertheless, there was a much larger decline in usage. Essentially, the tornado simply accelerated the conservation effect when homes were rebuilt, resulting in a compression of the time effect on conservation. This shows anecdotally what the models show, i.e., that time is the more influential on conservation of water use than is price.

Submitted by: Greg Roach